

# Evaluation of the NASA Artemis Regions of Interest for ISRU Water Mine Potential

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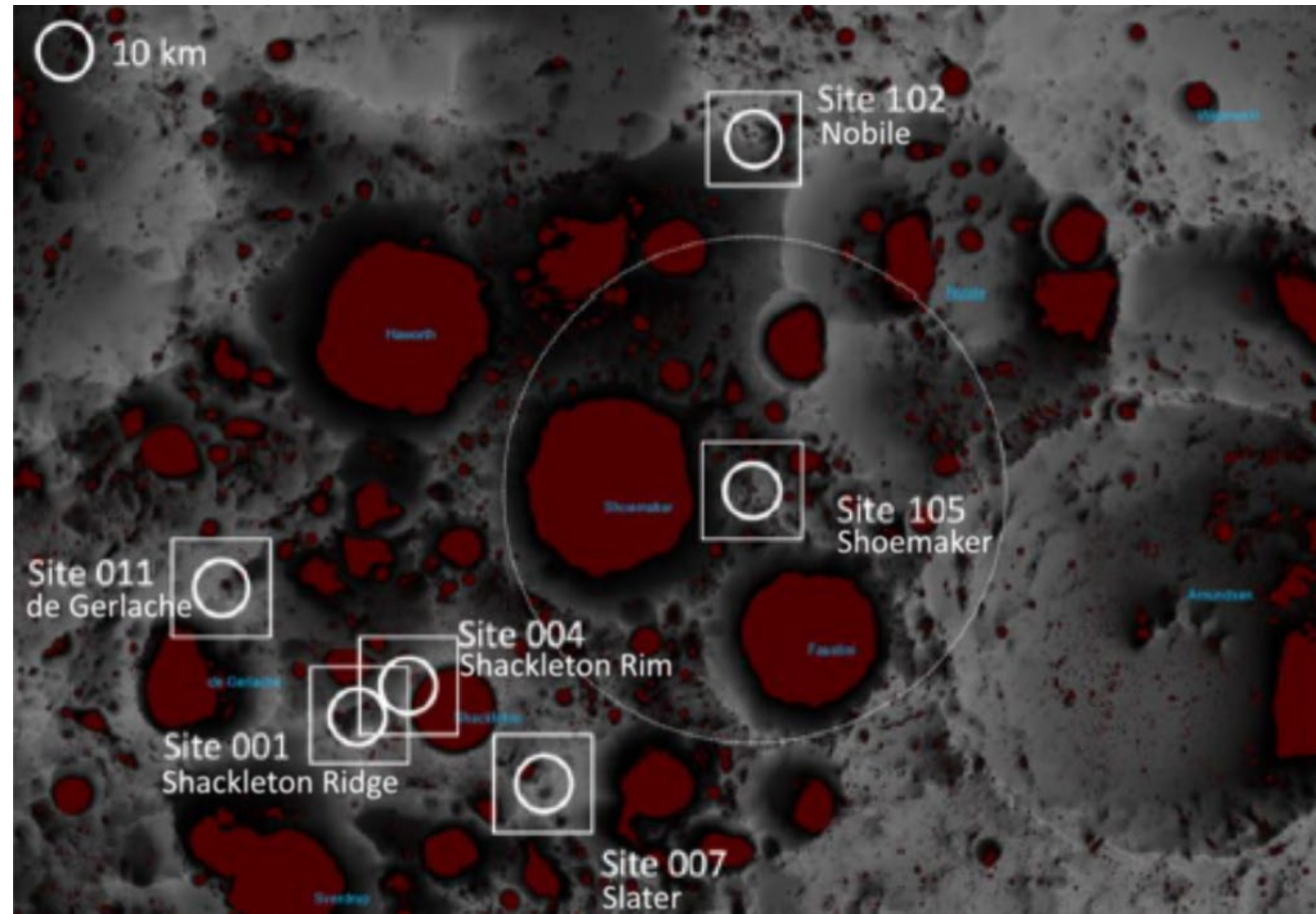
ASCEND 2022, October 24-26, 2022

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# Background



- Evaluate the Regions of Interest (ROIs) for the Artemis Campaign in terms of potential for ISRU water mining
- Ground rules have been defined based on
  - Anticipated customer needs
  - Projected lunar surface hardware capabilities
  - Limited infrastructure (evaluation for early missions)
  - Lunar environmental & terrain data
- Preliminary analysis, will evolve
  - Traverses are notional for broad preliminary evaluation only.
  - Ground rule criteria to evolve with down selection (architecture, regions, hardware, etc)
- Other evaluations of this type have been done with different assumptions or viewpoints.
  - Most previous studies focused on large PSR regions which do not suite ground rules & assumptions for early Artemis
  - This study can be used to focus water reconnaissance efforts



NASA'S Plan For Sustained Lunar Exploration and Development. April 2020.

[https://www.nasa.gov/sites/default/files/atoms/files/a\\_sustained\\_lunar\\_presence\\_nspc\\_report4220final.pdf](https://www.nasa.gov/sites/default/files/atoms/files/a_sustained_lunar_presence_nspc_report4220final.pdf)

# ISRU Baseline Architecture



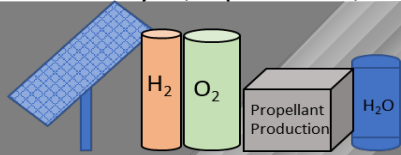
## Customer



Transport of product to the customer is not explicitly covered by ISRU system. Though proximity estimates are included here.

## Propellant Production Plant (PPP) Site

Production plant hardware performs **water processing** converts water, delivered by water tankers, into propellant: electrolysis, liquefaction, storage. Assumed to leverage solar power.



Two mobile water tankers transport water from the mine to the production plant. Each tanker must make ~10 trips per year in the current baseline.

## Mine Site (PSR)

Hardware here includes excavator and water extraction system that processes the raw regolith. Water is frozen capture & stored in mobile water tankers.

Water Tankers

Water Extraction

Excavator

Tailings

Mine

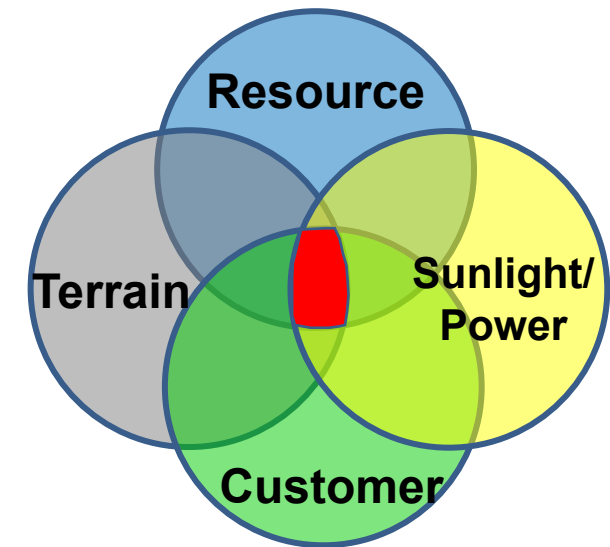
Details of Architecture published:  
Kleinhenz, J.E. and Paz, A., Case Studies for Lunar ISRU Systems Utilizing Polar Water, AIAA ASCEND, American Institute for Aeronautics and Astronautics, Nov. 16-18, 2020, AIAA-2020-4042

# Considerations



The ISRU Analysis considered the following factors to develop ground rules and perform the evaluation

Factor	Criteria	Reasoning
Customer	Fixed location	The highest ranked surface illuminated site in area from Mazarico et al 2011*)
Propellant Production plant (PPP)	Illumination (sun visibility)	<b>Located</b> in a highly illuminated region to leverage solar power and be more accessible to customer. Exact illumination needs will depend on ISRU technology used and power architecture.
	NOT co-located with Customer	Avoid interference with other customer activities and to provide better proximity to the mine site
Mine Site	Ice Stability	Permanently shadowed regions (PSRs) that offer surface ice stability
	PSR/Mine Size	Tonnage to support multiple years production cycles (>10mT production) for initial Artemis needs
Traverses between locations	Distances	Based on no path preparation and projected capabilities of mobility assets. Options were scored and ranked to assist with evaluation
	Slopes	

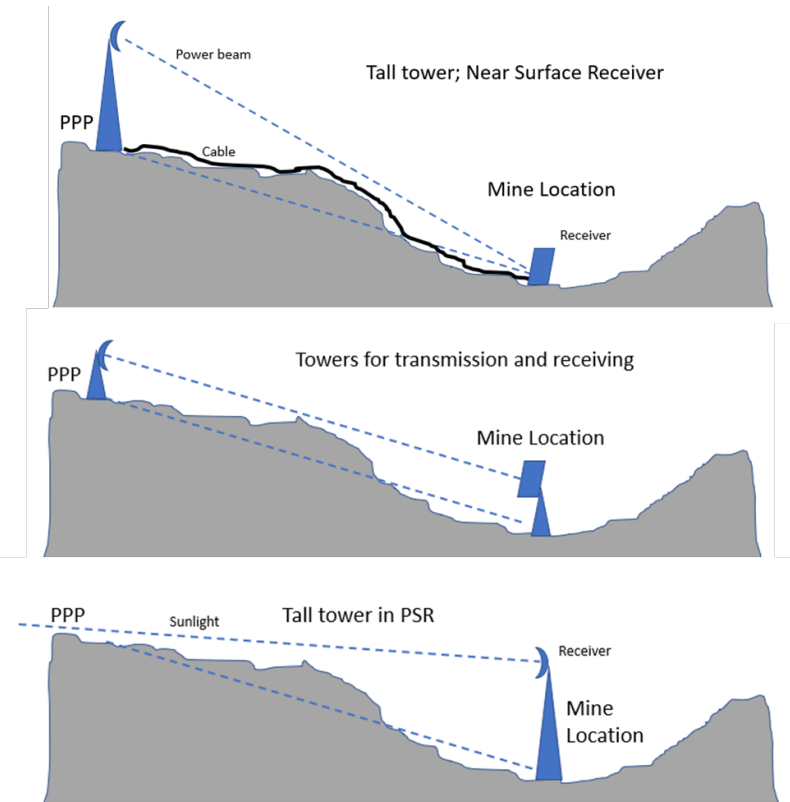


\*Mazarico, E., Neumann, G.A., Smith, D.E., Zuber, M.T., and Torrence, M.H., Illumination conditions of the lunar polar regions using LOLA topography. Icarus. 211, 2011, 1066-1081.

# Things NOT considered (that may impact criteria)



- Power options for the PSR
  - The power source for both the PSR and PPP may impact the criteria. However: the PSR presents a challenge. For example:
    - Beaming: Line of site to either a ridge transmitter or the sun itself may pose elevation requirements for PSR (relative to ridge)
    - Cable: The length of the cable to an unspecified source would add an additional/different proximity requirement
- Path preparation
  - For initial (early) mining ISRU assumes minimal infrastructure, so path planning assumes simple/direct traverses over unprepared ground. The following examples would alter assumptions and may open up options as an outpost is established
    - Roads/pipes/gondolas: more deliveries possible. ISRU system itself may be more flexible (e.g. faster production over less time = less sun needed for PPP)
    - Switchbacks: adding switchbacks into steeper craters may increase the maximum slope criteria.
- Exact placement and fine-tuned traverses (Disclaimer)
  - Locations of PPP and mine sites are notional in this analysis. Traverse paths were not fine tuned for smaller scale slope hazards. While reported results were held strictly to criteria, it may be possible to adjust path and placements to improve.



# Ground Rules for Evaluation

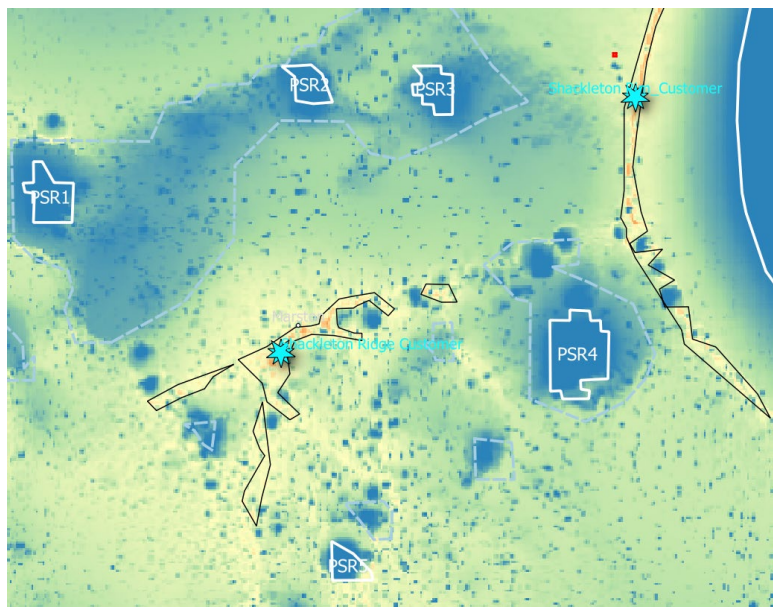
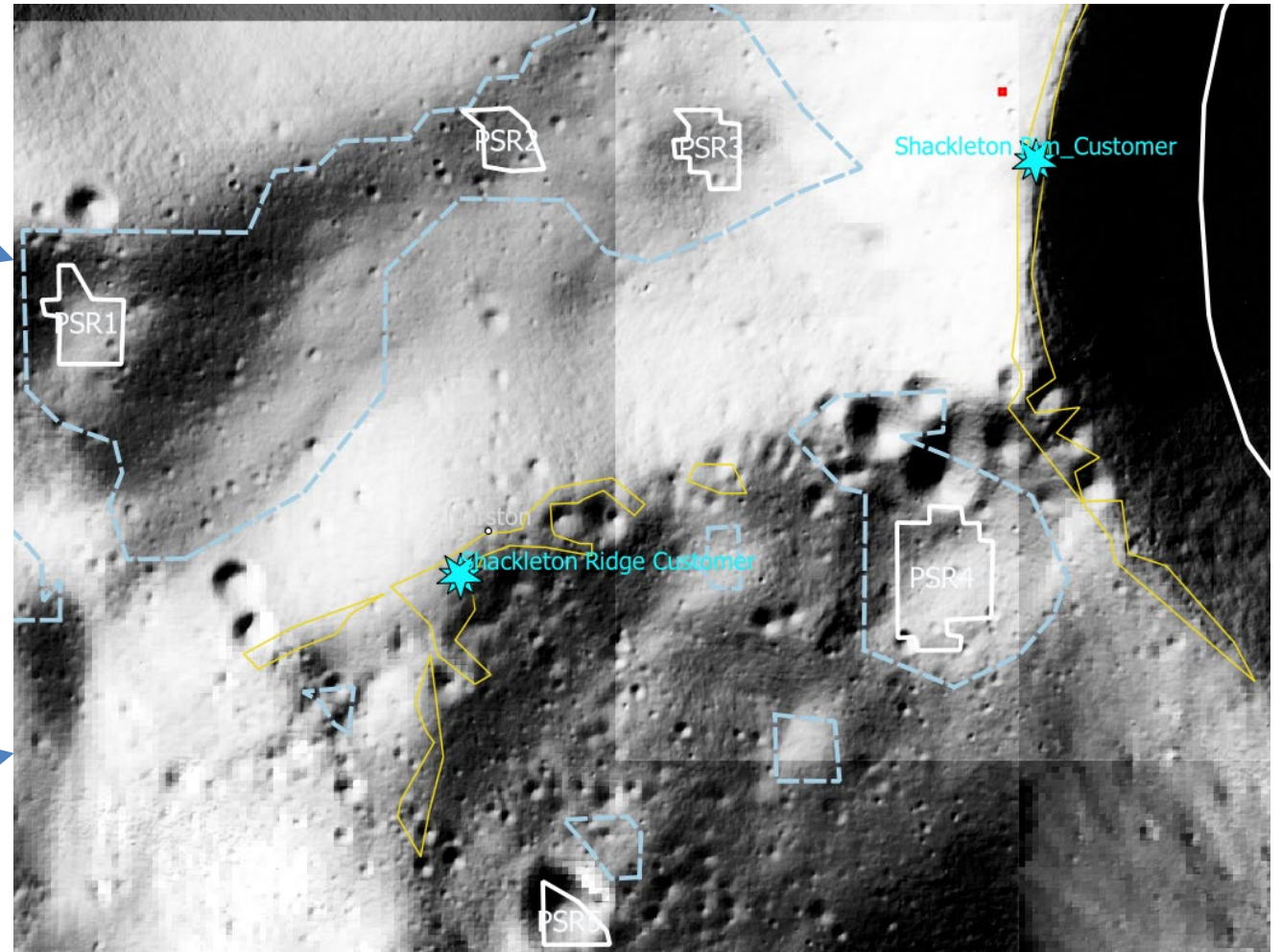
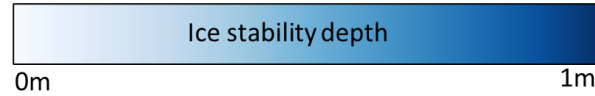
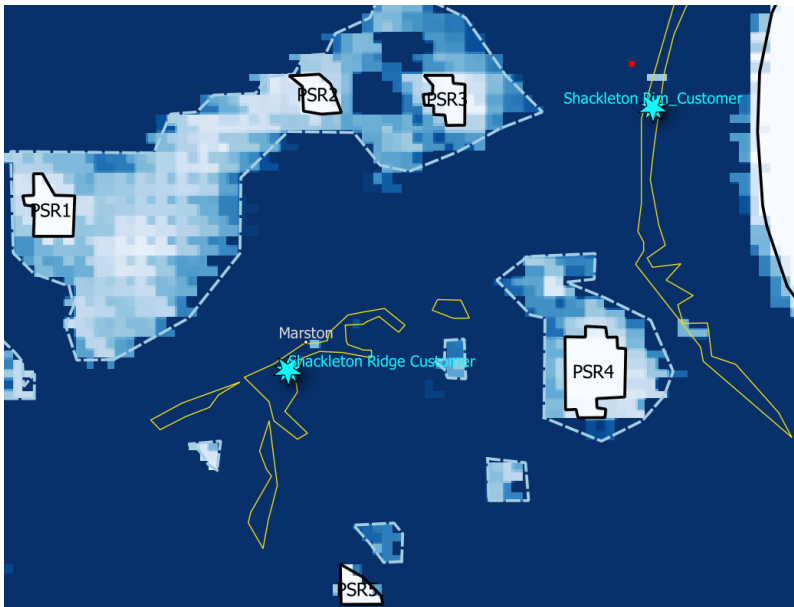


ISRU is not a fixed design, the ground rules are best on notional capabilities of current technology baseline

- Results of site evaluation will change as criteria evolve
- Analyses of both locations was done with expanded criteria to see alternatives

Parameter	Baseline	Expanded	Data product used
<b>Traverse Leg 1</b> (Customer to PPP)	5 km (prefer >1km)	10 km	5m/pix High Res LOLA Topography LDEMs from <a href="https://pgda.gsfc.nasa.gov/products/78">https://pgda.gsfc.nasa.gov/products/78</a>
<b>Traverse Leg 2</b> (PPP to Mine)	5 km	10 km	
<b>Traverse Total</b>	10 km	20 km	
<b>Slopes</b>	≤ 20 deg		5m/pix High Res LOLA Topography Slope from <a href="https://pgda.gsfc.nasa.gov/products/78">https://pgda.gsfc.nasa.gov/products/78</a>
<b>PSR/Mine Size</b>	≥ 1 km equivalent diameter (multiple pixels in the 240mpp ice stability product)		Diviner: Current Ice Stability layer from LROC Quickmap: based on Siegler 2017: 240mpp <a href="https://quickmap.lroc.asu.edu/">https://quickmap.lroc.asu.edu/</a>
<b>PSR Ice Stability (mine)</b>	Surface ice stability corresponding to PSR region		
<b>Sun Visibility (PPP)</b>	> 75% visibility		LOLA 60m/pix Sun Visibility LROC Quickmap <a href="https://quickmap.lroc.asu.edu/">https://quickmap.lroc.asu.edu/</a> : Percentage of timestamps when any fraction of solar disc is visible using Mazarico 2011 methodology [5].

# Map Orientation

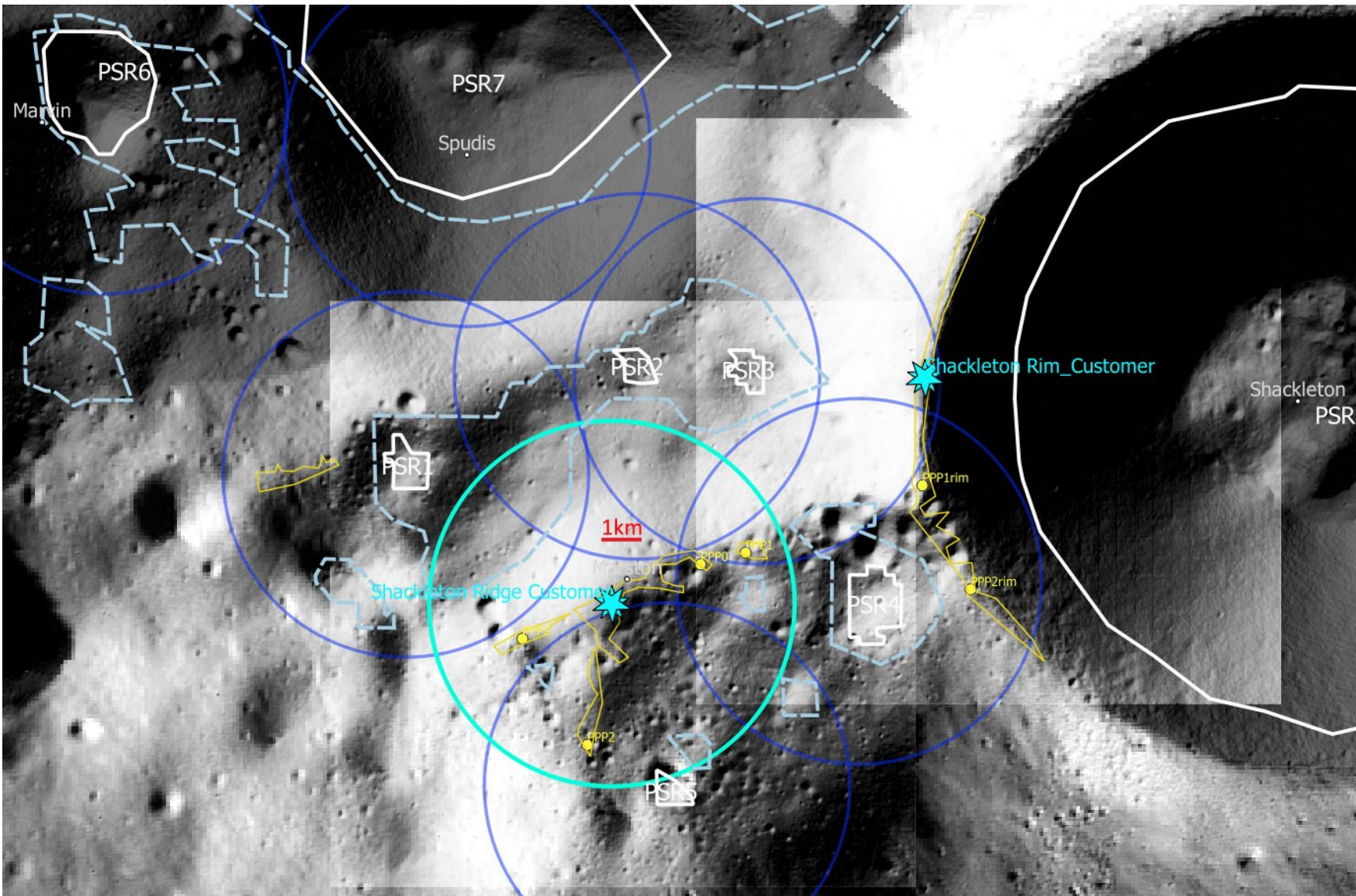


% of timesteps any fraction of sun disc is visible




# 001 Shackleton Ridge


# 001 Shackleton Ridge: ISRU Regions Of Interest





## Customer site

 5km radius around Customer


## Mine sites

 PSR = Shallow ice stability = deep crater

 ISR = 'Deeper' ice stability (50 to 100 cm) = shallow crater

 5km radius around mine

## Production sites

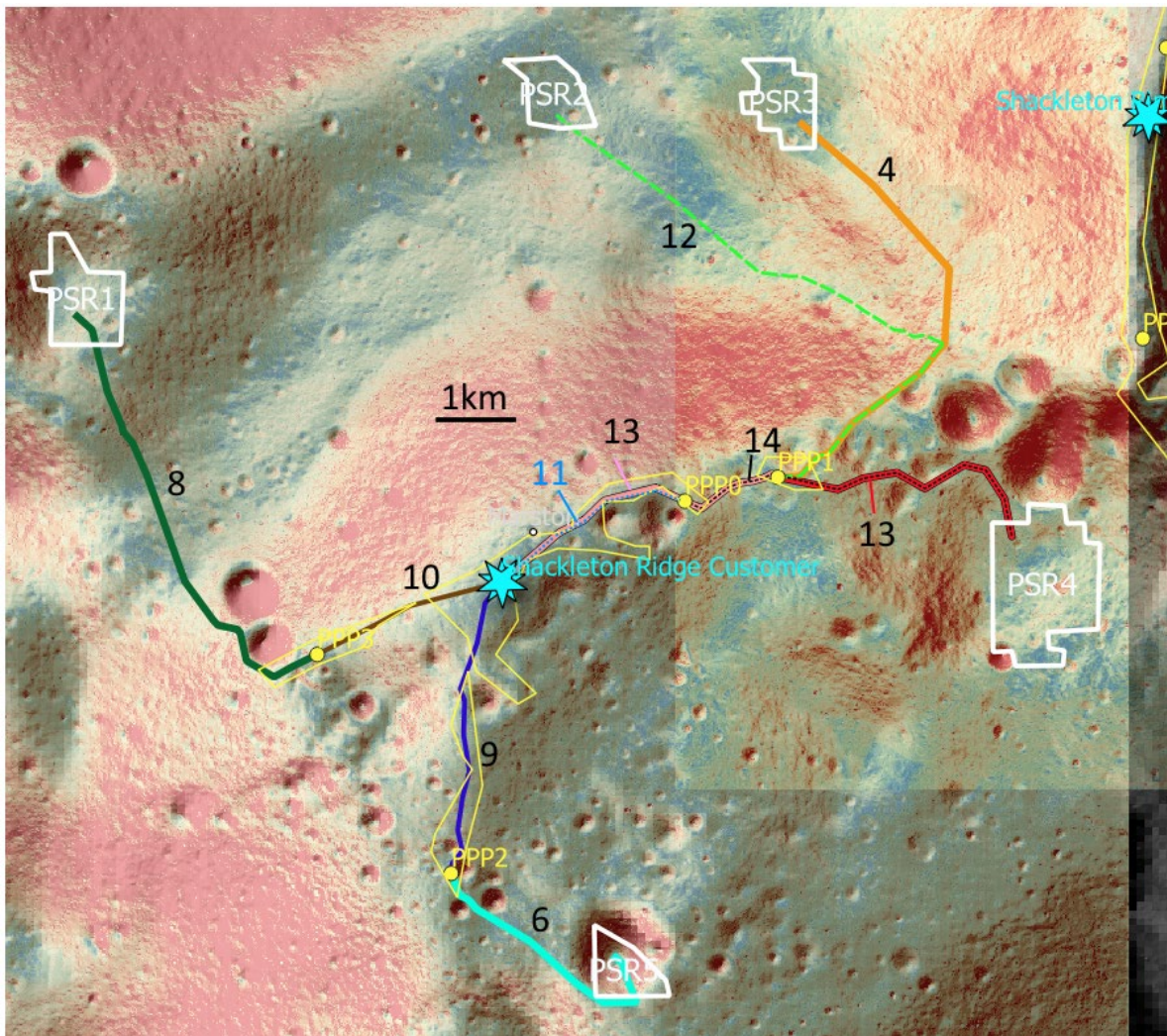
 PPP = ISRU propellant production plant @ illuminated site

## Analysis:

Valid sites should have a PPP options where light and blue circles overlap

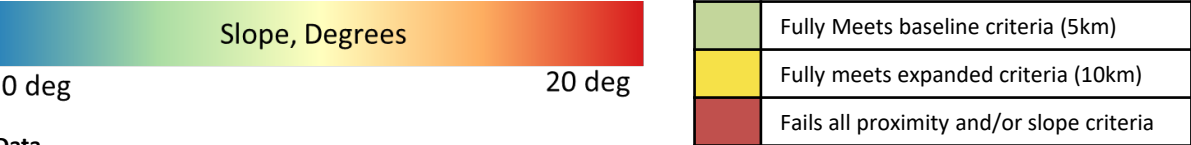
- PSR3, 4, and 5 are possible, with PSR2 just barely outside range
- Note that the large PSRs typically discussed in this region (Spudis, Shackleton) are not in range

# 001 Shackleton Ridge : Traverse Options



Option	Score	Rank	Path #	From - To	Length: leg (total) km	Slope		
						Max, °	>20% (m)	Avg, °
A	1.00	10	11	Customer – PPP0	2.9	12.2	0% (0m)	5.3
			14	PPP0 – PSR4	5.3 (8.2)	19.0	0% (0m)	8.4
B	1.05	6	13	Customer – PPP1	4.2	14.9	0% (0m)	6.3
			2	PPP1 – PSR4	3.9 (8.1)	19.0	0% (0m)	8.4
C	0.89	20	13	Customer – PPP1	4.2	14.9	0% (0m)	6.3
			4	PPP1 – PSR3	6.6 (10.8)	18.7	0% (0m)	10.2
D	0.82	23	9	Customer – PPP2	4.1	17.9	0% (0m)	6.8
			6	PPP2 – PSR5	3.8 (7.9)	20.8	1% (41m)	6.9
E	0.94	14	10	Customer – PPP3	2.6	17.2	0% (0m)	7.6
			8	PPP3 – PSR1	6.3 (8.9)	19.8	0% (0m)	8.0
F	0.86	21	13	Customer – PPP1	4.2	14.9	0% (0m)	6.3
			12	PPP1 – PSR2	9.0 (13.2)	18.2	0% (0m)	8.4

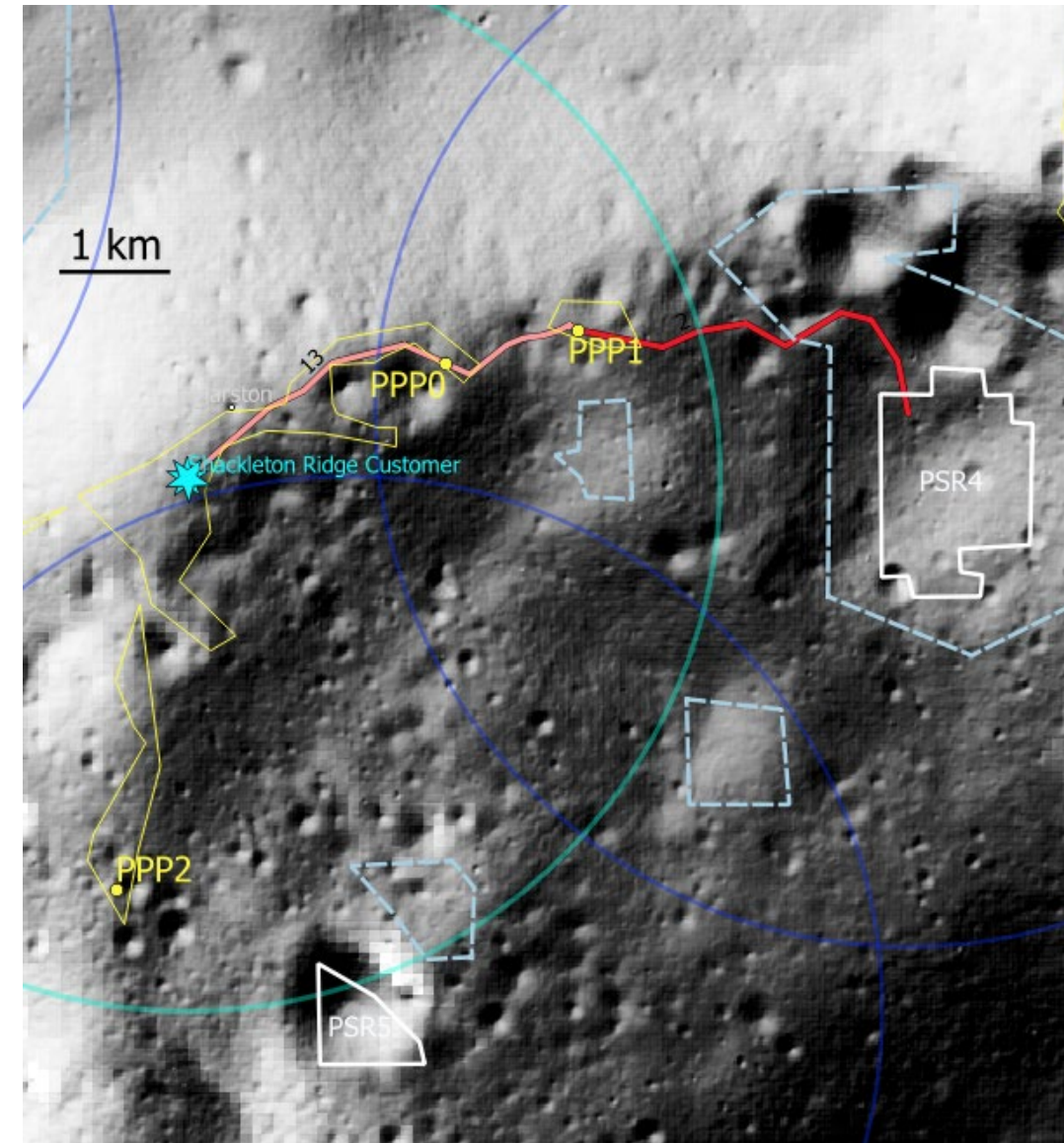
- Option A and B are the same path but if PPP1 is used all criteria are met. PPP0 would put the mine slightly out of the 5km range
  - Option A was used in AIAA-2020-4042



Data  
High Res LOLA Topography DEMs from PGDA: Site 01. <https://pgda.gsfc.nasa.gov/products/78>

# 001 Shackleton Ridge: PSR Summary

	5km Range	10km Range	Slope	PSR Size equivalent diameter, km	Mine size, equivalent diameter, km
PSR1	Acceptable traverse path exceeds distance (by ~1km)	PPP options in range	Paths available	1.20	1.04
PSR2	Acceptable traverse path exceeds distance	PPP options in range	Paths available	0.94	0.88
PSR3	Acceptable traverse path exceeds distance (by ~1.5km)	PPP options in range	Paths available, but high average slopes	1.03	0.94
PSR4	PPP options in range	PPP options in range	Paths available	1.75	1.47
PSR5	PPP options in range	PPP options in range	Slopes into PSR exceed 20deg in all directions	0.87	0.19

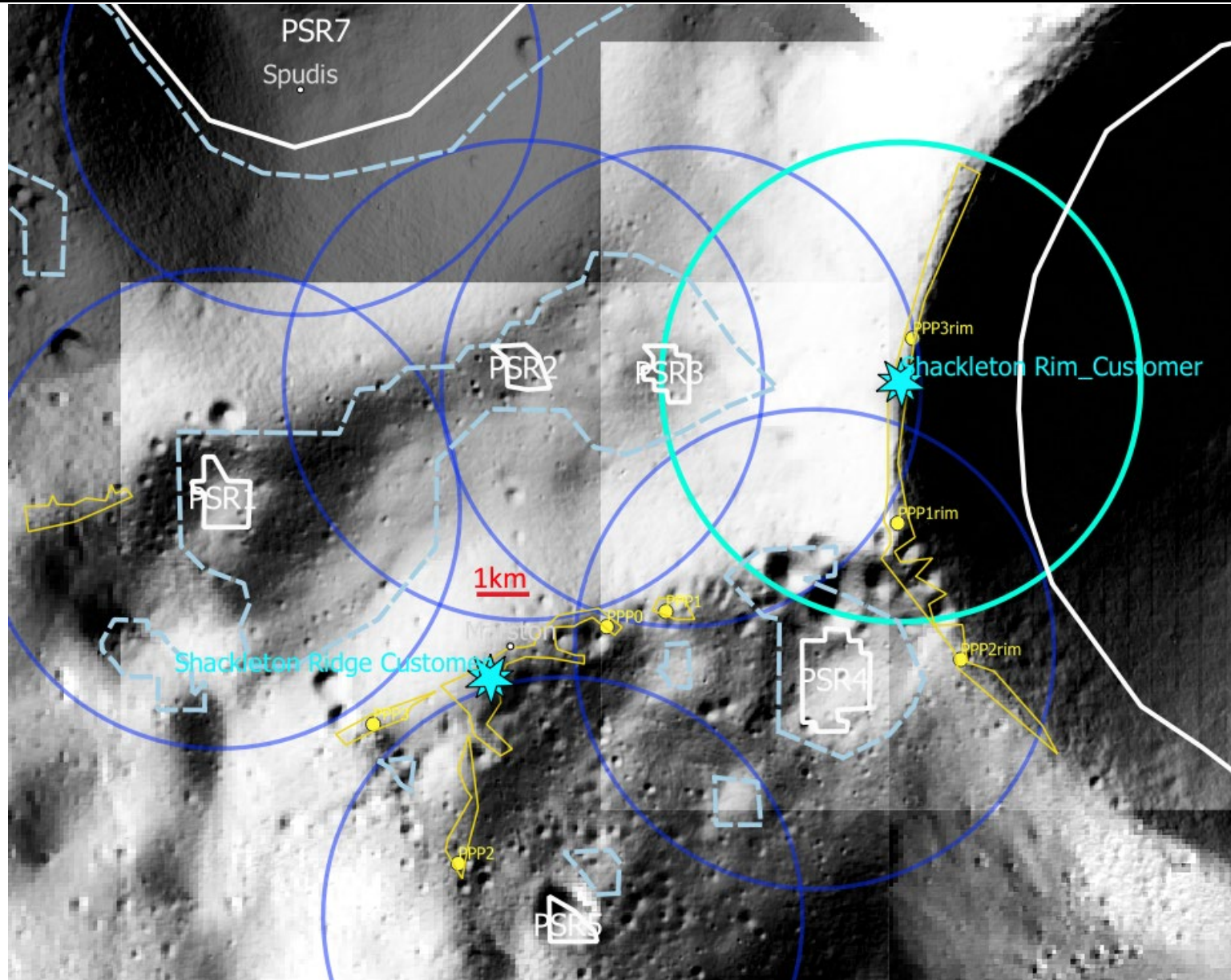


- One best option that meets all existing criteria. This was the baseline for the architecture study in 2020.
- Adding 1-2km to distance criteria would put all 5 in bounds.
- Of all the regions of interest, this region provides the most flexibility.



# 004 Shackleton Rim


# 004 Shackleton Rim: ISRU Regions Of Interest





## Customer site

 5km radius around Customer


## Mine sites

 PSR = Shallow ice stability = deep crater

 ISR = 'Deeper' ice stability (50 to 100 cm) = shallow crater

 5km radius around mine

## Production sites

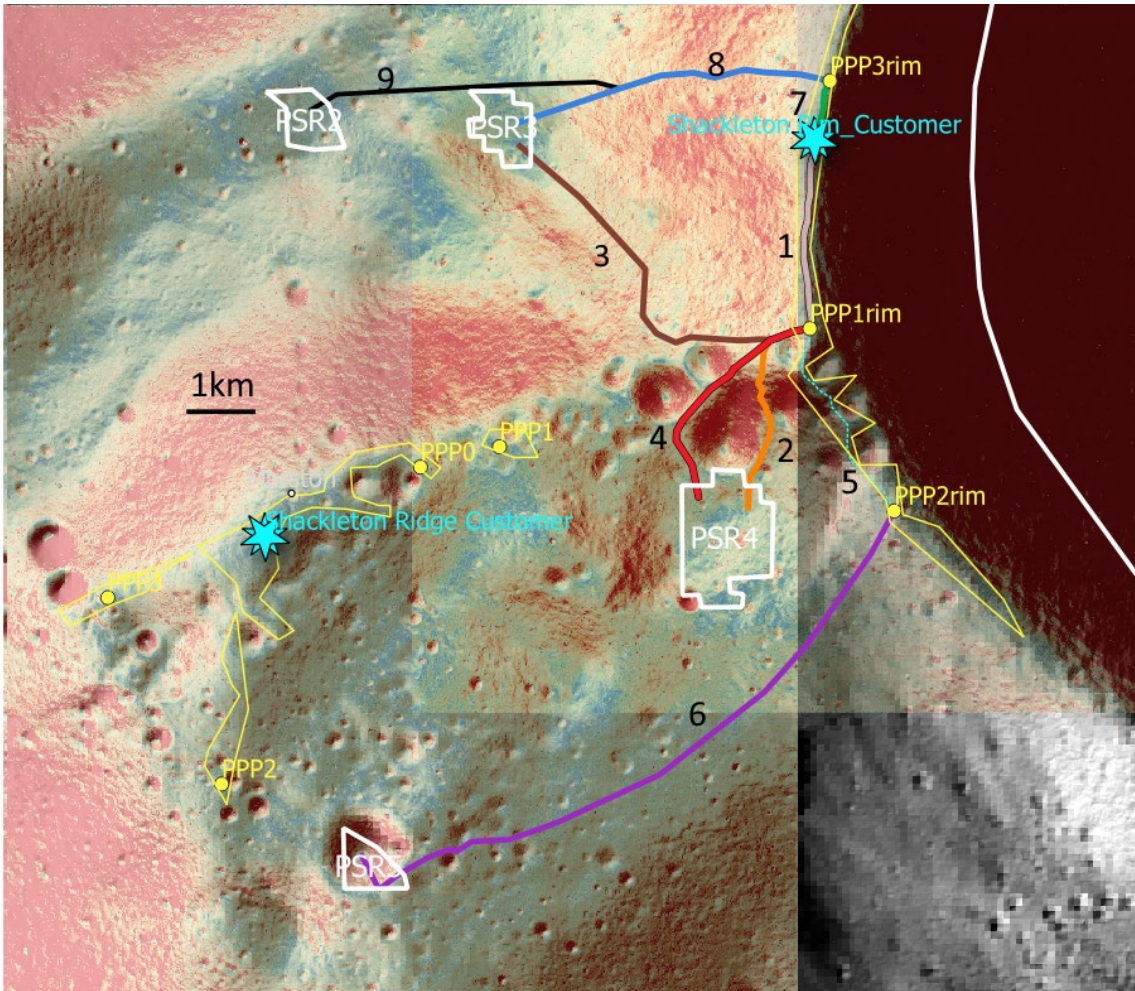
 PPP = ISRU propellant production plant @ illuminated site

## Analysis:

Valid sites should have a PPP options where light and blue circles overlap

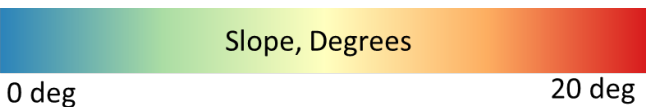
- All PSRs are same as those from Site 001
- PPPs restricted along rim (one direction), limits PSR options

# 004 Shackleton Rim: Traverse Options



Option	Score	Rank	Path #	From - To	Length (total), km	Slope		
						Max, °	>20° % (m)	Avg, °
A	0.92	16	1	Customer – PPP1r	2.98	15.8	0% (0m)	5.56
			3	PPP1r – PSR3	6.3 (9.28)	18.8	0% (0m)	10.9
★ B	1.08	4	1	Customer – PPP1r	2.98	15.8	0% (0m)	5.56
			4	PPP1r – PSR4	3.8 (6.8)	18.9	0% (0m)	9.36
C	1.08	5	1	Customer – PPP1r	2.98	15.8	0% (0m)	5.56
			2	PPP1r – PSR4e	3.4 (6.42)	19.9	0% (0m)	11.3
D	0.99	12	7	Customer – PPP3r	0.96	15.1	0% (0m)	5.8
			8	PPP3r – PSR3	5.0	20.1	0.1% (5m)	13.0
E	0.85	22	7	Customer – PPP3r	0.96	15.1	0% (0m)	5.8
			9	PPP3r – PSR2	8.2 (9.2)	20.0	0.1% (5m)	9.6
F	0.68	26	5	Customer – PPP2r	6.43	19.8	0% (0m)	7.09
			6	PPP2r – PSR5	10.9 (9.3)	22.1	0.3% (29m)	7.69

- PSR4, is best option, the same as site 001, and can be done from 2 different paths (B and C)

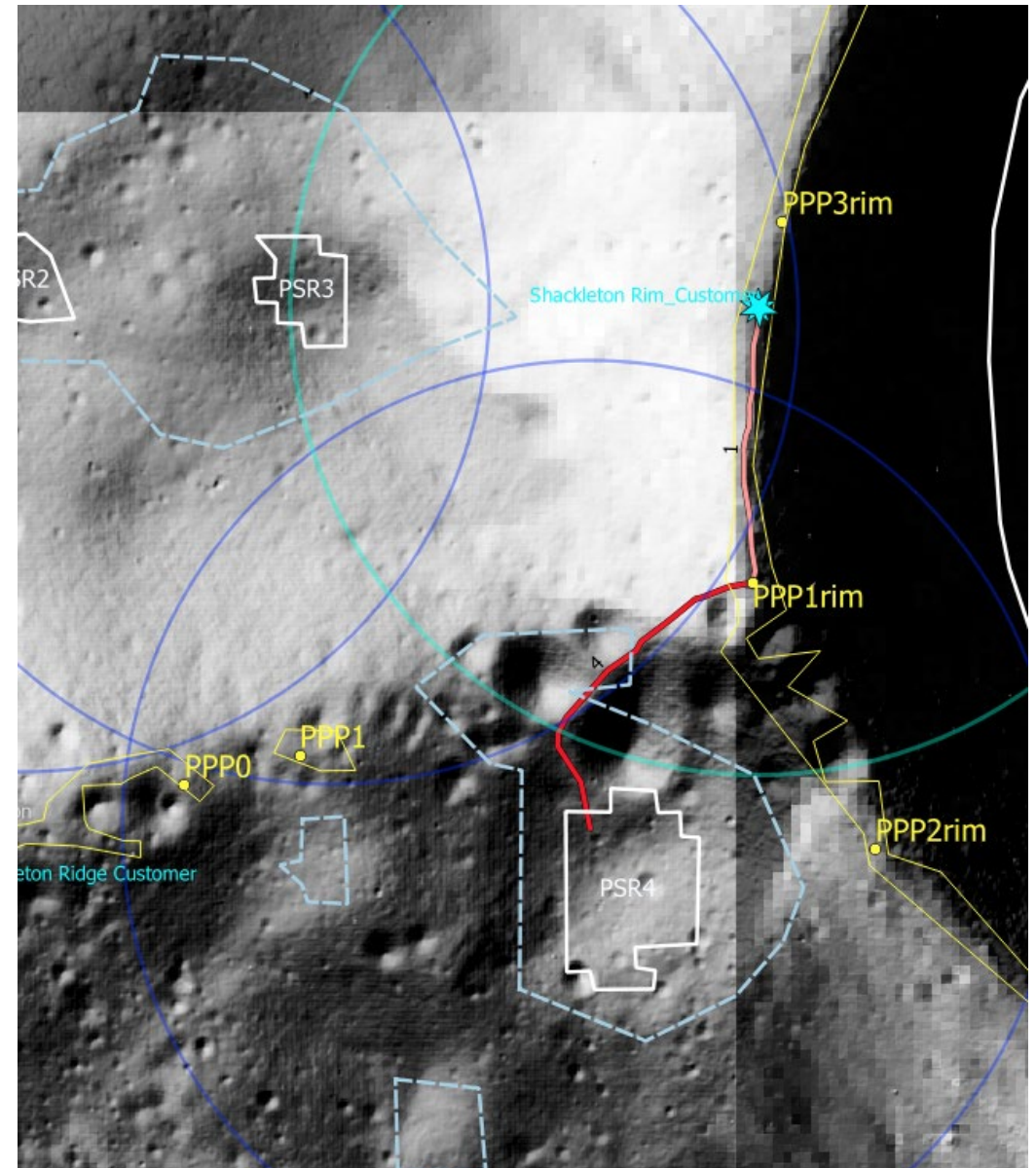


	Fully Meets baseline criteria (5km)
	Fully meets expanded criteria (10km)
	Fails all proximity and/or slope criteria

# 004 Shackleton Rim: Summary

	5km ranges	10km Range	Slope	PSR Size equivalent diameter, km	Mine size, equivalent diameter, km
PSR2	Out of range	PPP options in range	Paths available, but high average slopes	0.94	0.88
PSR3	PPP options in range but very close (1km) to customer	PPP options in range but very close (1km) to customer	Paths available, but high average slopes	1.03	0.94
PSR4	PPP options in range	PPP options in range	Paths available, but high average slopes	1.75	1.47
PSR5	Out of range	PPP options in range	Slopes into PSR exceed 20deg in all directions	0.87	0.19

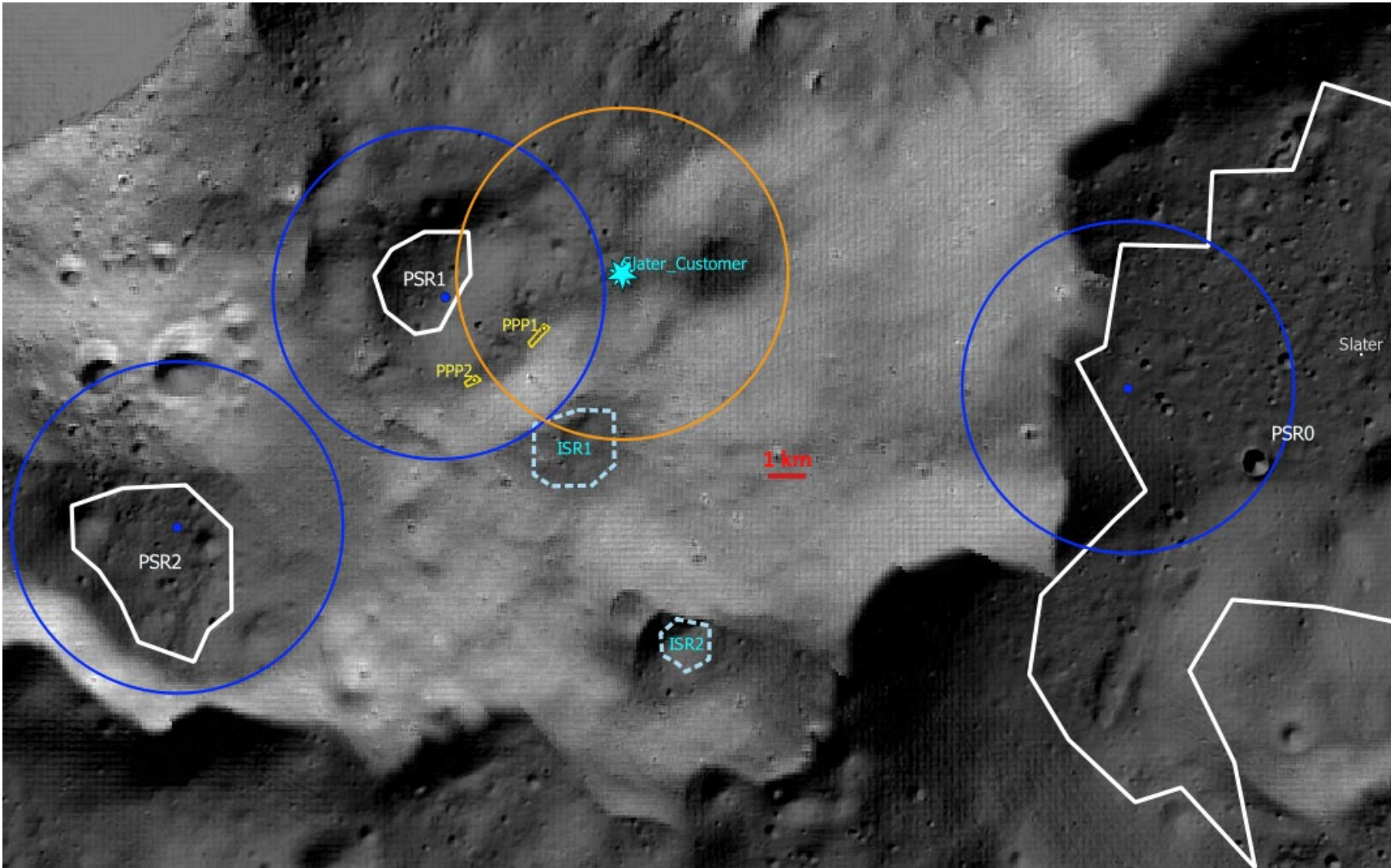
- One best PSR that meets all existing criteria, and is the same PSR that worked for 001 Shackleton Ridge
- Expanded proximity criteria opens up PSR 2 and 3, -
  - However, PSR3 is along the PSR2 traverse route so there is limited value





# 007 Slater


# 007 Slater: ISRU Regions Of Interest





## Customer site

 5km radius around Customer


## Mine sites

 PSR = Shallow ice stability = deep crater

 ISR = 'Deeper' ice stability (50 to 100 cm) = shallow crater

 5km radius around mine

## Production sites

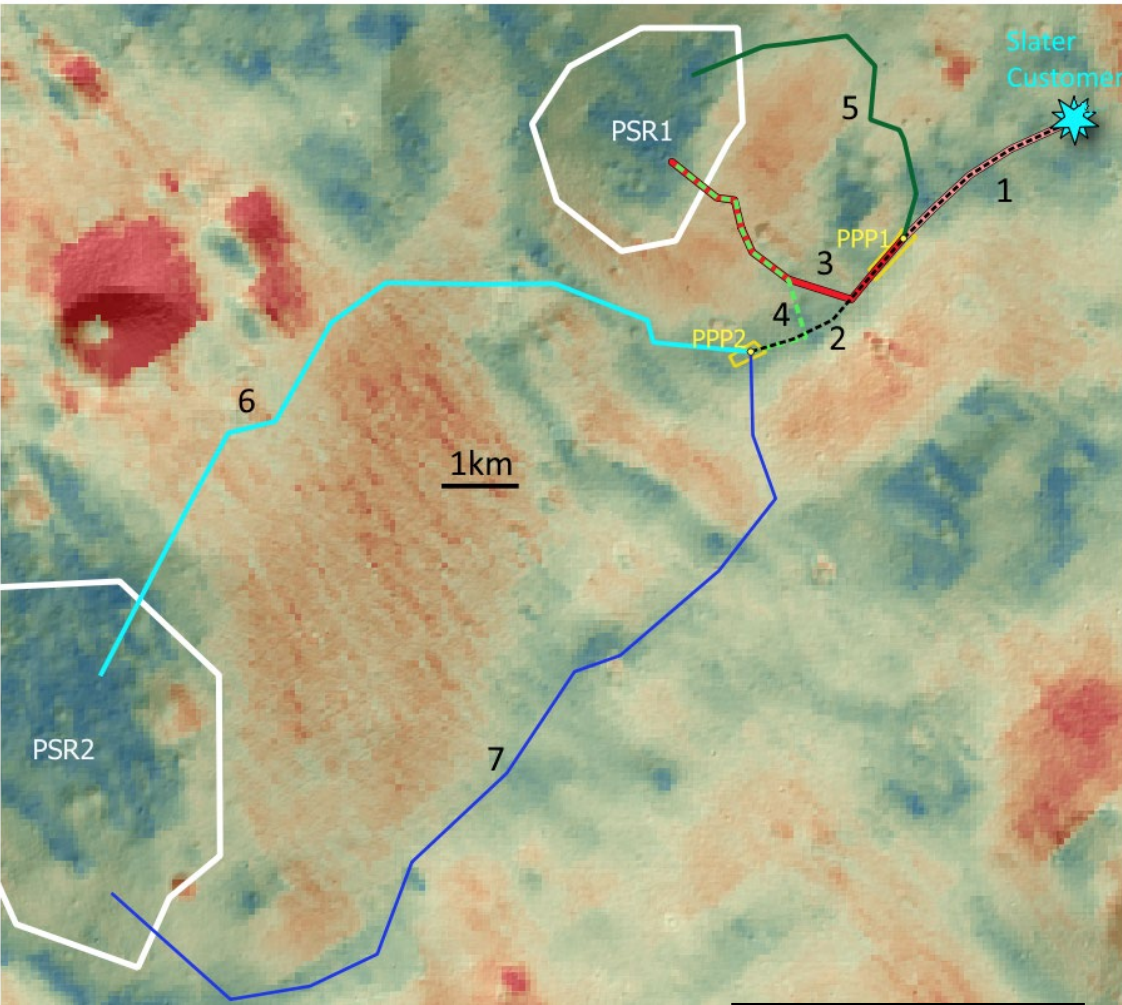
 PPP = ISRU propellant production plant @ illuminated site

## Analysis:

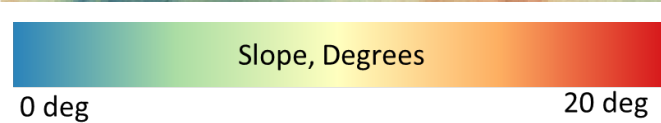
Valid sites should have a PPP options where light and blue circles overlap

- To meet the 5km travel limits only 1 PSR is viable for ISRU mining

# 007 Slater: Traverse Options



Option	Score	Rank	Path #	From - To	Length: leg (total) km	Slope		
						Max, °	>20° % (m)	Avg, °
★ A	1.1	3	1	Customer - PPP1	2.91	14.5	0% (0m)	5.5
			3	PPP1 - PSR1	4.4 (3.9)	16.4	0% (0m)	8.2
B	1.03	8	1	Customer - PPP1	2.91	14.5	0% (0m)	5.5
			5	PPP1 - PSR1N	5.5 (8.41)	15.4	0% (0m)	6.8
C	1.00	11	2	Customer - PPP2	5.62	17.6	0% (0m)	5.0
			4	PPP2 - PSR1	4.05 (9.67)	16.2	0% (0m)	7.7
D	0.58	28	2	Customer - PPP2	5.62	17.6	0% (0m)	5.0
			6	PPP2 - PSR2	12.2 (17.8)	34.9	3.3% (401m)	8.6
E	0.71	25	2	Customer - PPP2	5.62	17.6	0% (0m)	5.0
			7	PPP2 - PSR2s	14.9 (20.5)	26.5*	0.3% (47m)	6.5



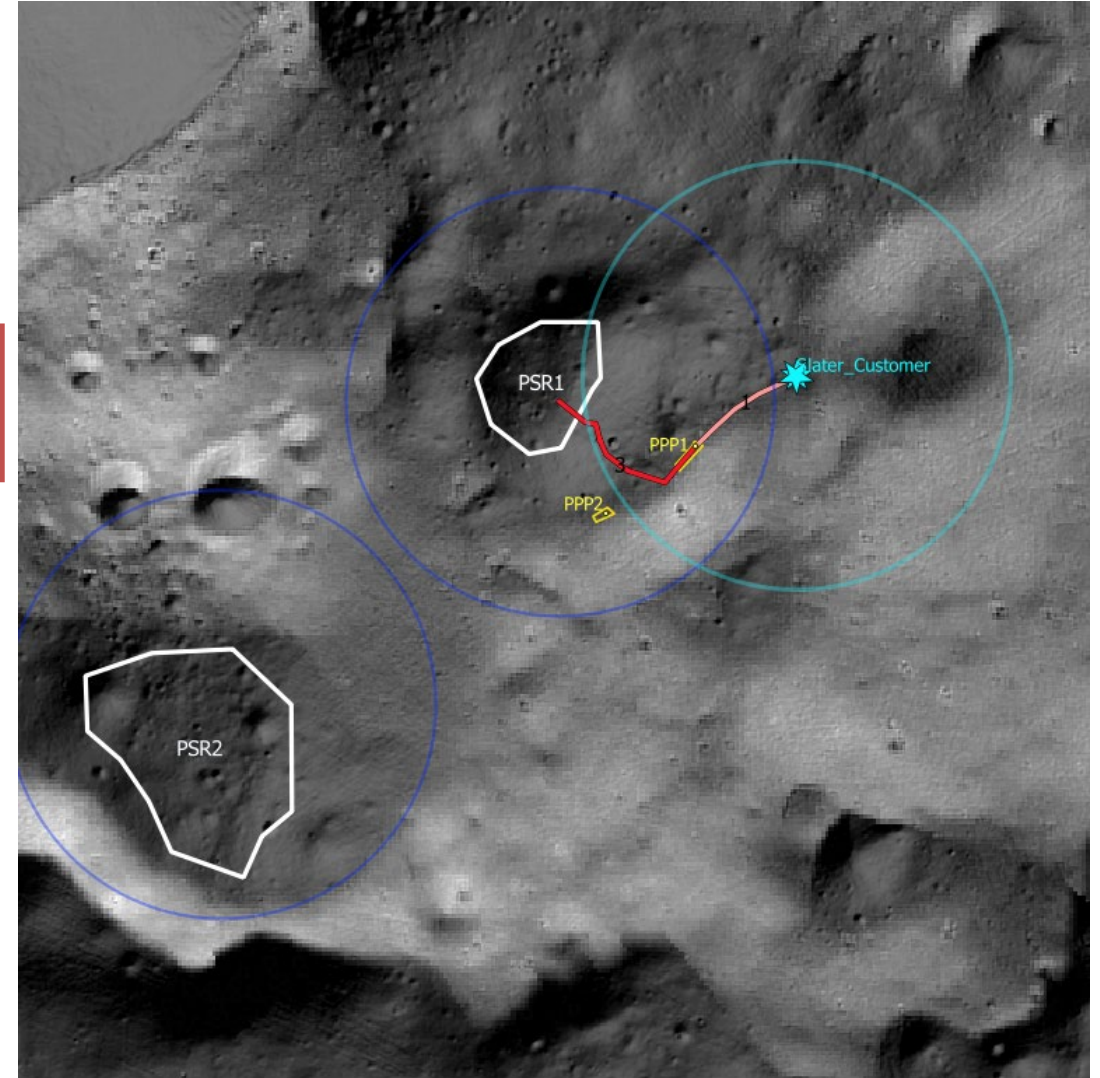
Green	Fully Meets baseline criteria (5km)
Yellow	Fully meets expanded criteria (10km)
Red	Fails all proximity and/or slope criteria

- There is a clear optimal slope path (a 'pass') into PSR1
- Expanding criteria opens up an additional PPP location and an additional path into PSR1
- To get to another PSR, proximity criteria would have to increase to 15km.

# 007 Slater: Summary



	5km Range	10km Range	Slope	PSR Size equivalent diameter, km	Mine size, equivalent diameter, km
PSR0 (Slater)	Out of range	No PPP options in range	Not Evaluated, but one Path available	17.33	12.65
PSR1	PPP options in range	PPP options in range	Paths Available : 1 clear best path	2.87	2.62
PSR2	Out of range	PPP option in range	Slopes favorable to SE, but requires longer traverses (~15 km)	4.77	4.53

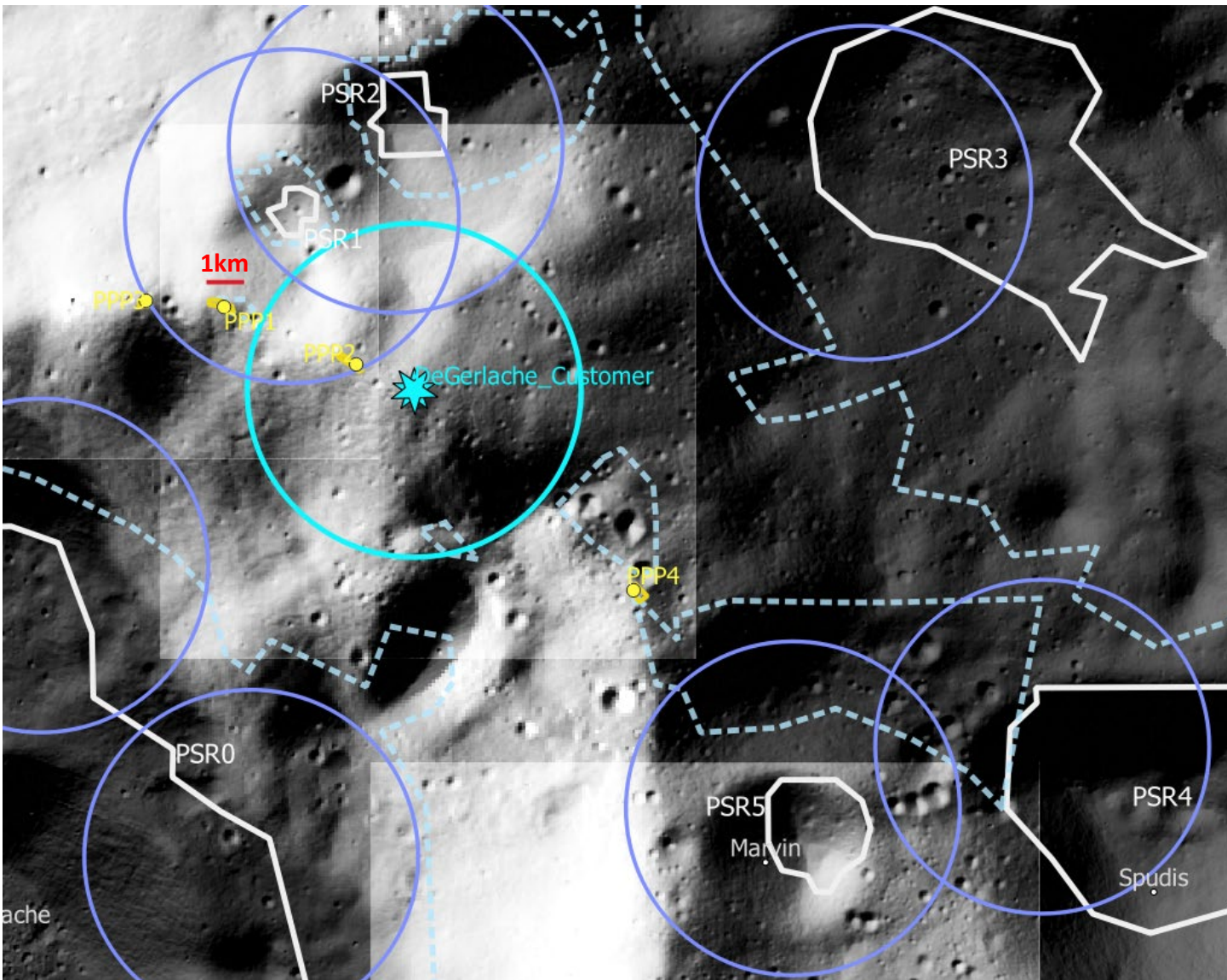


- There is a best option for ISRU that meets ground rule criteria
- Other options would require expanded criteria
  - For the same PSR, there are is an additional PPP region that only requires an additional 0.5 km
  - Expanding proximity criteria to 10km for each leg puts PSR2 in range, but path finding would cause traverses to exceed 10km by 5km




# 011 De Gerlache


# 011 De Gerlache: ISRU Regions Of Interest




## Customer site

 5km radius around Customer


## Mine sites

 PSR = Shallow ice stability = deep crater

 ISR = 'Deeper' ice stability (50 to 100 cm) = shallow crater

 5km radius around mine

## Production sites

 PPP = ISRU propellant production plant @ illuminated site

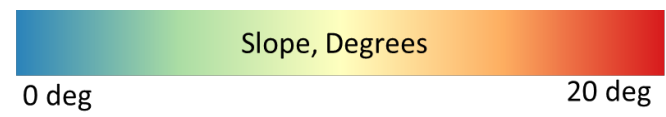
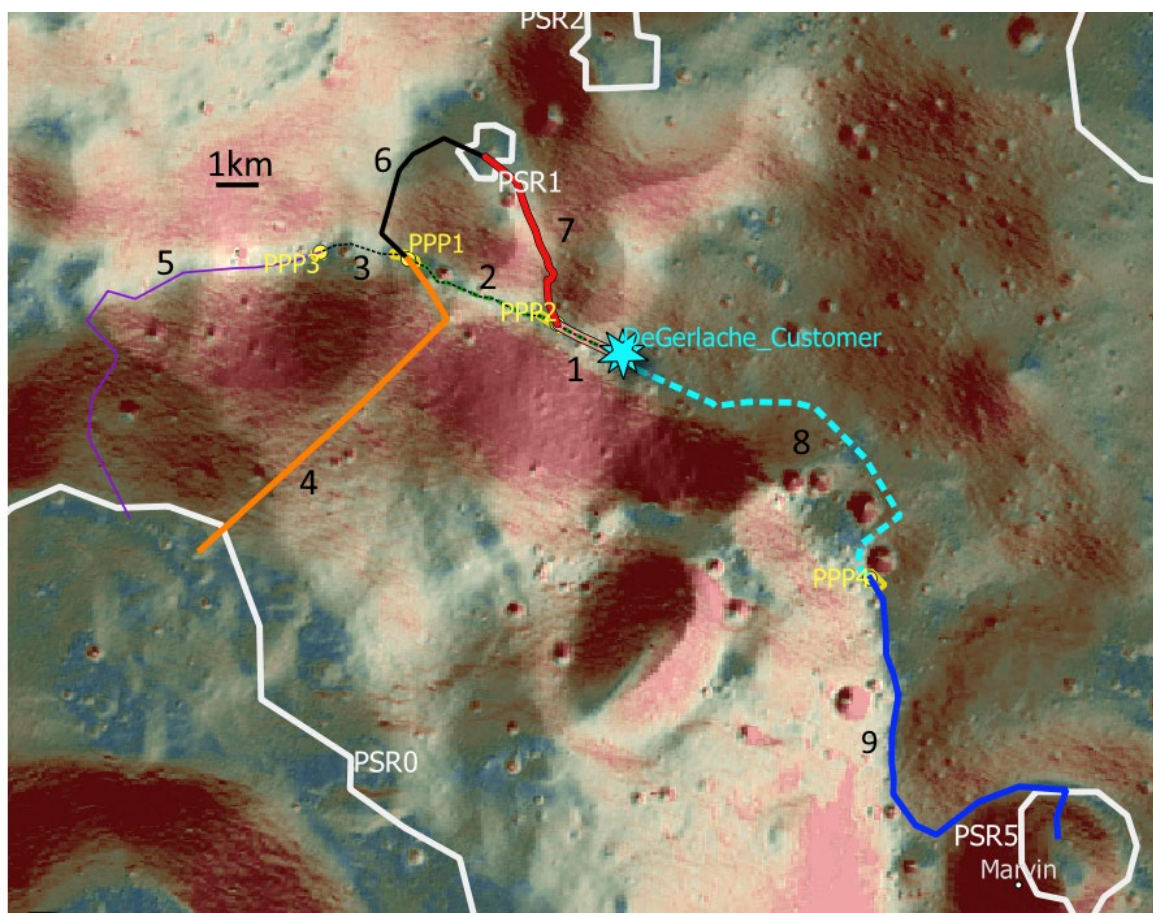
## Analysis:

Valid sites should have a PPP options where light and blue circles overlap

- Only one PSR (PSR1) and one PPP area (PPP2) is in proximity range



# 011 De Gerlache: Traverse Options



	Fully Meets baseline criteria (5km)
	Fully meets expanded criteria (10km)
	Fails all proximity and/or slope criteria

**Data**  
 High Res LOLA Topography DEMs from PGDA: Site 11, SL2, SL3 .  
<https://pgda.gsfc.nasa.gov/products/78>.  
 PDS data from Polar Stereographic GDR, 5mpp, latitude 87.5 deg,  
[http://imbrium.mit.edu/BROWSE/LOLA\\_GDR/POLAR/SOUTH\\_POLE/](http://imbrium.mit.edu/BROWSE/LOLA_GDR/POLAR/SOUTH_POLE/)

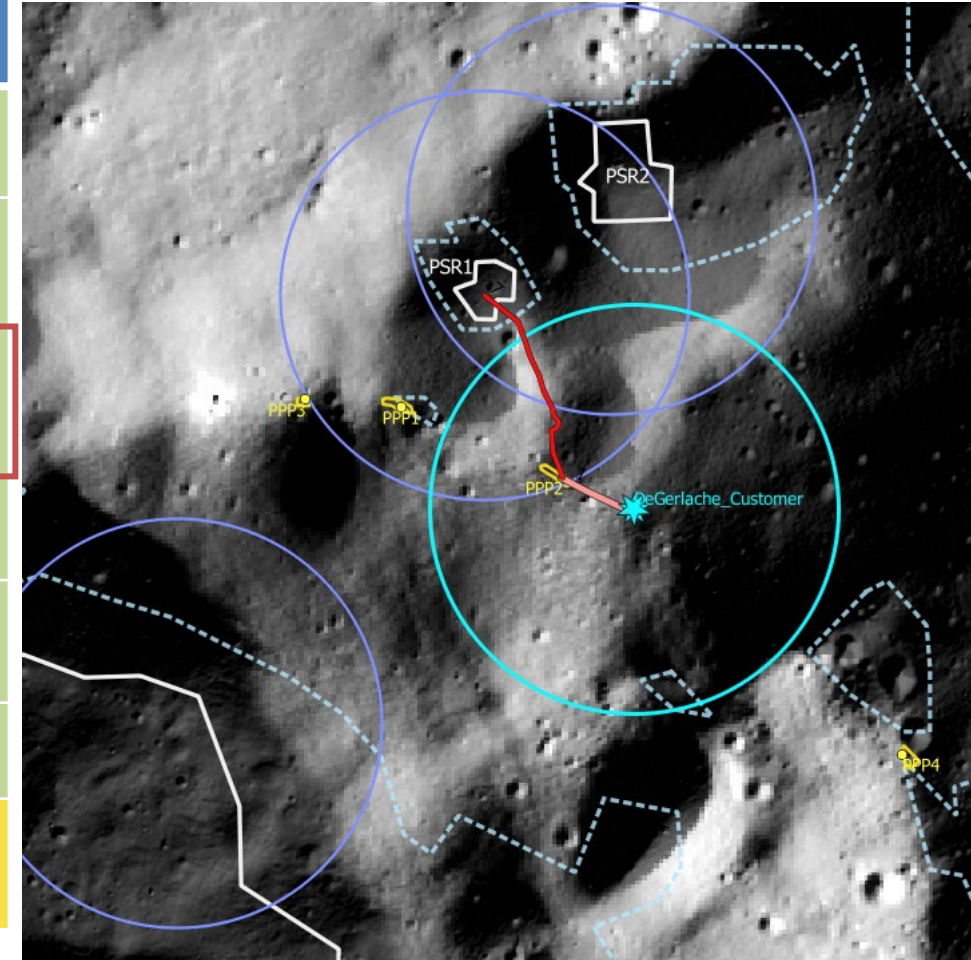
Option	Score	Rank	Path #	From - To	Length (total), km	Slope		
						Max, °	>20° % (m)	Avg, °
A	1.02	9	1	Customer – PPP2	1.96	11.1	0% (0m)	4.4
			7	PPP2 – PSR1	5.2 (7.2)	19.7	0% (0m)	11.1
B	0.90	19	2	Customer – PPP1	6.39	12.7	0% (0m)	5.7
			6	PPP1 – PSR1	5.44 (11.8)	19.8	0% (0m)	8.8
C	0.49	30	3	Customer – PPP3	8.85	14.8	0% (0m)	5.6
			5	PPP3 – PSR0	12.8 (21.7)	31.9	2% (238m)	11.3
D	0.52	29	2	Customer – PPP1	6.39	12.7	0% (0m)	5.7
			4	PPP1 – PSR0	10.9 (17.3)	30.6	12% (1314m)	13.7
E	0.58	27	8	Customer – PPP4	11.5	19.6	0% (0m)	9.2
			9	PPP4 - PSR5	12.6 (24.1)	21.5	0.3% (38m)	8.3

- No path fully meet baseline criteria - All paths exceed proximity requirement (though B only by 200m)
- Option A and B are possible with only an addition 1-2km proximity criteria
- All other options exceed expanded criteria somewhat due to pathfinding around high slopes and all exceed Slope criteria

# 011 De Gerlache: Summary



	5km Range	10km Range	Slope	PSR Size equivalent diameter, km	Mine size, equivalent diameter, km
PSR0 (DeGerlache)	Out of range	PPP options in range	No <20deg paths	19.37	9.60
PSR0a (DeGerlache East)	Out of range	No PPP options in range	Paths available	19.37	9.60
PSR1	Acceptable traverse path exceeds distance (by 0.2km)	PPP options in range	Paths available	1.29	1.06
PSR2	No PPP options in range	PPP options in range	No <20deg paths	2.26	1.62
PSR3	Out of range	No PPP options in range	Options are on Northwest side, would require longer traverses	8.81	8.05
PSR4 (Spudis)	Out of range	Out of range	No <20deg paths	8.28	4.01
PSR5 (Marvin)	Out of range	Acceptable traverse path exceeds distances (by <5km)	Paths available on far (east) side of crater, but surrounding slopes high	3.16	0.75

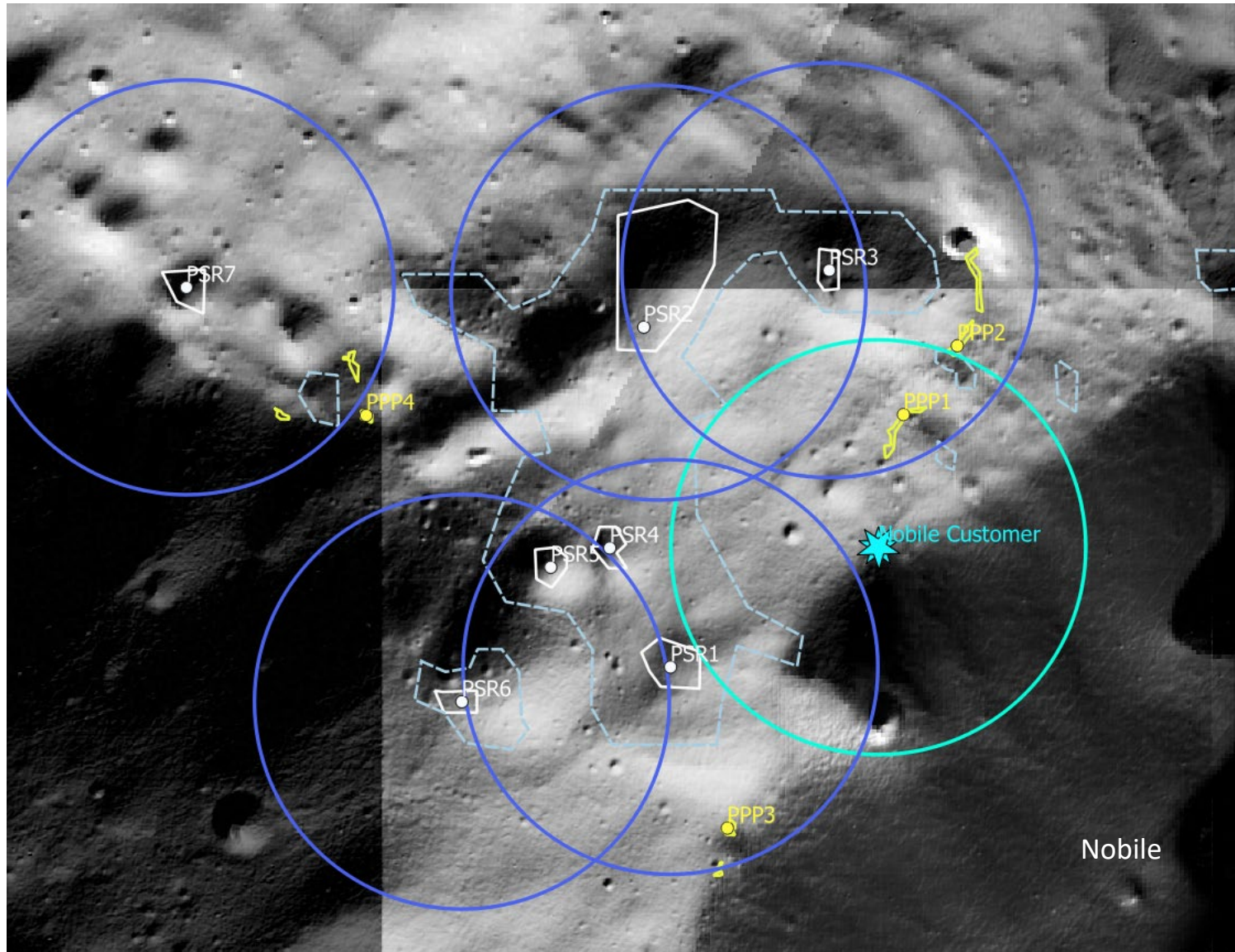


- No options fully meet baseline, but PSR1 has one option that is only 0.2km exceedance
- Larger PSR access requires expanded ground rule requirements
- Several ISRs (deeper ice) available in area, some even are along ridge. This would require other ISRU methods to make use of.




# 102 Nobile




# 102 Nobile: ISRU Regions Of Interest




## Customer site

-  5km radius around Customer

## Mine sites

-  PSR = Shallow ice stability = deep crater
-  ISR = 'Deeper' ice stability (50 to 100 cm) = shallow crater
-  5km radius around mine

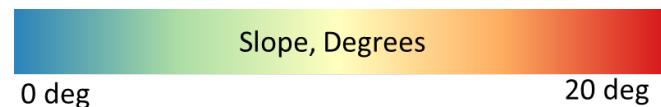
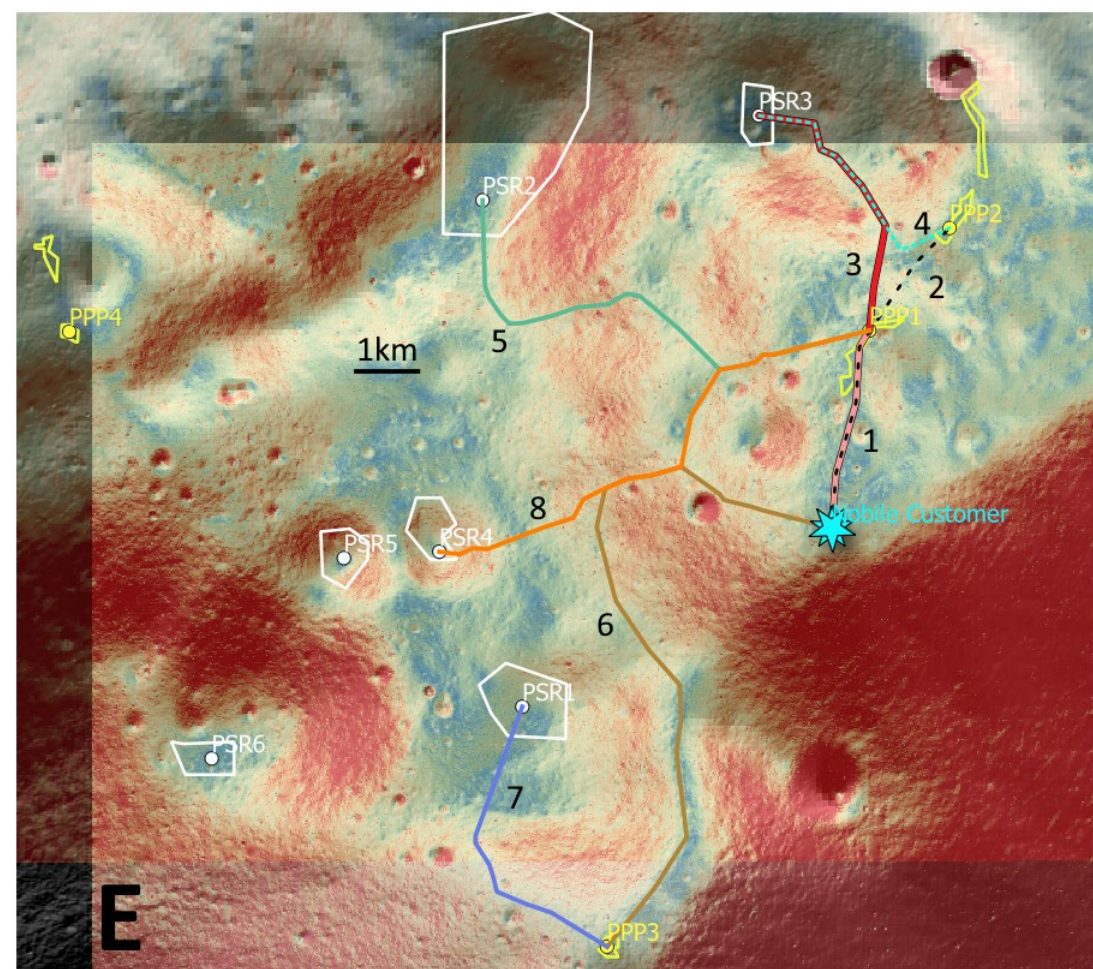
## Production sites

-  PPP = ISRU propellant production plant @ illuminated site

## Analysis:

- Valid sites should have a PPP options where light and blue circles overlap
- Only one PSR (PSR3) and one PPP area (PPP1) is in proximity range, though PPP2 is not far

# 102 Nobile: Traverse Options



	Fully Meets baseline criteria (5km)
	Fully meets expanded criteria (10km)
	Fails all proximity and/or slope criteria

Option	Score	Rank	Path #	From - To	Length (total), km	Slope		
						Max, °	>20° % (m)	Avg, °
★ A	1.12	2	1	Customer – PPP1	3.3	9.9	0% (0m)	4.1
			3	PPP1 – PSR3	4.7 (8.0)	14.3	0% (0m)	8.2
B	0.92	17	1	Customer – PPP1	3.3	9.9	0% (0m)	4.1
			5	PPP1 – PSR2	8.6 (11.9)	18.3	0% (0m)	9.3
C	0.99	13	2	Customer – PPP2	5.4	15.7	0% (0m)	5.0
			4	PPP2 – PSR3	4.3 (9.7)	17.1	0% (0m)	8.3
D	0.78	24	6	Customer – PPP3	12.2	21.8	0.2% (22m)	8.3
			7	PPP3 – PSR1	5.2 (17.4)	14.8	0% (0m)	7.7
E	0.91	18	1	Customer – PPP1	3.3	9.9	0% (0m)	4.1
			8	PPP1 – PSR4	8.6 (11.9)	17.7	0% (0m)	9.8

- Customer site in difficult position relative to PSRs (high slope on 3 sides)
- One path (A) fully meets baseline criteria.
- Expanding criteria opens three additional options:
  - B is a larger PSR and only exceeds baseline criteria by 400m
  - C is a different PPP site but same PSR as path A
  - E has high average slope to a small PSR

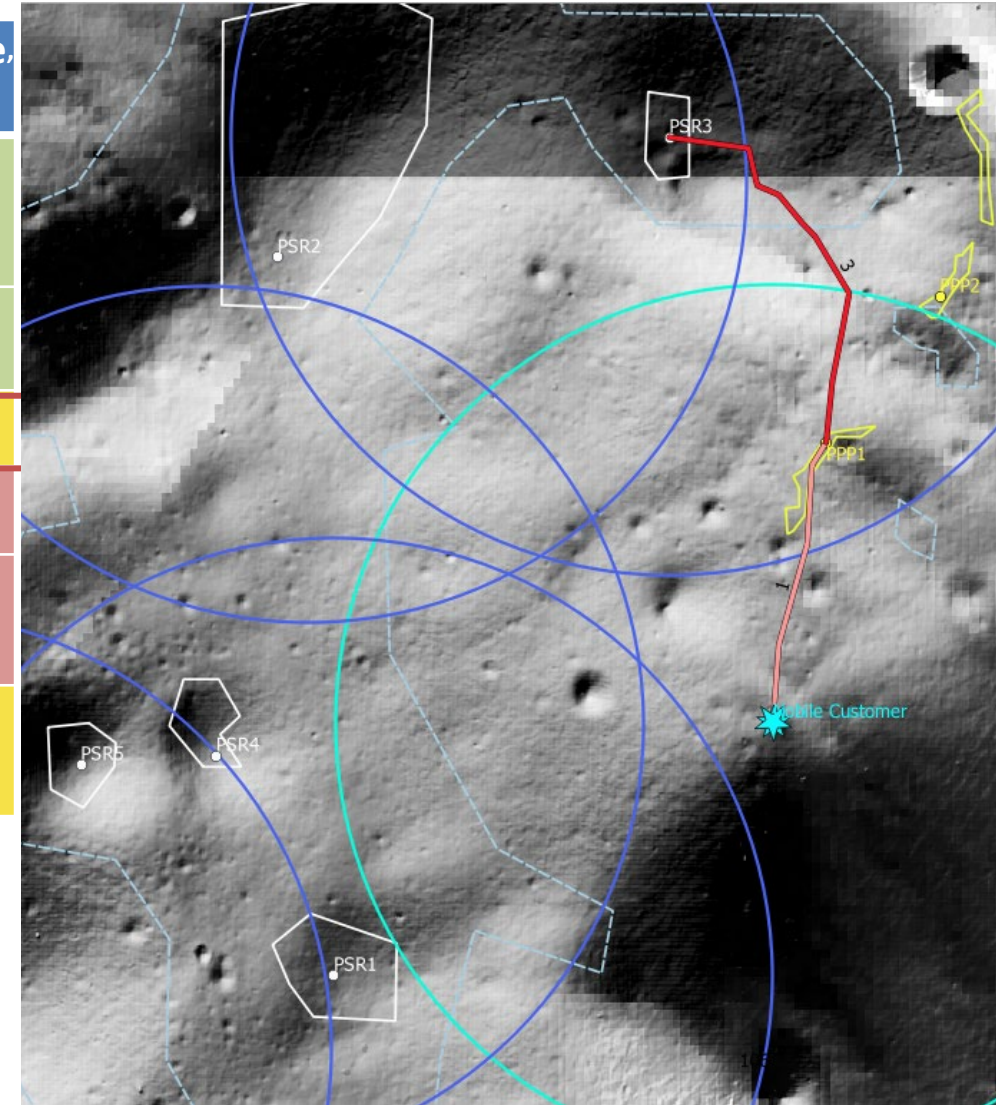
**Data**  
 High Res LOLA Topography DEMs from PGDA.:  
<https://pgda.gsfc.nasa.gov/products/78>.  
 PDS data from Polar Stereographic GDR, 5mpp, latitude 87.5 deg,  
[http://imbrium.mit.edu/BROWSE/LOLA\\_GDR/POLAR/SOUTH\\_POLE/](http://imbrium.mit.edu/BROWSE/LOLA_GDR/POLAR/SOUTH_POLE/)

# 102 Nobile : Summary



	5km Range	10km Range	Slope	PSR Size equivalent diameter, km	Mine size, equivalent diameter, km
PSR1	No PPP options in range	Acceptable traverse path exceeds distances (by 2km)	Paths available	1.27	1.10
PSR2	No PPP options in range	PPP options in range	Paths available, but high average slopes	2.95	1.33
PSR3	PPP options in range	PPP options in range	Paths available	0.77	0.65
PSR4	No PPP options in range	PPP options in range	Paths available, but high average slopes	0.84	0.31
PSR5	No PPP options in range	No PPP options in range	Path not evaluated - high crater slope limits mineable area	0.84	0.37
PSR6	No PPP options in range	No PPP options in range	Not evaluated. One possible path but will have high average slopes	0.76	0.74

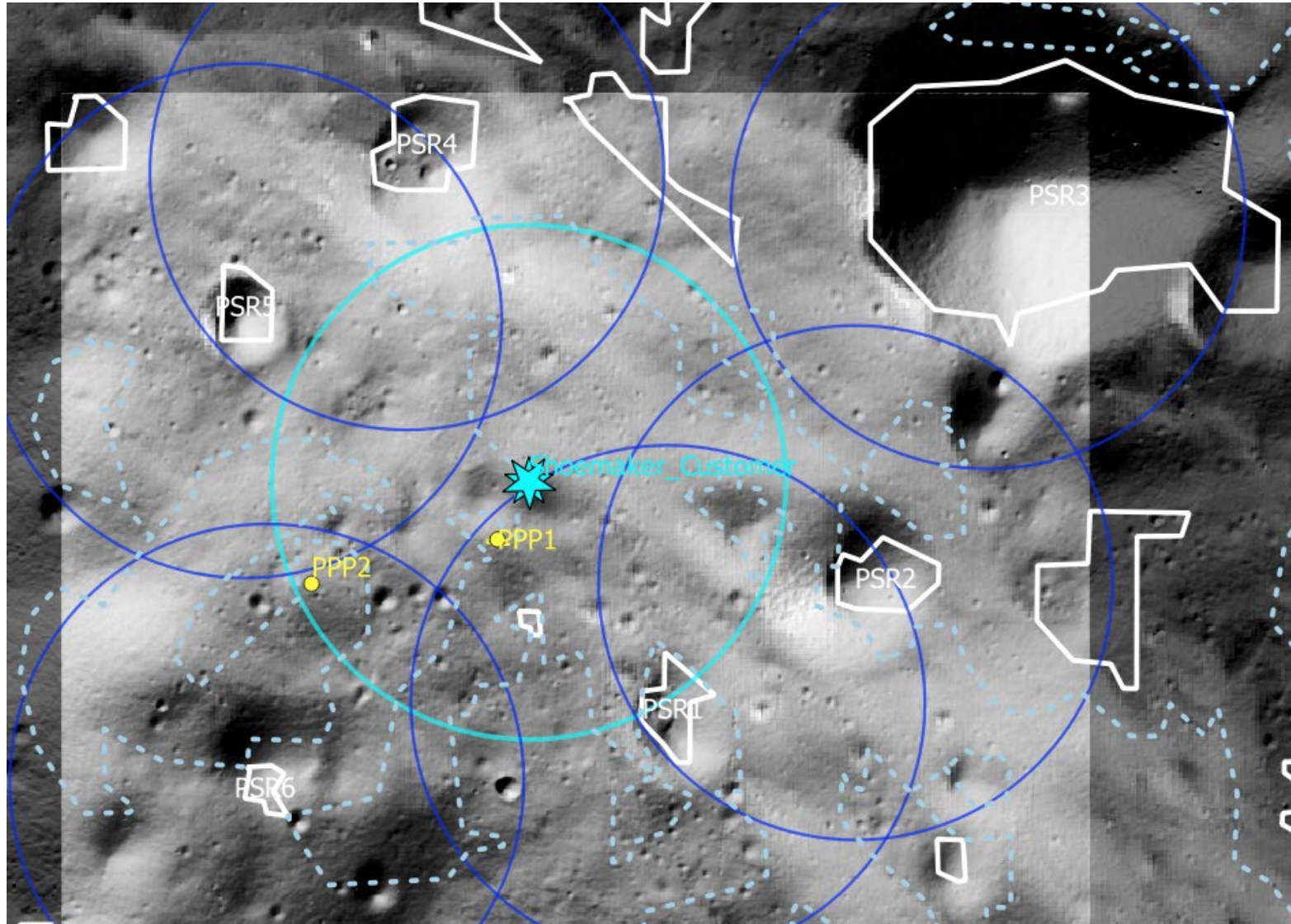
- One PSR option fully meets criteria. A second PPP site using same PSR only exceeds criteria by 400m.
- Many PSRs do not meet 1 km size criteria and/or have restricted mineable area





# 105 Shoemaker




# 105 Shoemaker: ISRU Regions Of Interest




## Customer site

-  5km radius around Customer Site

## Mine sites

-  PSR = Shallow ice stability = deep crater
-  ISR = 'Deeper' ice stability (50 to 100 cm) = shallow crater
-  5km radius around mine

## Production sites

-  PPP = ISRU propellant production plant @ illuminated site

## Analysis:

- Valid sites should have a PPP options where light and blue circles overlap
- The PPP regions are low quality and barely meet the criteria (only few pixels)
  - Technically PSR1 and PSR2 are in range (though PSR2 has high slope)

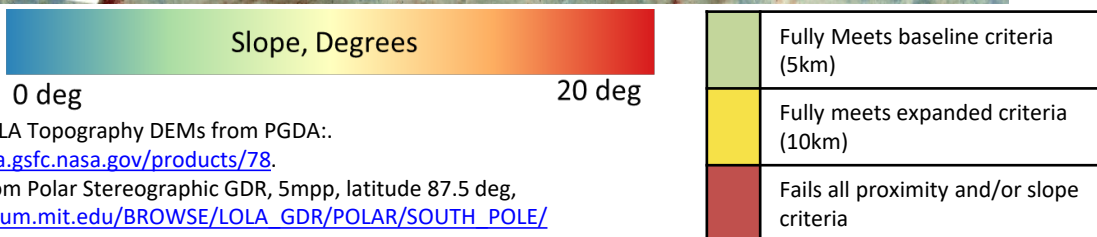
# 105 Shoemaker: Traverse Options



Option	Score	Rank	Path #	From - To	Length (total), km	Slope		
						Max, °	>20° % (m)	Avg, °
★ A	1.23	1	1	Customer – PPP1	1.3	10.8	0% (0m)	4.32
			3	PPP1 – PSR1	4.9 (6.2)	13.9	0% (0m)	5.5
B	1.04	7	2	Customer – PPP2	4.7	12.8	0% (0m)	5.6
			4	PPP2 – PSR6	5.0 (9.7)	19.0	0% (0m)	7.5
C	0.93	15	1	Customer – PPP1	1.3	10.8	0% (0m)	4.32
			5	PPP1 – PSR4	9.3 (10.6)	19.9	0% (0m)	8.9

- Two PSRs have viable solutions that meet all ground rules.
  - Paths A (to PSR1) and B (to PSR6)
  - Path A more favorable because crater slopes, and path average slope, are lower.
- With extended criteria, path C (to PSR4) is possible though slopes near PSR are high.
- Other PSRs (2, 3, and 5) were not considered because crater wall slopes are high, either providing no path in and/or severely limiting minable area

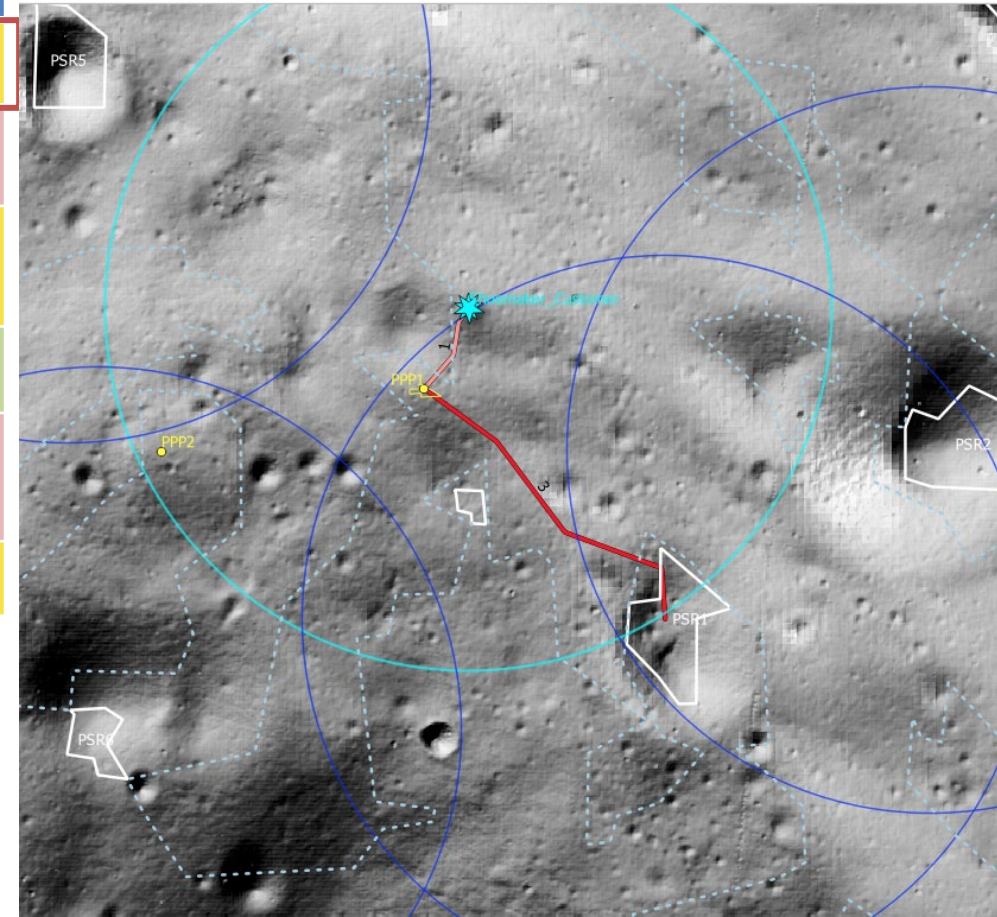
**Data**  
 High Res LOLA Topography DEMs from PGDA.:  
<https://pgda.gsfc.nasa.gov/products/78>.  
 PDS data from Polar Stereographic GDR, 5mpp, latitude 87.5 deg,  
[http://imbrium.mit.edu/BROWSE/LOLA\\_GDR/POLAR/SOUTH\\_POLE/](http://imbrium.mit.edu/BROWSE/LOLA_GDR/POLAR/SOUTH_POLE/)



# 105 Shoemaker : Summary



	5km Range	10km Range	Slope	PSR Size equivalent diameter, km	Mine size, equivalent diameter, km
PSR1	PPP options in range	PPP options in range	Paths available	1.35	0.89
PSR2	No PPP options in range	Not evaluated due to slope limitation	Slopes into PSR exceed 20deg in all directions	1.60	0.47
PSR3	Out of range	Not evaluated due to slope limitation	Slopes into PSR exceed 20deg in all directions	6.12	0.85
PSR4	No PPP options in range	PPP options in range	Paths available	1.90	1.16
PSR5	Not evaluated due to slope limitation	Not evaluated due to slope limitation	Slopes into PSR exceed 20deg in all directions	1.26	0.16
PSR6	PPP options in range	PPP options in range	Paths available	0.78	0.76



- Two PSRs have options that fully meet criteria, though both have restricted mineable area
- Three of the six PSR have high slope crater walls which both restrict path finding and severely limit the minable PSR area. These PSRs were not evaluated

# Summary 1/3



## 001: Shackleton Connecting Ridge:

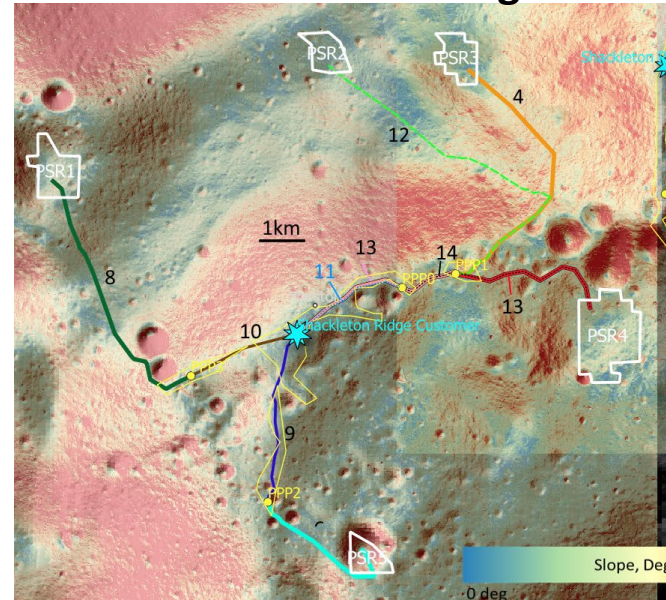
- There are 4 viable PSRs within expanded criteria, the most of any of the evaluated regions.
- Some features in the area have high slopes but generally there are passes available between features to enable path finding. There is one clear best traverse (and PSR) solution which was used in the architecture study AIAA-2020-4042
- The high illumination in the region opens up flexibility in PPP locations, which is part of the reason so many PSRs are accessible.

	# of traverses mapped	Best Traverse Path Score	Mine size for Best Traverse, km (equivalent diameter)	Best mine size in expanded criteria, km (equivalent diameter)	# PSRs accessible in Baseline criteria	# PSRs accessible in Expanded criteria	Available PPP size, km (equivalent diameter)
001 Shackleton Ridge	6	1.05	1.47	1.47	1	4	2.18
004 Shackleton Rim	6	1.08	1.47	1.47	2	3	2.37
007 Slater	5	1.10	2.62	2.62	1	1	0.52
011 de Gerlache	5	1.02	1.06	1.06	0	1	0.76
102 Nobile	5	1.12	0.65	1.33	1	3	0.85
105 Shoemaker	3	1.23	0.89	1.16	2	3	0.22

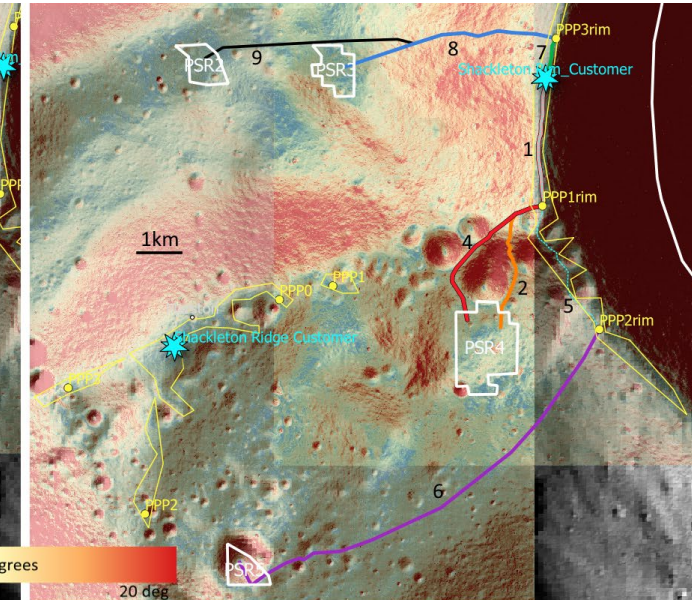
## 004: Shackleton Rim:

- The available PSRs are all common with 001; no new PSRs are in range due to the dominance of Shackleton crater itself (which is not accessible due to slopes). The best PSR solution is the same as that of Shackleton Ridge.
- Most area of any region for PPP locations; but these areas are on a restricted path (the rim itself) with limited off-ramps due to high slope, so traverse paths are limited.

### 001 Shackleton Ridge



### 004 Shackleton Rim



## 007: Slater:

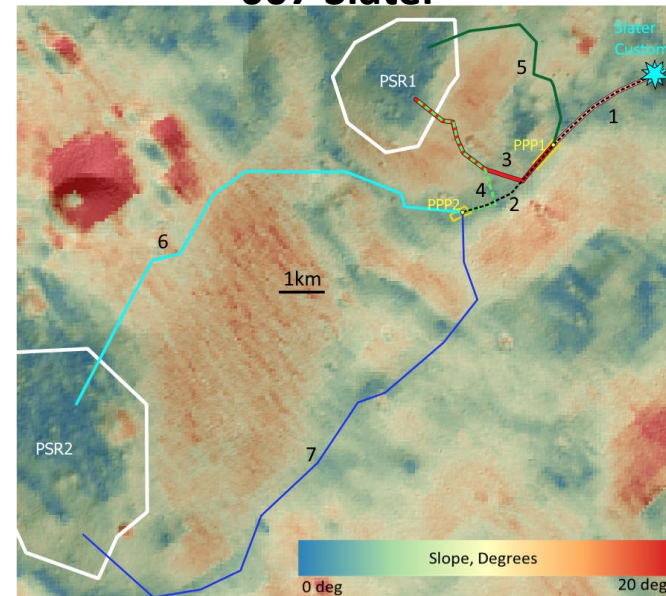
- Fewest PSRs available. Expanding to 10 km per travel leg does not add much value; the criteria would need to go to 15 km reach the other PSR.
- Only one traverse solution meets all baseline criteria, though it is one of the best options in terms of path score and PSR/mine size.
- Slopes in regions are favorable, so some traverses even come close to meeting a <15deg path criteria.
- Limited flexibility both in terms of PSRs and PPP areas.

## 011: De Gerlache:

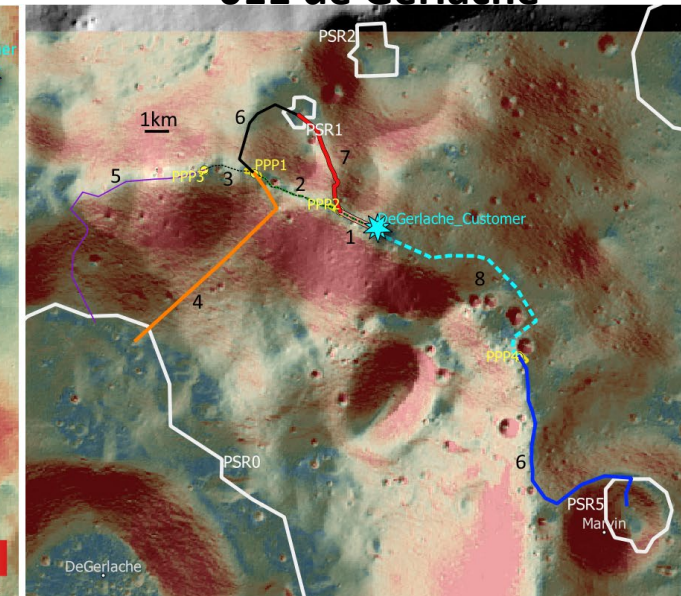
- Only one accessible PSR in the region just meets the 1 km size target. While the outskirts of de Gerlache itself can be reached with traverses >12 km, these paths all exceed slope criteria.
- No options fully meet the baseline criteria. Slopes in the region tend to necessitate longer traverses for pathfinding
- There are several smaller PPP areas spread out along the ridgeline, which would offer options in PPP placement if the PSRs could be accessed.

	# of traverses mapped	Best Traverse Path Score	Mine size for Best Traverse, km (equivalent diameter)	Best mine size in expanded criteria, km (equivalent diameter)	# PSRs accessible in Baseline criteria	# PSRs accessible in Expanded criteria	Available PPP size, km (equivalent diameter)
001 Shackleton Ridge	6	1.05	1.47	1.47	1	4	2.18
004 Shackleton Rim	6	1.08	1.47	1.47	2	3	2.37
007 Slater	5	1.10	2.62	2.62	1	1	0.52
011 de Gerlache	5	1.02	1.06	1.06	0	1	0.76
102 Nobile	5	1.12	0.65	1.33	1	3	0.85
105 Shoemaker	3	1.23	0.89	1.16	2	3	0.22

### 007 Slater



### 011 de Gerlache



# Summary 3/3



## 102 Nobile:

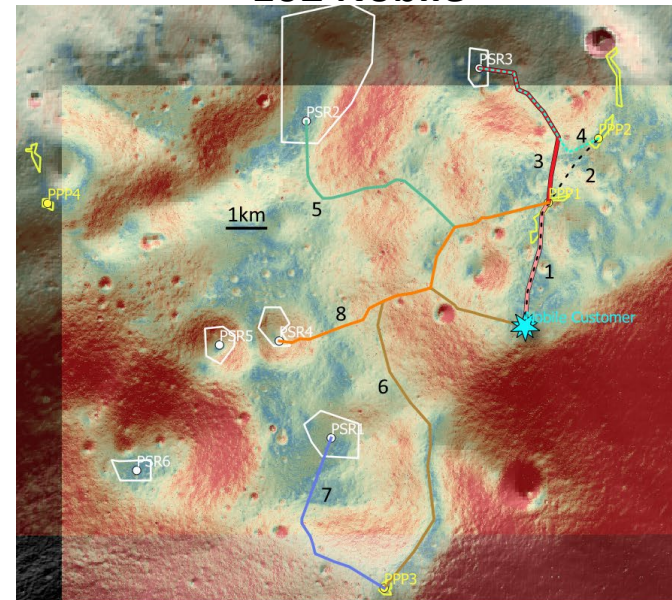
- Region is broken up by high slope features, with the customer site located in a difficult position among them.
- While there are several PPP areas available, many are in the opposite direction of the PSRs, so getting to them require some amount of backtracking from the customer site.
- One PSR meets baseline criterion but is small (<1 km) with limited mineable area. The expanded distance criteria does open up two more PSRs, one fully meets size criteria

## 105: Shoemaker:

- Of all the regions, this is the most favorable in terms of slopes for the traverse paths.
- While quite a few PSRs in the region of appropriate size, but the high slopes into these PSRs restricts mineable area (such that only one PSR has acceptable mine area) and either limits or eliminates traverses into the PSR.
- The challenge is the illumination potential, where there are very few options for PPP locations. The confidence of these areas is low, & is the only region where the customer site was not ranked in Mazarico et al 2011
- However, it should be noted that practically the entire region is an ISR.

	# of traverses mapped	Best Traverse Path Score	Mine size for Best Traverse, km (equivalent diameter)	Best mine size in expanded criteria, km (equivalent diameter)	# PSRs accessible in Baseline criteria	# PSRs accessible in Expanded criteria	Available PPP size, km (equivalent diameter)
001 Shackleton Ridge	6	1.05	1.47	1.47	1	4	2.18
004 Shackleton Rim	6	1.08	1.47	1.47	2	3	2.37
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011 de Gerlache	5	1.02	1.06	1.06	0	1	0.76
102 Nobile	5	1.12	0.65	1.33	1	3	0.85
105 Shoemaker	3	1.23	0.89	1.16	2	3	0.22

### 102 Nobile



### 105 Shoemaker

