Lunar Power Beaming Tower and Architecture

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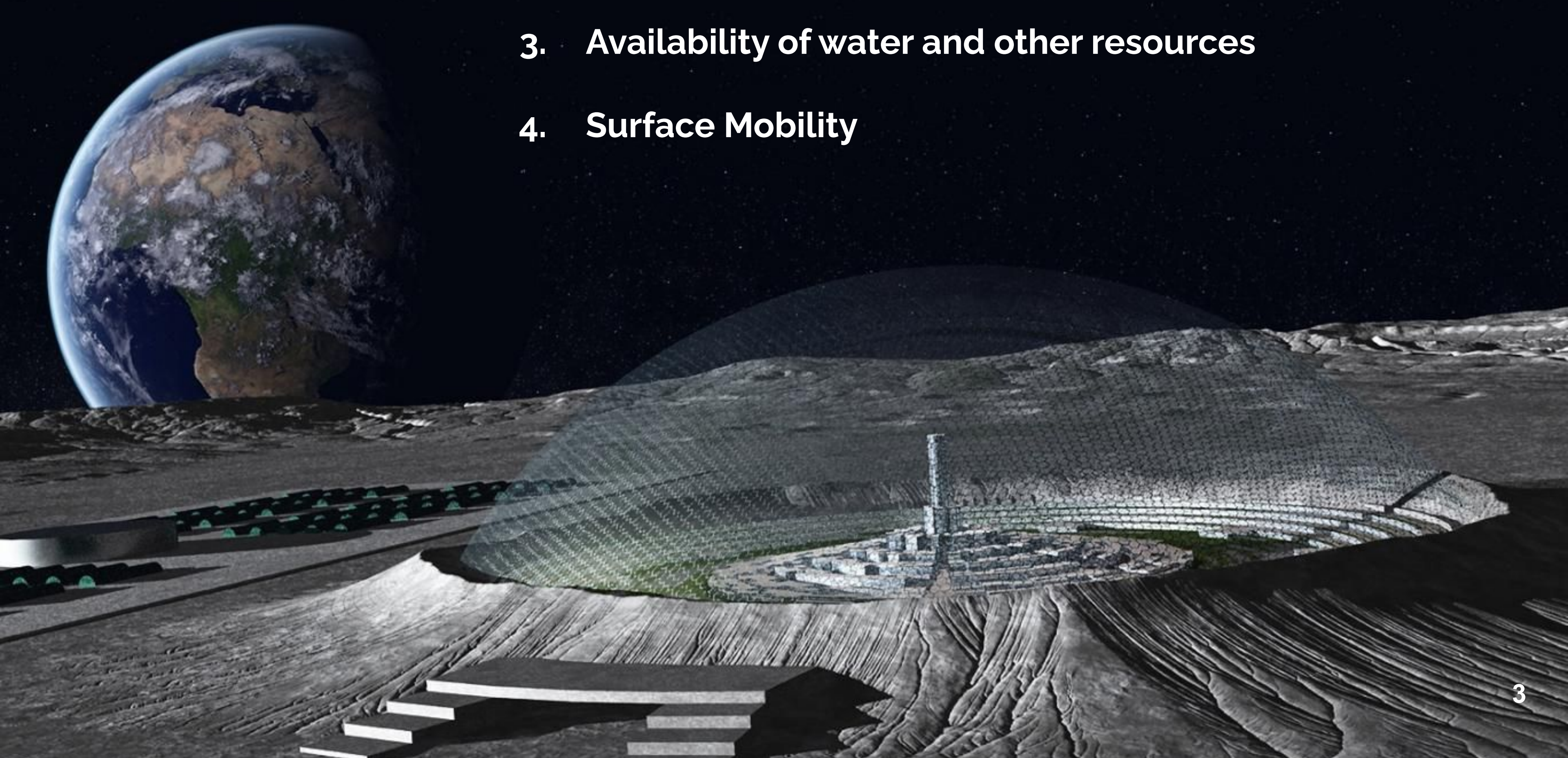
Outline

1. Fundamentals for Off-world Development
2. Key Challenges for Power Beaming
3. NASA Watts on Moon Competition Details
4. Lunar Surface Power Beaming Prototype
5. Lunar Tower ConOps
6. Enabling Water Ice Excavation Missions
7. Power Beaming Architecture
8. Cost Analysis: Energy on Surface
9. Project Key Questions

Fundamentals for Off-world Development

1. Power Availability
2. Low-cost Communications
3. Availability of water and other resources
4. Surface Mobility



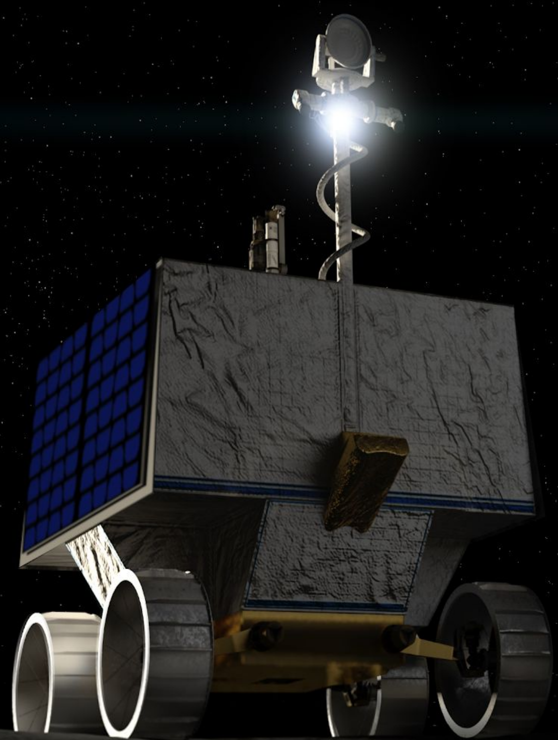
Key Challenges for Power Beaming

Altitude/Accessibility of PEL's

Power Availability

$10,000 per kg to Surface

NASA Watts on Moon Challenge



Rover Requirements, Assumptions

- Provides up to 10 or 20 kW electrical power
- Generate and deliver 100W/hr continuously
- 1 - 1.5km power beaming capability
- Power only during illuminated periods, $\geq$ 300 hours

South Pole vs. North Pole

Power: South

Resources: South

Communications: N or S

Mobility & Terrain: N > S

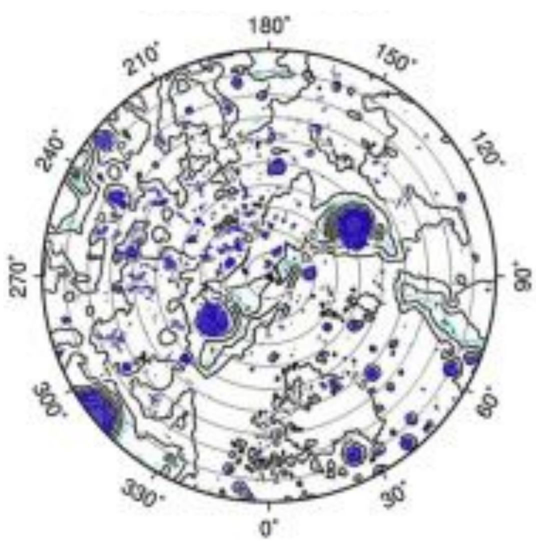
N ice sparsely spread out

Size Distribution of Permanently Shadowed Regions		
	N Pole (80-90deg)	S Pole (80-90deg)
> 1 km sq	1,457	892
> 5 km sq	344	314
> 10 km sq	182	177
> 25 km sq	68	91
> 50 km sq	37	59
> 100 km sq	17	30
> 200 km sq	7	13
> 400 km sq	0	4
> 600 km sq	0	3
> 1,000 km sq	0	2
Total PSR Area	12,866 km sq	16,055 km sq

Assumptions: 100 kW solar power supply, 93% total efficiency

Lunar Development Power (kWh)	Nonpolar	N Pole	N Pole 10m	S Pole	S Pole 10 m
Power available during day	35,400	59,868	61185	63019	65915
Max Power per month	17,700	50625	52876	56093	61367
Actual Power per month	16461	47081	49175	52167	57071
Power Losses	1239	3544	3701	3927	4296
Average kWh Available	23.25	66.5	69.46	73.68	80.61

North Pole PSR Peaks of Eternal Light, >88



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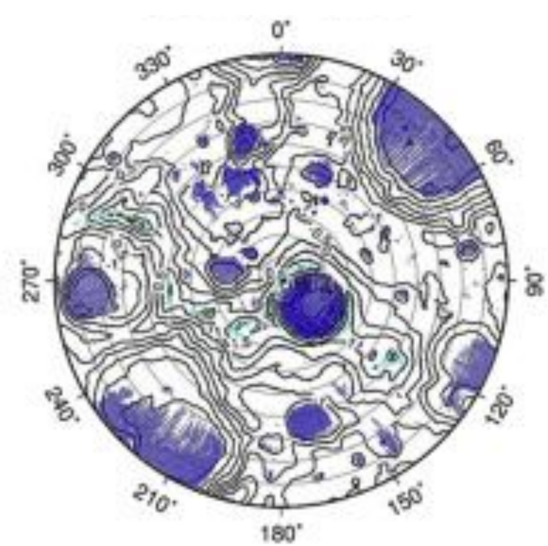


Lunar Surface Power Beaming Prototype

<u>WoM Mission Activities</u>

#1: Deliver power for a mobility platform operating inside the crater to collect and deliver water bearing material

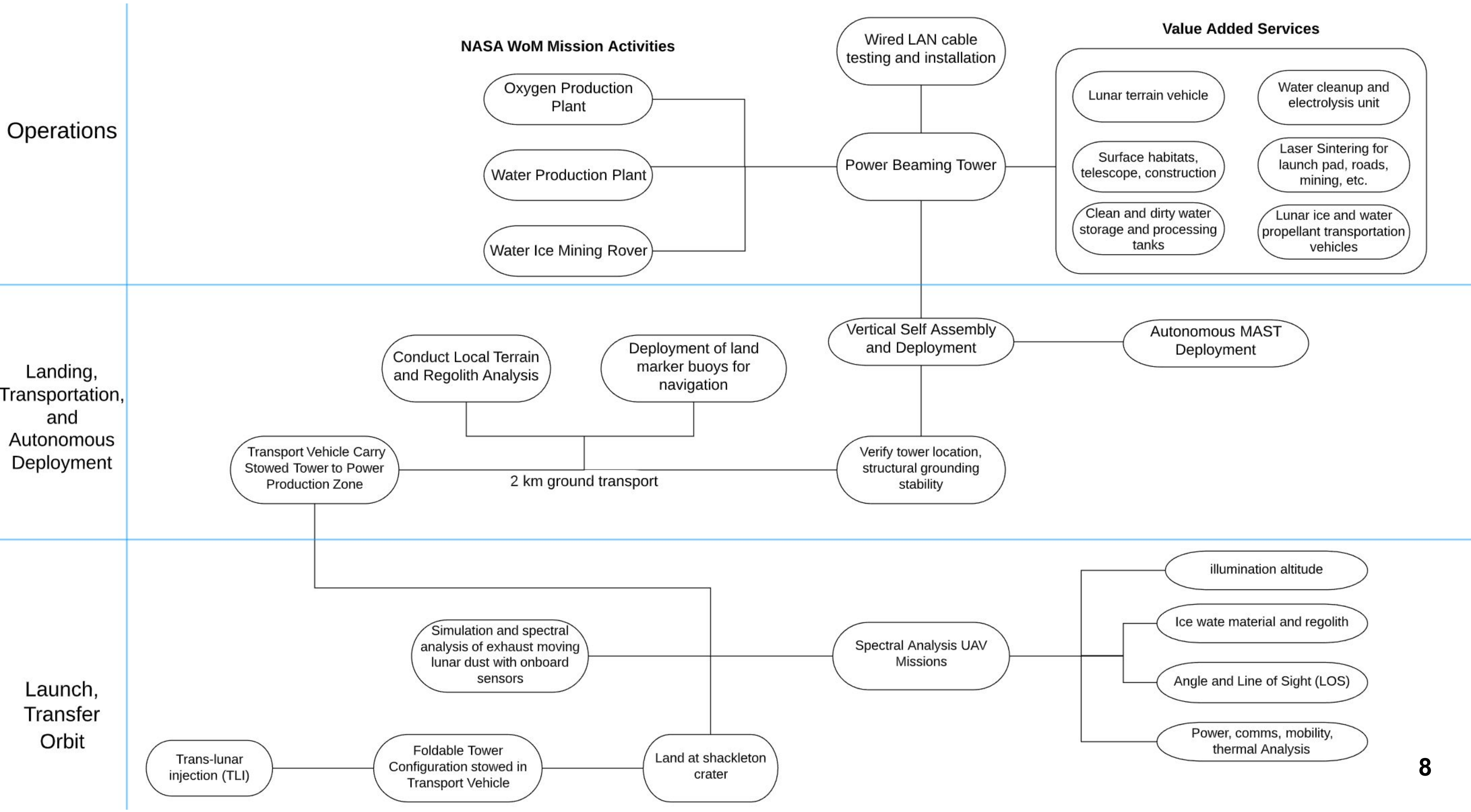
#2: Deliver power for a water production plant operating inside the crater to extract and purify water from delivered material.

#3: Address thermal energy needs of an oxygen production plant outside the crater

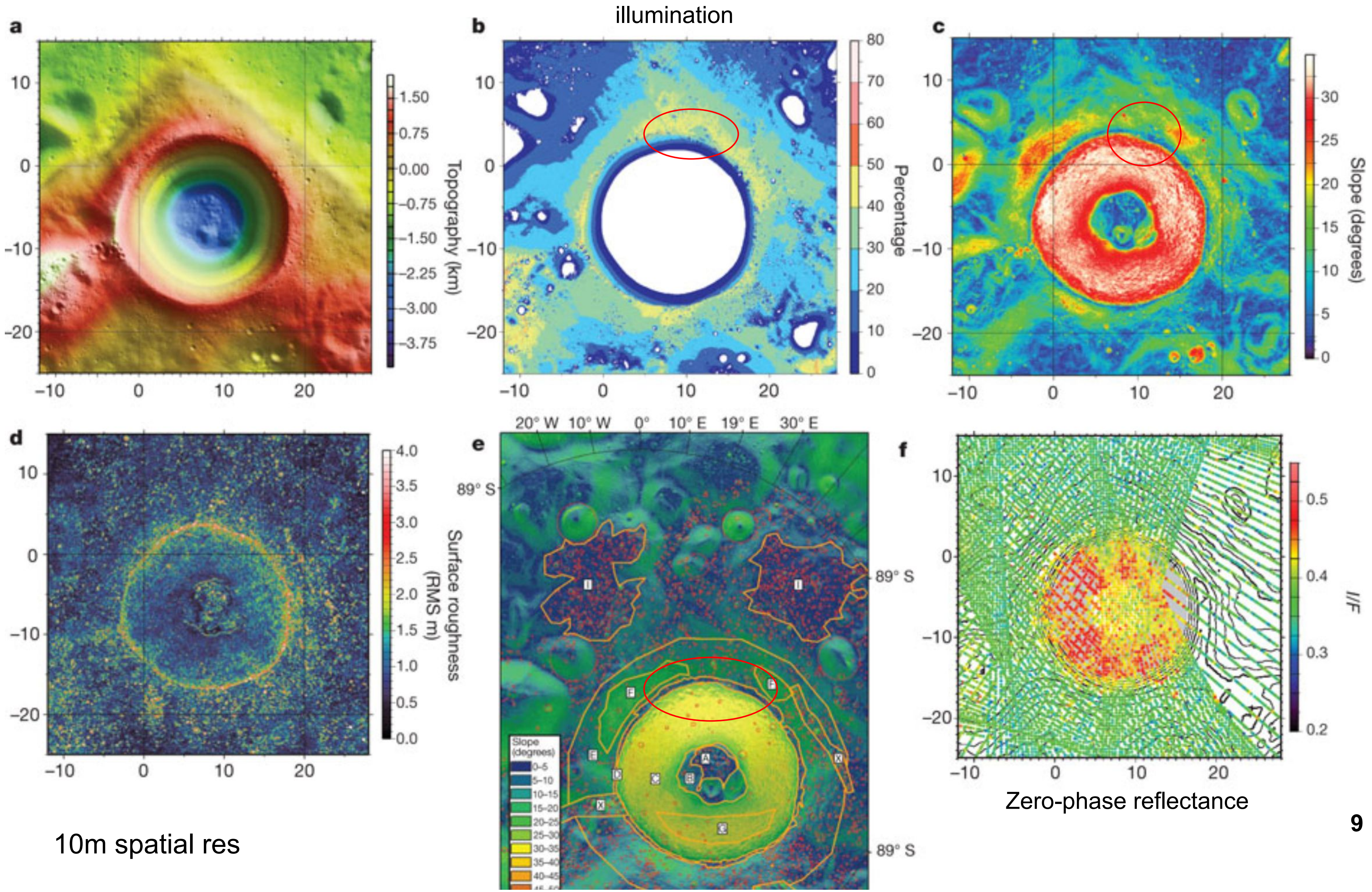
Mission Components

- Power Beaming Platform and Laser
- Stowed Tower Infrastructure
- Autonomous Transport Vehicle
- Low cost UAV

Lunar Tower ConOps

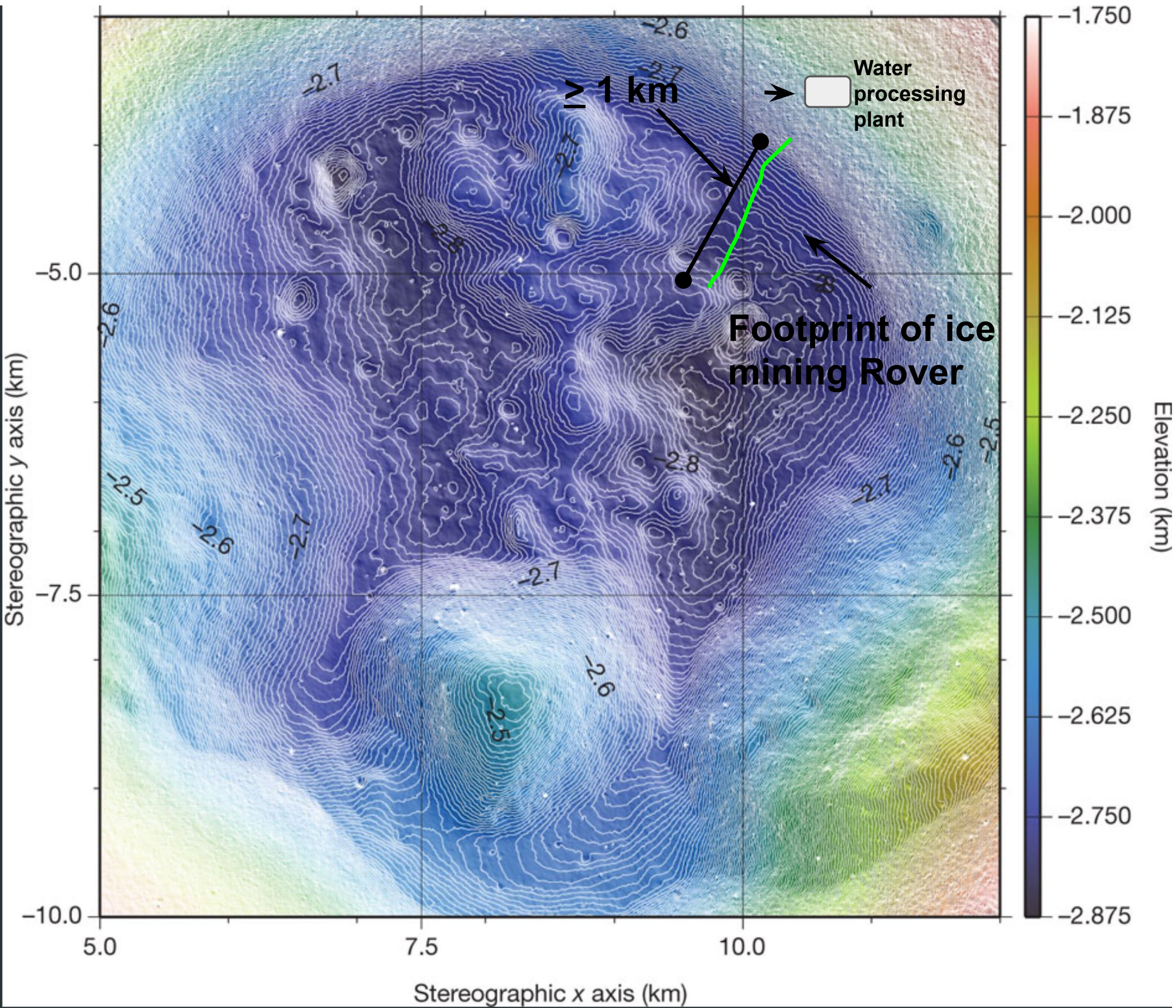


Characterization of Shackleton Crater



10m spatial res

Enabling Water Ice Excavation Missions at Shackleton Crater

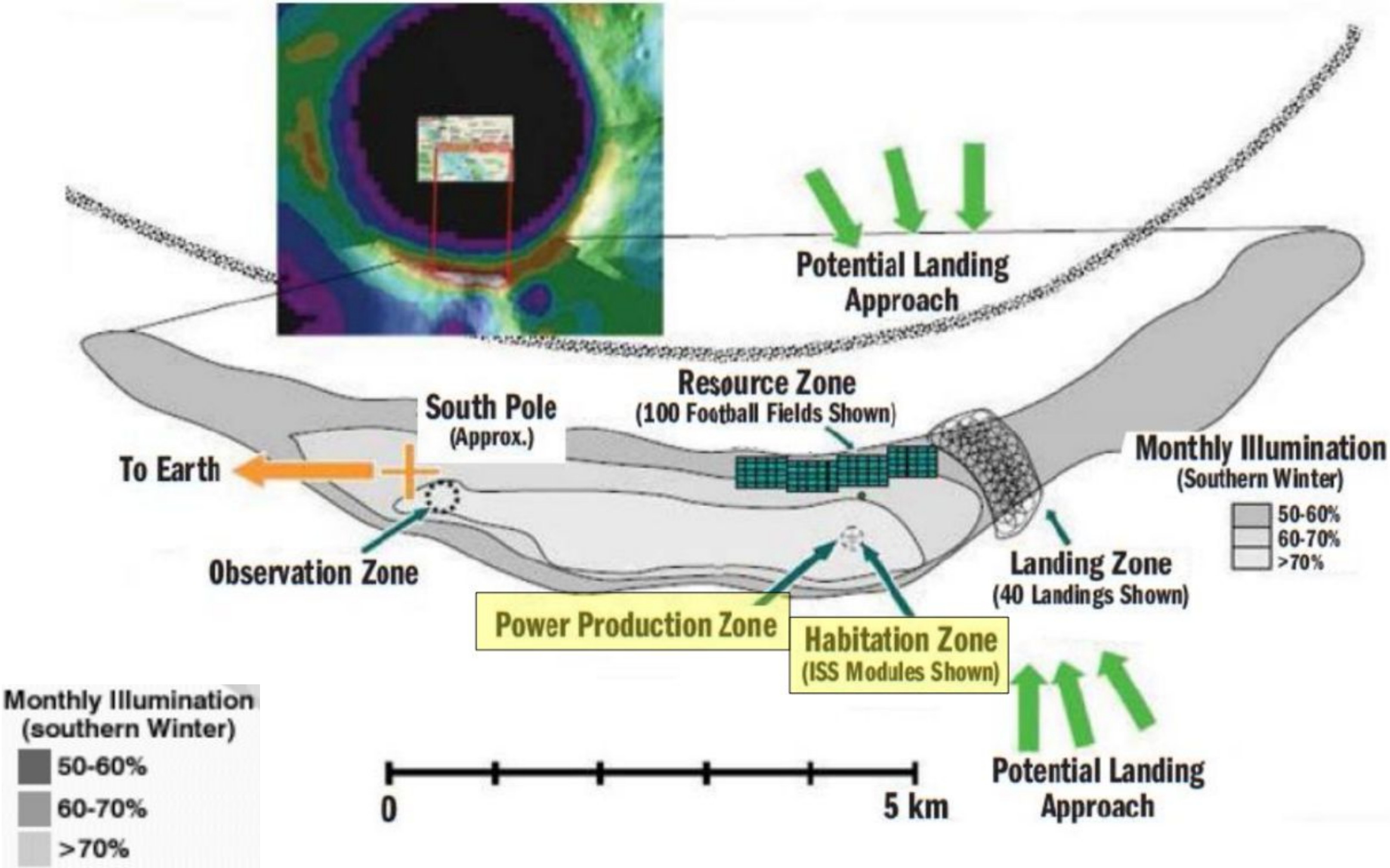


PSR Ice Mining Rover Assumptions from WoM Challenge

10 hr ascent and descent using 150 WE

plus 50 WTH for thermal Protection

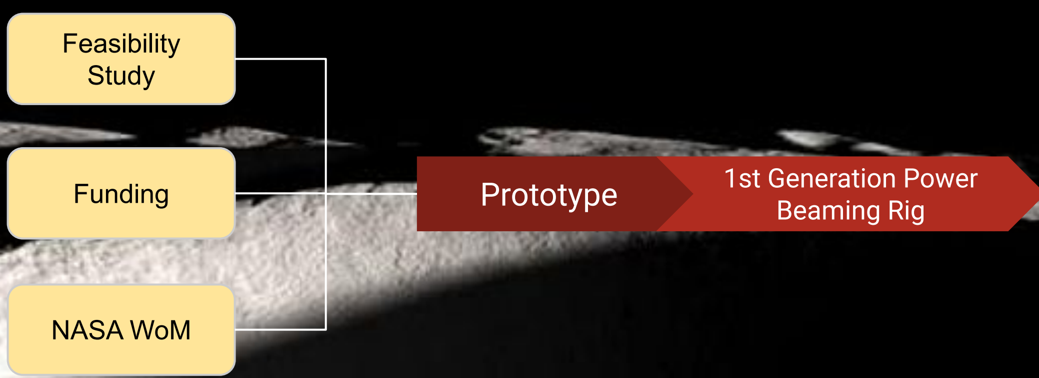
Supply Power for One of First Lunar Cities



Project Road Map

Lunar Laser Power Beaming Rig

- Small prototype reduces risk and initial stakeholder costs
- Dual purpose comms/power services for shackelton
- Electronically steered phase-locking gimbaled lasers able to rotate~360deg possibly on circular track to correspond with the Lunar day/night cycle
- Increase in surface area and availability at higher altitude of tower platform enables multiple solid-state laser transmission systems and possible landing and repair from lunar UAS
- Service-utility-based model is scalable across other PSRs



Project Key Questions

Fundamental Challenges
What is desired illumination altitude for solar collection and targeted elevation range of tower at desirable side of Shackleton?
Who would be considered local competitors and customers?
What is optimal mobility platform path, velocity, and accessible power beaming area of interest? Integrate more research on PSR topography
What is optimal split/amount of electronically steered phase-locking gimbaled lasers on top of tower structure?

Technical Challenges
What are optimal power beaming angular degrees of freedom to service partners?
What are optimal pointing requirements to beam to ground mobility platform? How about other alternative power beaming applications?
What is avg/range of distance to and desired locations of water processing plant, ice mining tent, storage, dump sites?
If ground attachment mechanism is optimal, what material and drilling/fastening mechanism to lunar regolith is logical
Could parabolic thin-film pointing reflectors be installed along upper sides of tower structure to loosen frozen volatiles for ice mining?

Power/Communication
Is it more efficient to position solar collectors at base of tower and transmit energy through optical fiber to gimballed laser at apex?
What are power requirements to transport main components to site location and to autonomously build tower infrastructure upward?
Does sunlight on ground provide enough power to deploy tower? If so, how long to charge?
How to determine surface area size of solar panel to meet stabilization and surface power requirements?

Tower Design Challenges
What is optimal transport vehicle size to autonomously carry and deploy tower infrastructure? What other purposes might vehicle serve?
What are optimal ground surface beam separation? Is traditional design of four vertical pillars desired for structural support?
How to maximize resource utilization and services of X amount of mid-tower junction platforms? Could self assembling thin film ‘mosaic shades’ form reflective and/or PV surface(s) along the side(s) of tower?
Is a perpendicular network of steerable parabolic mirrors desired toward top of lunar tower to maximize energy availability on surface?
What are optimal methods for spacebots to access power/comms to make adjustments/improvements? (i.e. ladder, drone, elevator,pulley,cables)

Questions?