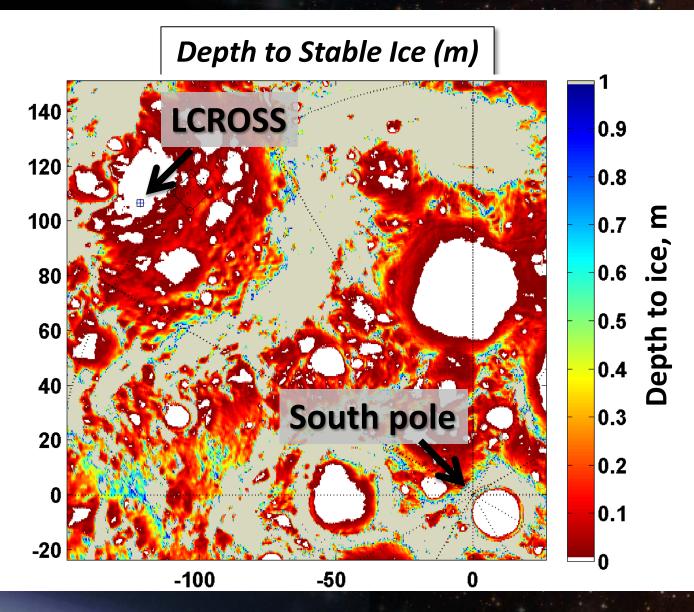


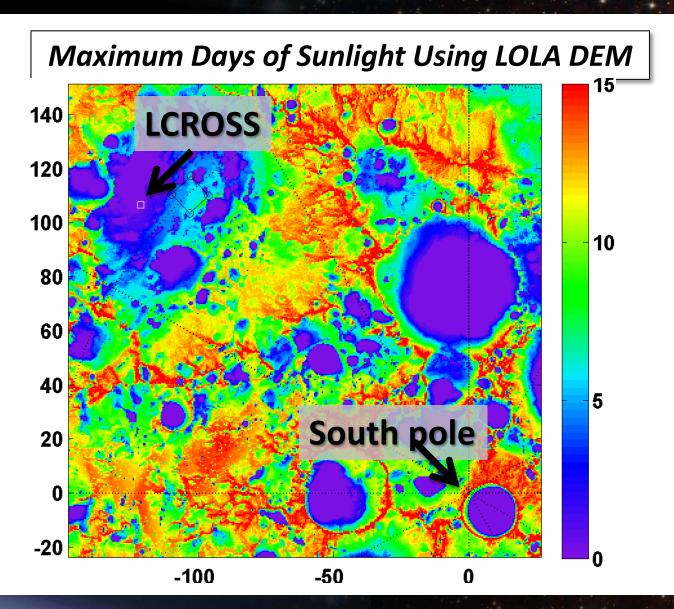
# **Resource Prospector – Traverse Planning**

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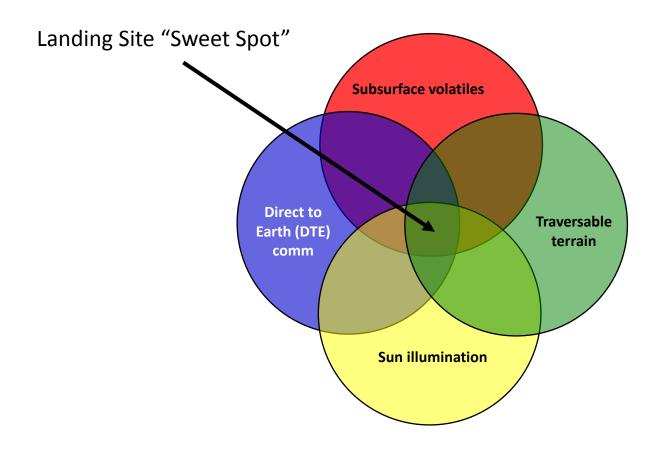














#### **Combined Site Analysis**

Mission duration  $\rightarrow 2-7$  days of expected sunlight.

Due to the limited operational time, science operations must be near real time.

Site:	Α	В	С
Shallow "Frost Line"	<0.1 m	<0.2 m	<0.1 m
Slopes	<10°	<15°	<10°
Neutron Depletion	4.5 cps	4.7 cps	4.9 cps
Temporary Sun*	4 days	2-4 days	5-7 d
Comm Line of Sight*	8 days	17 days	17 days
* may not coincide			

→ Requires immediate situational awareness, data analysis and decision support tools.

Site selection affects concept of operations.

# Science Concept of Operations



#### **Front Room**

- Real-Time Science: Direct comm with Rover Driver to recommend RT science-based rover operations decisions
- Science Lead: Overall science management & assurance

### **Science Operations Center (SOC)**

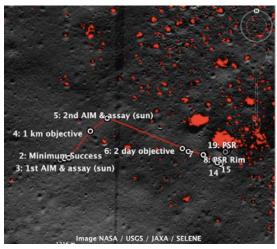
- → Includes Strategic and Tactical planning roles.
- SciCom: Direct comm between Science Backroom to Front Room
- <u>Traverse Planning</u>: Update rover traverse plans based on RT science data
- NIRVSS, NS, Camera, LOVEN Sci data positions: RT monitoring of data, ops recommendations based on datastream

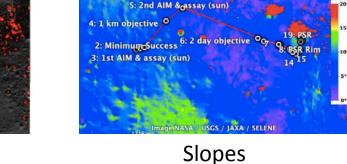
## Traverse Plan Data/Model Inputs



#### The traverse plan includes the following inputs:

- Solar illumination as a function of time
- Direct to Earth (DTE) communications coverage as a function of time
- Terrain slopes
- Camera imagery
- PSR (Permanently Shadowed Region) locations





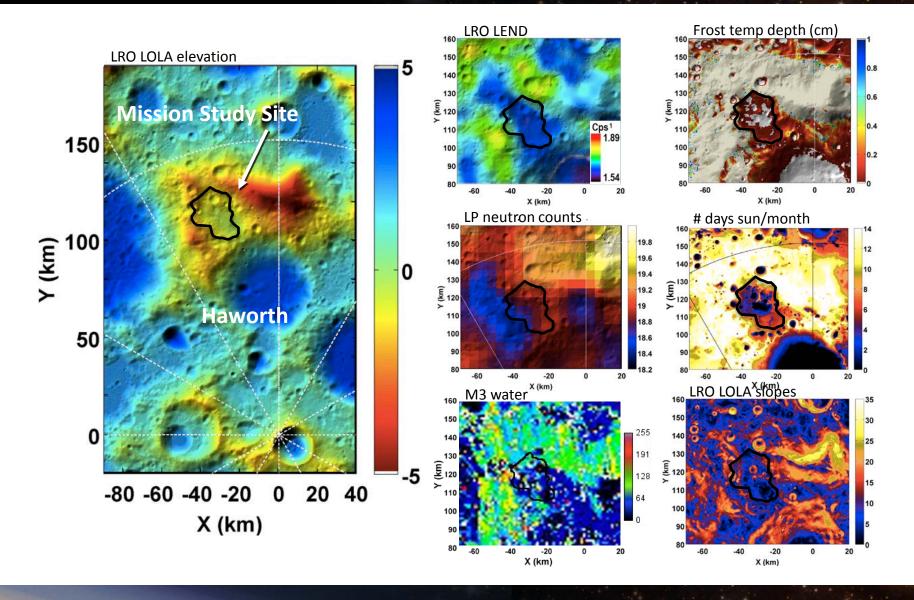


**PSR Map** 

DTE

# Notional Study Site: Haworth Crater





# Mission Planning Assumptions



#### At/After landing, while still on lander:

- NSS and NIRVSS calibrated on lander
- Drill/OVEN/LAVA checked-out
- Localization from lander: Identified landing site in operating area map
- Any immediate (tactical) updates to traverse plan

#### Once on ground:

- 48 hours of roving/prospecting to understand systems and calibrate thresholds
  - > If NSS or NIRVSS is on we can accomplish the L1 requirements while doing this
- Pursue "Full Success" goals, in priority order:
  - 1. 1st Shallow subsurface assay (sunlit)
  - 2. 1<sup>st</sup> Sample acquisition and processing (sunlit)
  - 3. Prospect to reach 1000 meter baseline
  - 4. 2<sup>nd</sup> Shallow subsurface assay (sunlit)
  - 5. 2<sup>nd</sup> Sample acquisition and processing (sunlit)
  - 6. Prospect to selected PSR
  - 7. Prospect in PSR
  - 8. 3<sup>nd</sup> Shallow subsurface assay (shadow)
  - 9. 3<sup>nd</sup> Sample acquisition and processing (shadow)
  - 10. Identification of location to sample material for ROE
  - 11. Rove to, sample and perform ROE demo

# **ConOps Assumptions**



- •Rover speed is kept constant at 0.02 m/sec. This represents a conservative traverse plan since nominally the rover speed could be increased after 48 hours of roving.
- •A 15 minute halt is included before entering a shadowed region for decision making purposes.
- •The first entry into shadow is a "toe-dip" (enter shadow, return to sunlight, assess, then reenter shadow for AIM and sample acquisition).
- •Battery recharge after entering shadow is while rover is halted for twice the length of time the rover was in shadow.
- •Rover will operate in areas of sunlight (illumination maps) unless specifically entering a region of shadow / PSR for science purposes.
- Plan will aim to maintain DTE (note only not possible when entering large PSRs).
- •Plan will aim to traverse low slope regions (below 10-15°, note this plan is below 10° slope).

# Science Activities

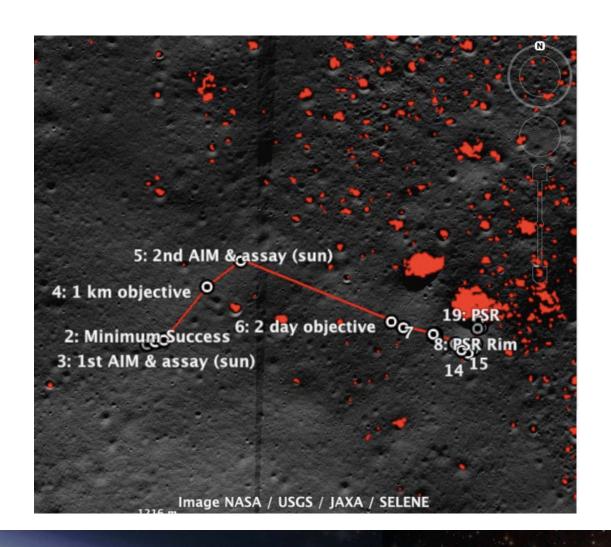


Activities	Duration (h)	Instruments
Prospecting	TBD	Neutron Spectrometer, NIR Spectrometer
Area of Interest Mapping	0.5	Neutron Spectrometer, NIR Spectrometer
Near-surface assay	1.5	Auger, Neutron Spectrometer, NIR Spectrometer
Detailed subsurface assay	4.25	Drill Core, LAVA, OVEN, Neutron Spectrometer, NIR Spectrometer
Extended subsurface assay	4.25	Drill Core, LAVA, OVEN, Neutron Spectrometer, NIR Spectrometer
Shadowed area traverse	TBD	Neutron Spectrometer, NIR Spectrometer
Shadowed area near surface assay	1.5	Auger, Neutron Spectrometer, NIR Spectrometer
Shadowed area subsurface sampling	2 hr + rove time to leave shadow	Drill Core, LAVA, OVEN, Neutron Spectrometer, NIR Spectrometer
ROE	3	Drill, core, LAVA, OVEN

# **Exploration Ground Data Systems (xGDS)**



xGDS (Exploration Ground Data Systems) software is used to create traverse plans.

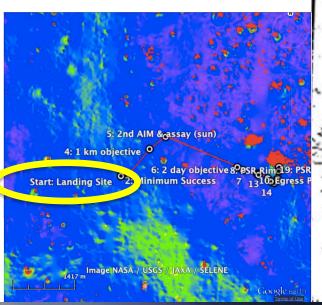


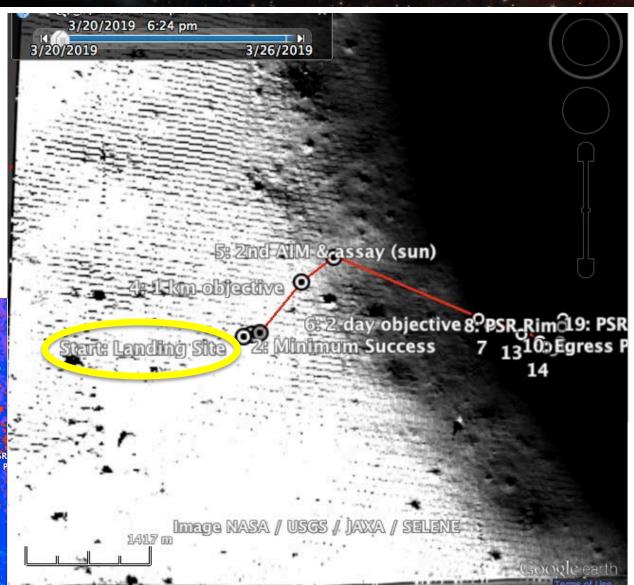
# Haworth Landing Site



Landing site is chosen in a region of low slope and in sunlight.

Also chosen in an area that will enable sunlit operations to achieve mission success criteria.







Minimum Success (100 m distance) @ 1 hr 23 min.

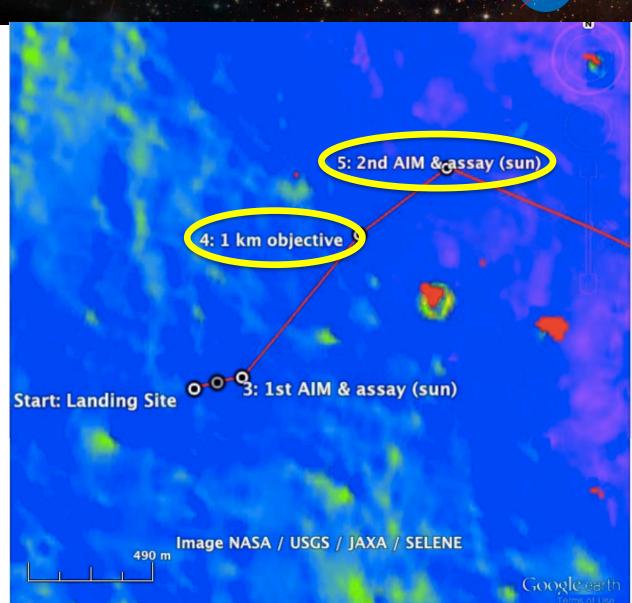
1<sup>st</sup> AIM and assay (sun) complete @ 9 hr 19 min.



NASA

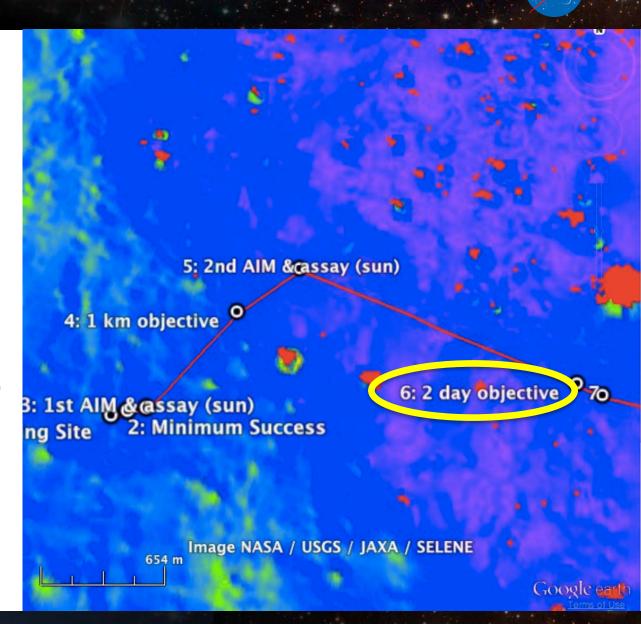
1 km roving distance achieved at 20 hr 23 min.

2<sup>nd</sup> AIM & assay (sun) complete at 33 hr 53 min.



2 day driving objective met at 61 hr 05 min in xGDS.

Note this represents 48 hours of roving/prospecting (13 hours are when rover is conducting AIM/Assay at waypoints 3 and 5. Technically AIM (30 mins each) can be counted towards drive time, so total rover stop time until this point is 12 hours → 2 day driving objective met at 60 hr).





Explore first PSR. Choose small PSR on order of 20 m diameter.

WP 8: Stop at rim to assess (15 min halt).

WP 9: Entered PSR, PSR mid-

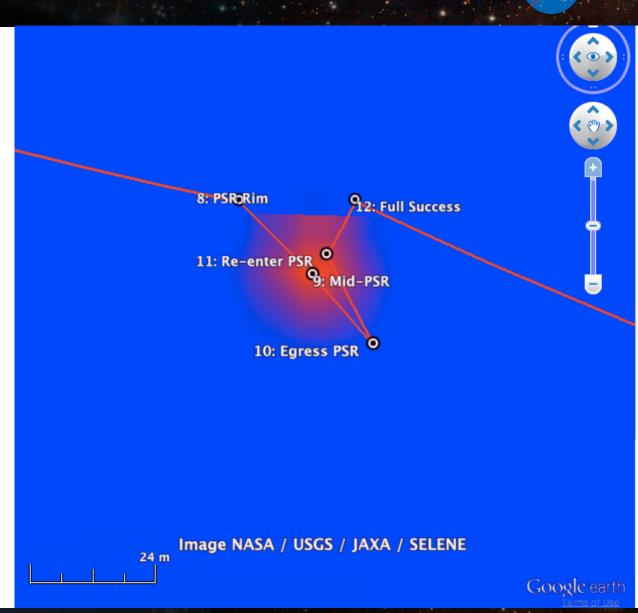
point.

WP 10: Egress PSR, recharge batteries, decision making halt (15 mins)

WP 11: Re-enter PSR, AIM, assay.

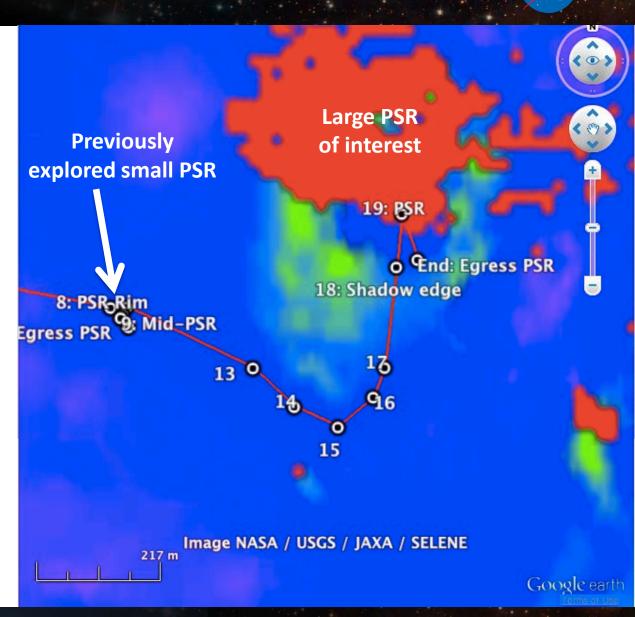
WP 12: Exit PSR, conduct ROE, full success.

WP 8 @ 68 hr 50 min. WP 12 @ 95 hr 22 min.



NASA

Continue traverse path from small PSR (previously explored) towards large PSR. Follow route to avoid topography (higher slopes). Conduct sunlit augers along the way (WPs 13, 14, 15, 16) to achieve stretch goals.



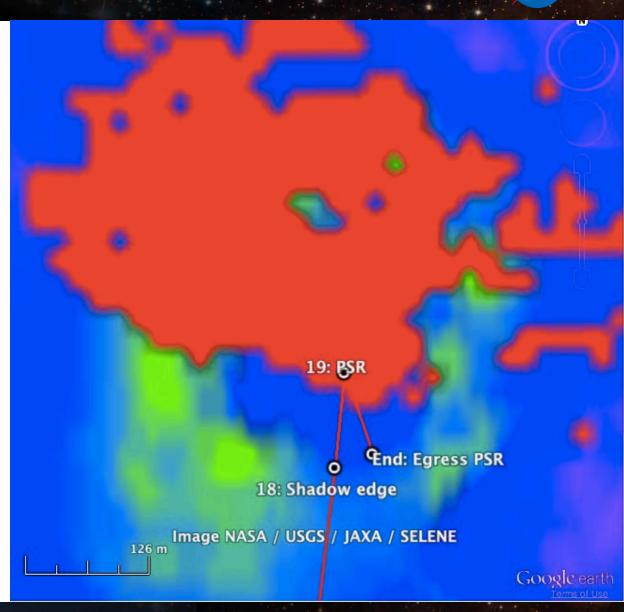
NASA

WP 18 is the shadow edge for this location and time. Note the edge of shadow is ~85 m away from the edge of the actual PSR. Include 15 min halt for decision making at WP 18.

Enter PSR and at WP 19 perform AIM and sample acquisition.

Egress PSR at "End" location. Note this site is still illuminated when DTE is lost.

Plan ends at 140 hr 19 min.



# Lessons Learned for Haworth 1/2



- Landing site is critical. This plan lands at edge of shadow and traverses to follow the sunlight. Sites outside of this region experience significant periods of shadow during this time period and thus are not suitable for an RP traverse. Note the most interesting areas with the highest density of PSRs occur in regions where shadow prohibits rover traverses so must find the "sweet spot" between presence of PSRs and illumination.
- Illumination conditions change significantly on timescales of hours and days. Illumination drives the general traverse plan location (10s to 100s of km scale) and also affects tactical traverse plan decisions (<10 m scale).
- Permanent shadow is not the same as shadow. Especially near large PSRs, the rover will often enter shadow before entering the PSR. Must be aware of the time-dependent illumination conditions.

# Lessons Learned for Haworth 2/2

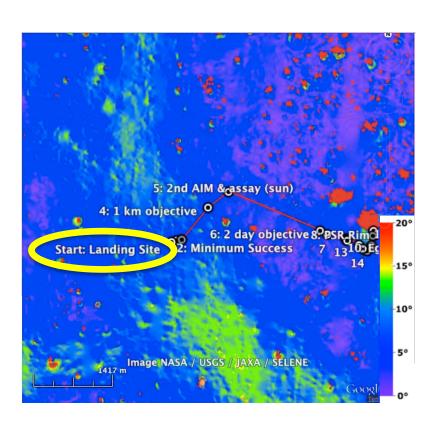


- Because non-PSR shadow often surrounds PSR regions (~85-100 m of shadow prior to entering the large PSR in this traverse plan), it takes a significant amount of time to traverse into the PSR, back to the light, and recharge batteries. Therefore, the first PSR visited is a small PSR (several 10s m diameter), which allows for faster access to the PSR of interest and requires less driving distance in shadow to access the PSR.
- DTE does not change significantly over the ~6 days of the mission for this site. DTE exists in most locations and only at the very end (final hours) does DTE disappear DTE does not exist is most large PSRs at any time, though, so traveling into a large PSR results in comm loss.
- "End" location can be strategically chosen to maximize time in sunlight. This plan "ends" in a location which is still in sunlight when DTE is lost.
- Increasing the effective rover traverse speed allows for additional exploration and science. Increasing the rover speed to 0.10 m/s after the 48 hour roving threshold is reached results in 25 additional mission hours which would allow additional exploration of the sea of PSRs near the planned "End" location.

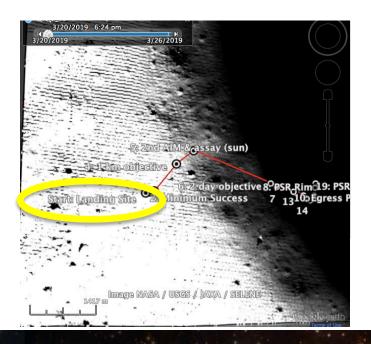
# Summary



#### **Haworth Crater Case Study**



- Demonstrates RP mission closes and can be executed at Haworth Crater near lunar south pole
- Identifies need for advanced traverse planning tools



# **Nobile Context**

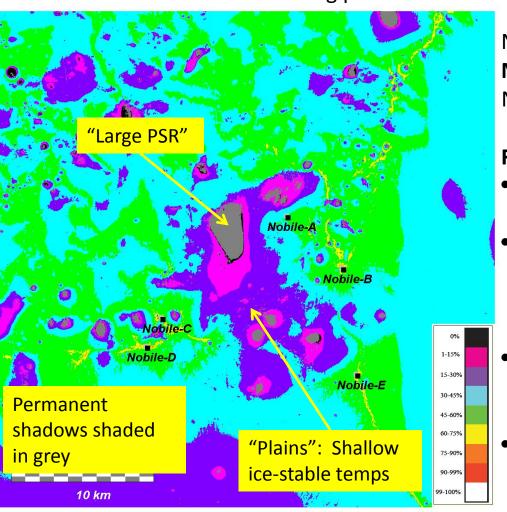




#### Nobile-North Ridge Landing Sites



- These landing sites generally allow of significant solar illumination
- Consider as starting points for traverse



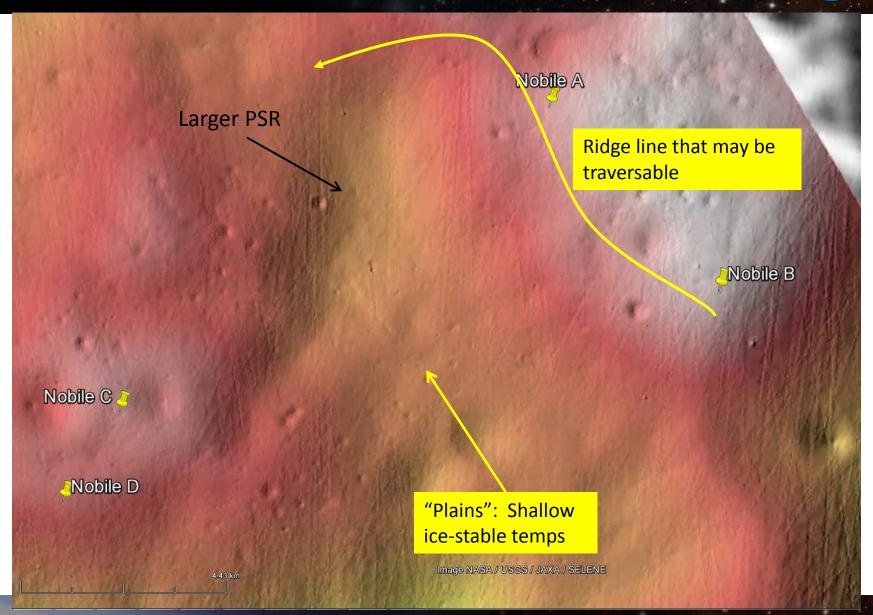
Nobile A: 85.1943°S, 35.4360° E **Nobile B: 85.3127°S, 37.0174° E** Nobile C: 85.4230°S, 31.8427° E

#### For now just consider Nobile B Start:

- General plan is to get to "Plains" and prospect into one of several large PSRs
- Possibly skirt along ridge lines surrounding plains and "Large PSR" and conduct sorties into plains through several possible "entry points"
- Next several slides gives an example of a sortie and the activities planned for each sortie
- No PSR sortie is exampled, but could be after review of the first few steps

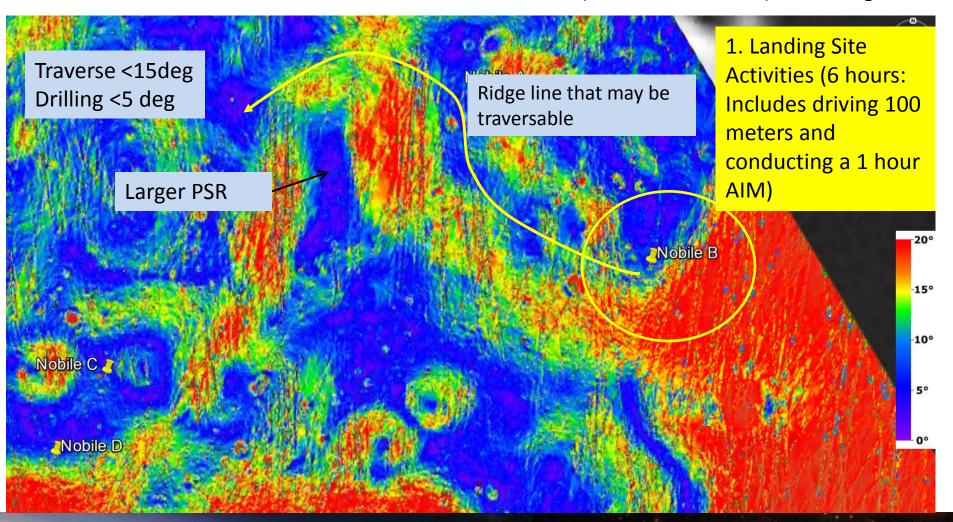
### Notional Traverse Planning: Nobile-North Terrain





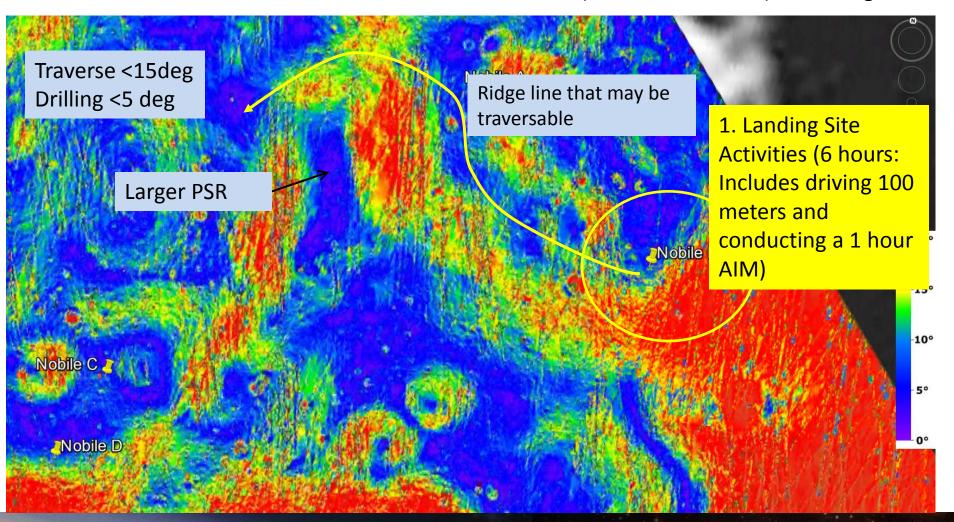


Slopes (10 meter baseline) in North Nobile Region
Assume start at Nobile B, 6 hours of activities around (within 100 meters) of landing site



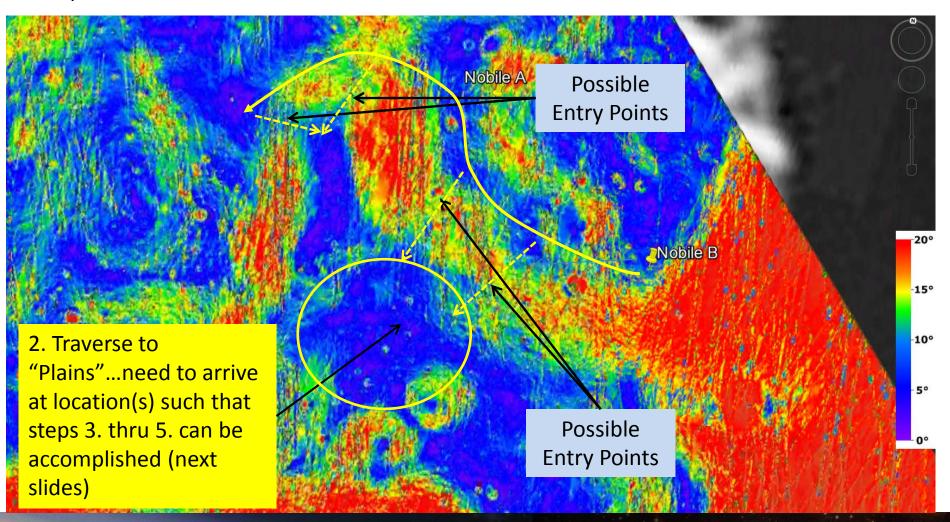


Slopes (10 meter baseline) in North Nobile Region
Assume start at Nobile B, 6 hours of activities around (within 100 meters) of landing site



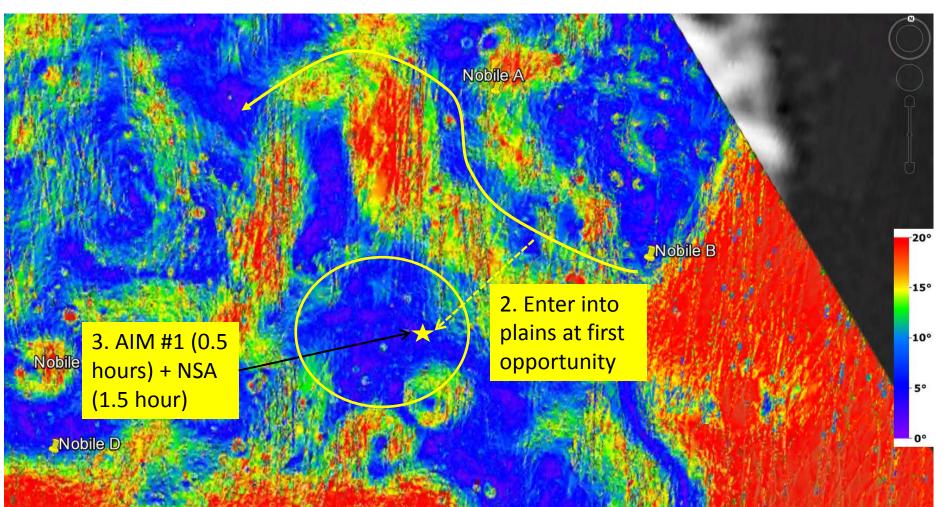


Plan showing possible ridge run (solid yellow curve) and entry points from ridge to the "plains"



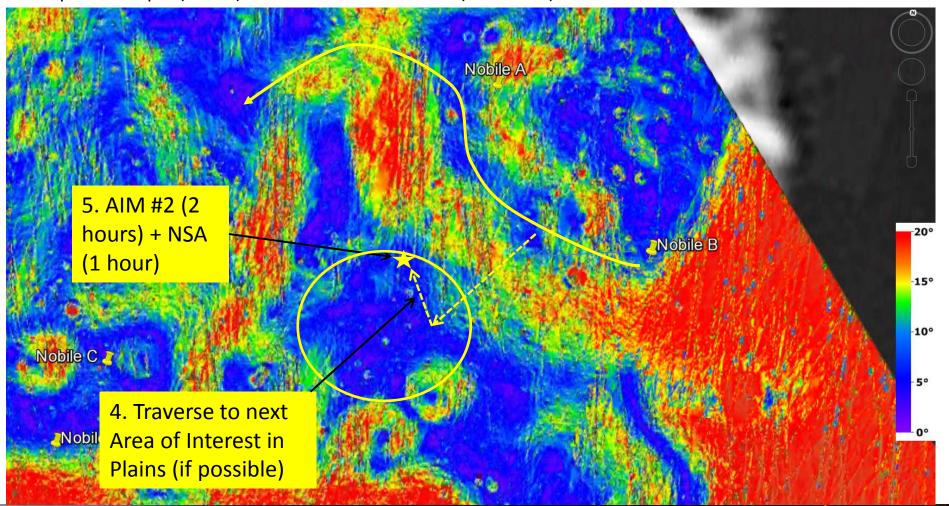


Assuming we take the first entry we proceed to plains and conduct an AIM (0.5 hrs) NSA (1.5 hrs)



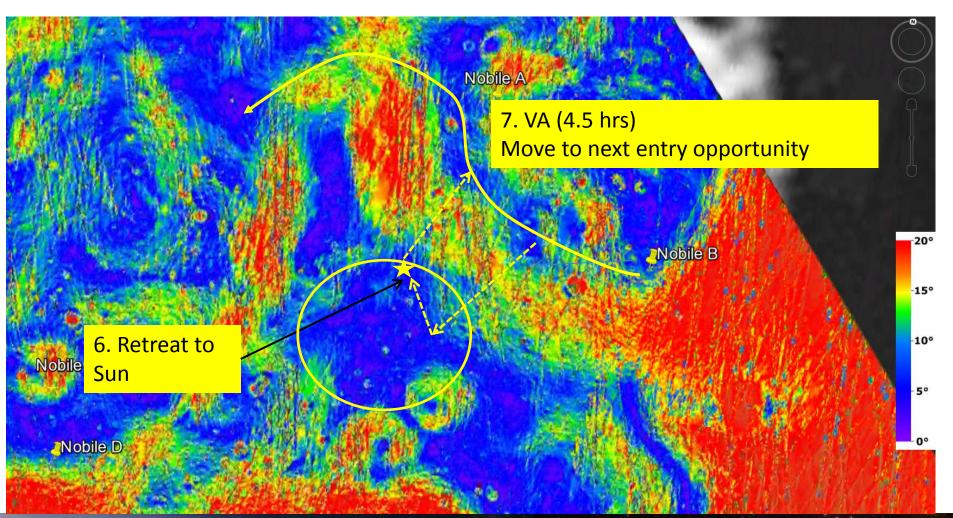


- After first AIM and NSA we proceed to next Area of Interest (here picked to be toward larger PSR)
  and conduct another AIM and NSA
- Capture sample (0.5 hr) for VA in "sun rich area" (next slide)



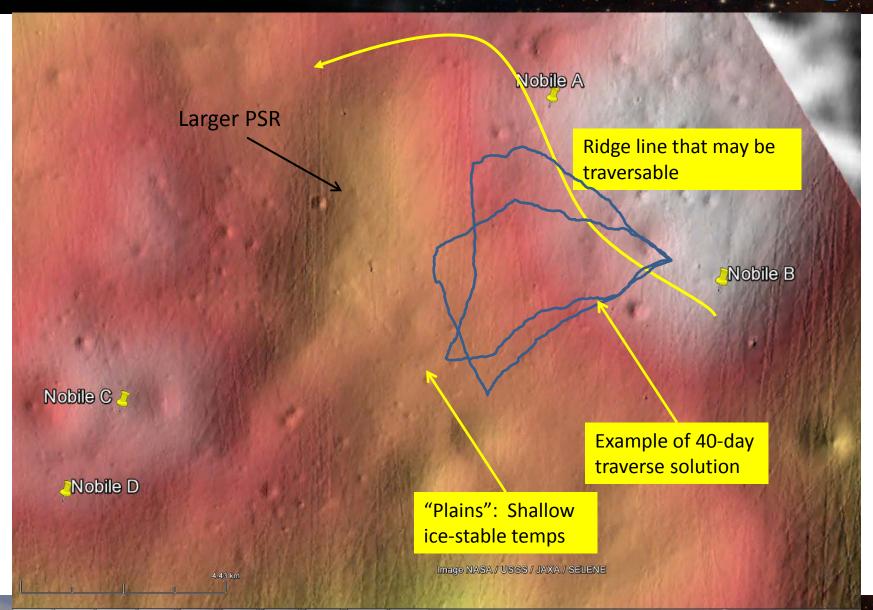


- Retreat to sun & comm rich area for VA analysis
- VA duration is 4.5 hrs.



# Notional Traverse Planning: Nobile-North Terrain







Example solution that used sun and comm constraints, but not slopes

