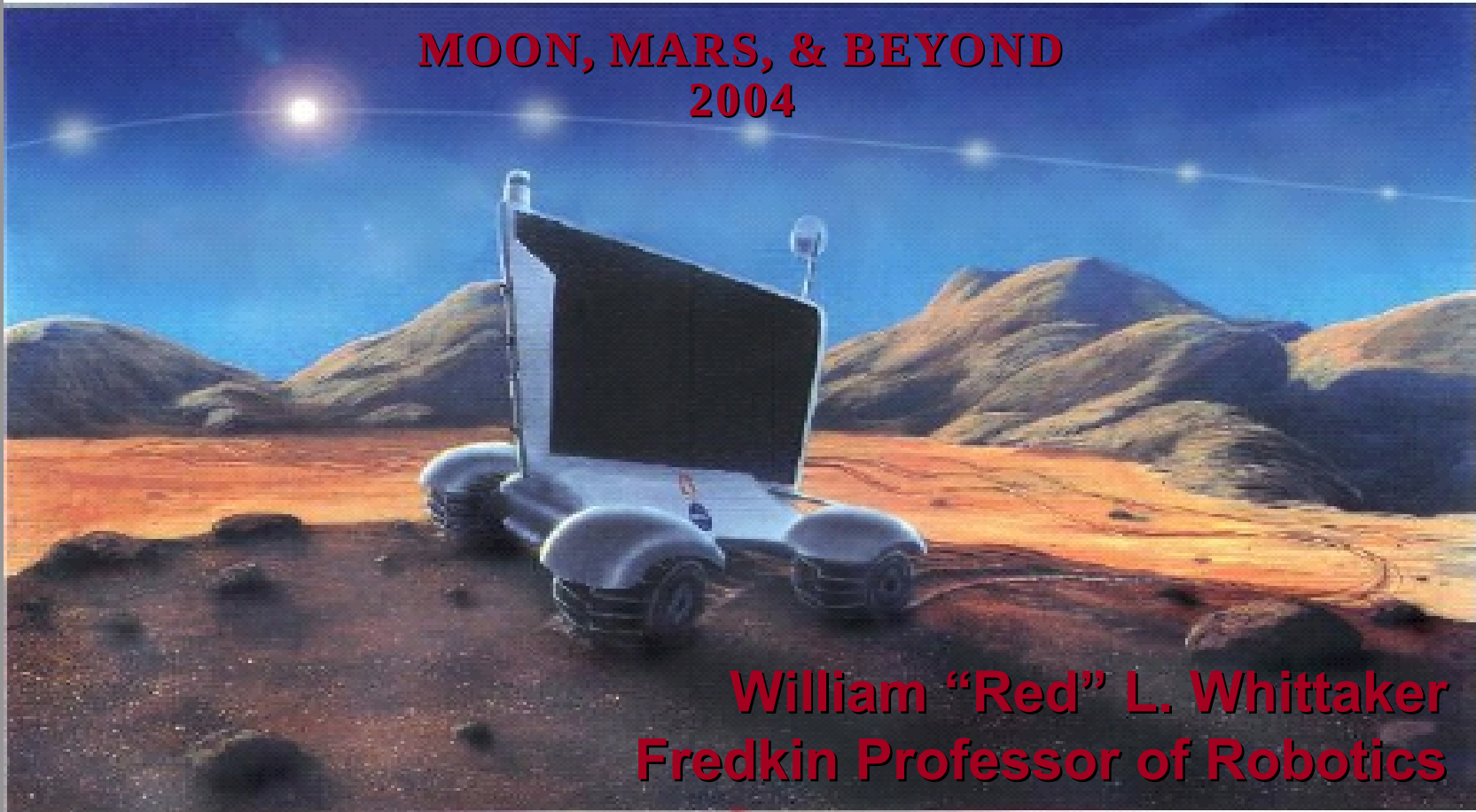




GO FOR THE POLES

**MOON, MARS, & BEYOND
2004**



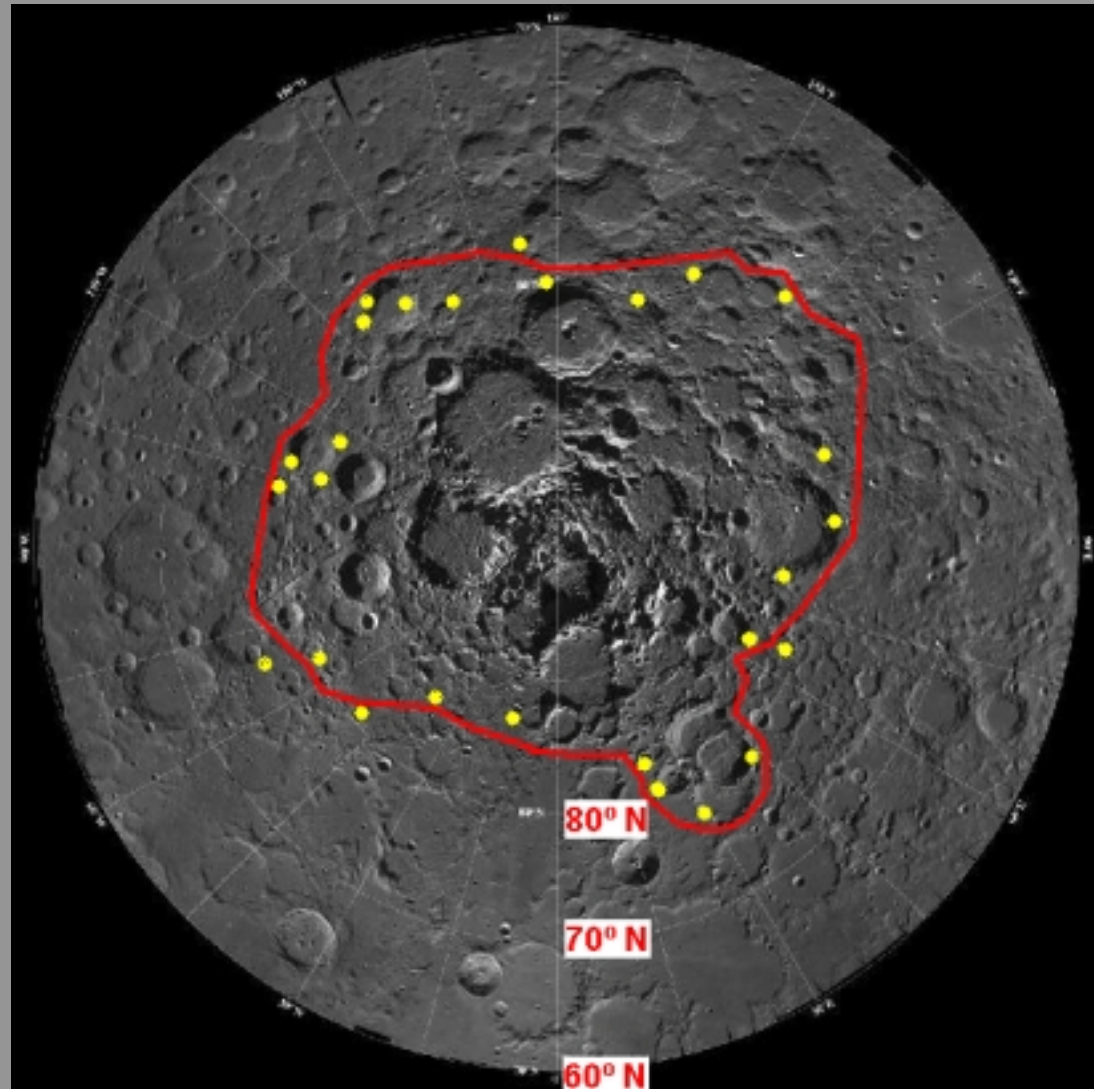
**William “Red” L. Whittaker
Fredkin Professor of Robotics**

**The Robotics Institute
Carnegie Mellon University**



Polar Opportunities

- Volatiles
- Resources
- Landing sites
- Habitation sites
- Magellan routes





Illumination at the Poles

**(Courtesy of
Ben Bussey,
John's Hopkins APL)**





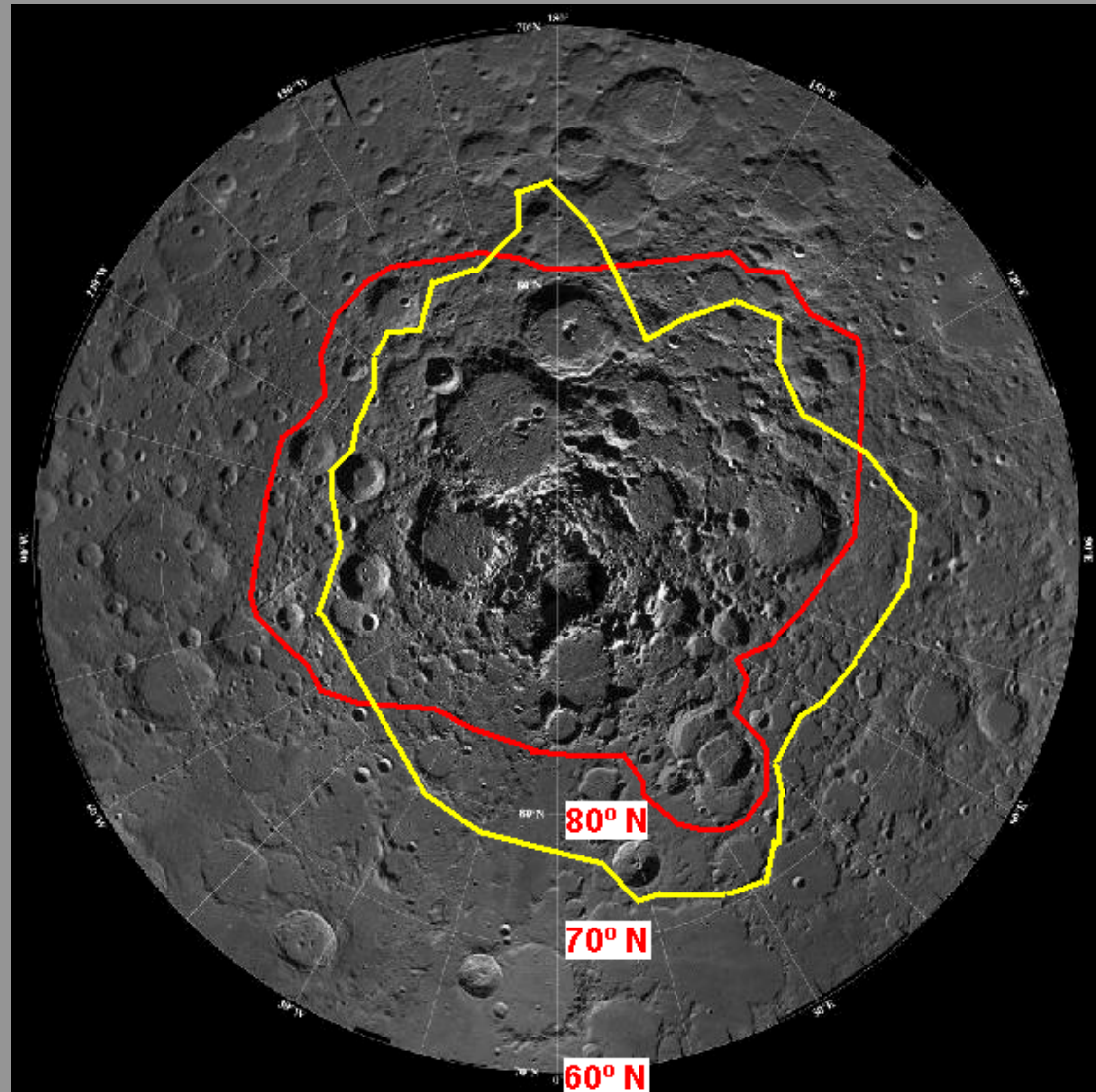
Magellan Routes

No *point* of
eternal sun

But *routes* of
eternal sun

Myriad routes
exist

Seasonal
illumination
on Mars Poles





Circumnavigation

Navigation of Magellan routes

- Follow daylight
- Enable persistent mobile operations
- Possible within a range of polar latitudes

Circumnavigate

- Features
- Poles
- Regions



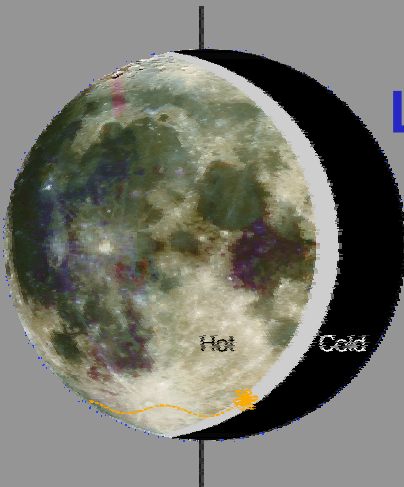
Sun-Synchrony Advantages

High solar flux
Abundant solar energy

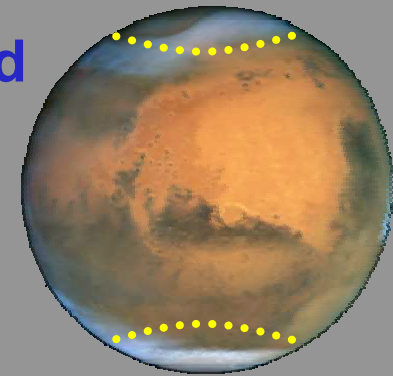
Moderate gravity
Lower locomotion power needed

Small planetary diameter
Traversable circumnavigation

Persistent Power
Without isotopes



MOON



MARS

Generous rotational period ≈ 29 days

Long seasons

Little planetary axial tilt

Substantial tilt

Persistent polar exploration

Seasonal polar exploration



Achievable Sun-Synchronous Speeds

Latitude (degrees)	Lunar Circumference (km)	Rover Speed (m/s)
(Pole) 89	191	0.07
87	572	0.22
85	952	0.37
75	2826	1.11
60	5460	2.14
45	7722	3.03

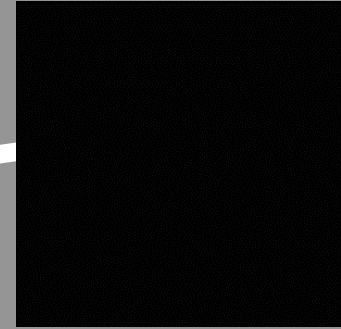
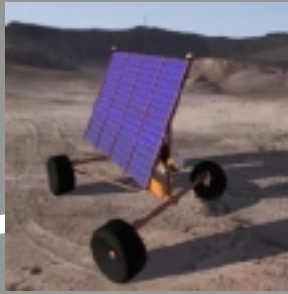
0.3 m/s Earth speed
6:1 Lunar gravity advantage
2:1 Lunar sun advantage



3.6 m/s Lunar
speed
achievable



Robotic pathway to the poles





Atacama Trek



**Rover Independence
200 km Range**



Antarctic Meteorite Search



**Science Autonomy
Isotope Analogue**



Hyperion Sun Synchrony

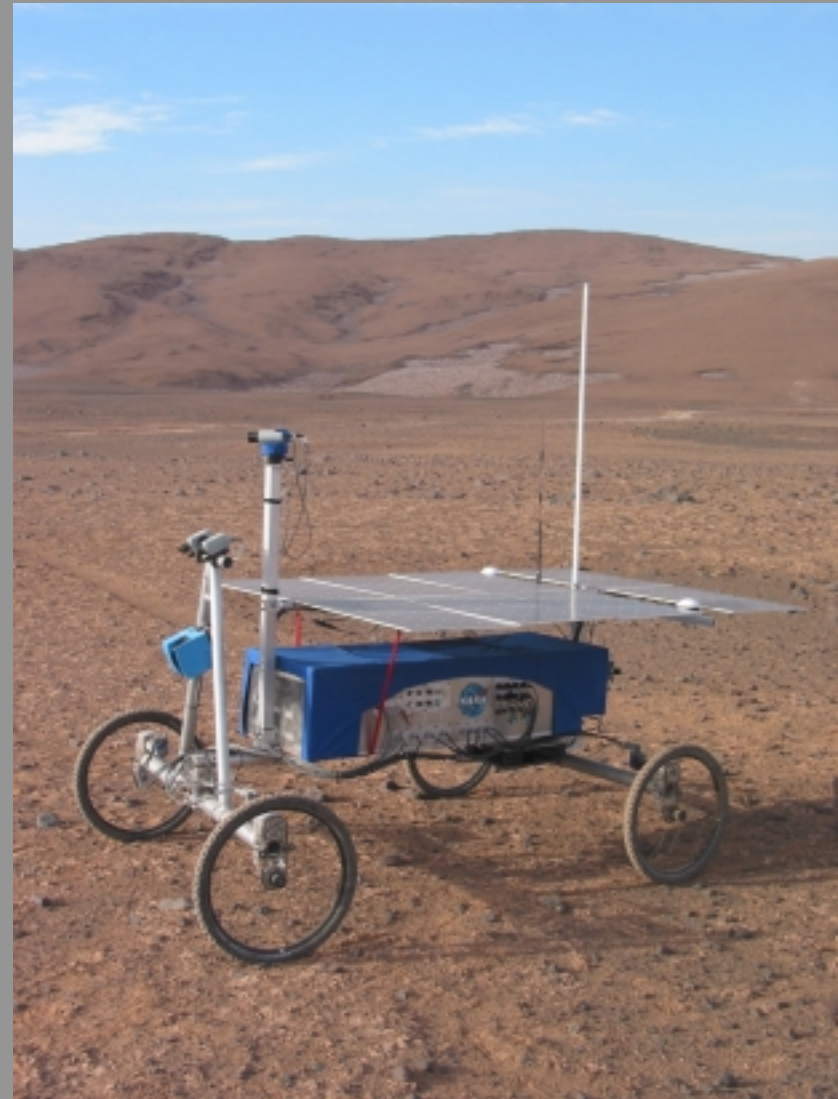


**Productive Solar Exploration
0.3 m/s Rover Speed 24/7**



Life in the Atacama

**Kilometer per Command
1 m/s Navigation
Science on the Fly**





Sandstorm



**Fast Navigation of Unrehearsed Irregular Terrain
Meters/Mips/Seconds**



Skip the Landers – Go for Circumnavigation

2004

- Mission simulation
- Mission design
- Mapping
- Route studies

2005

- Lander design
- Robot design
- Component prototyping

2006

- Lander brass boards
- Rover brass boards
- Payload brass boards
- Preliminary design review

2007

- Critical design review
- Rover build-up and testing
- Upper stage build-up
- Lander testing
- Surrogate testing

2008

- Flight article build-up
- Landing site selection
- Test & evaluation
- Launch integration
- Readiness review
- Flight
- Circumnavigation



Sun-Synchronous Future: Lunar

Explore sites, regions and routes

Characterize volatiles and cold traps

Explore and produce resources

Support power, and infrastructure



Sun-Synchronous Future: Mars and Beyond

Investigate ice caps and hydrogen (water?) permafrost

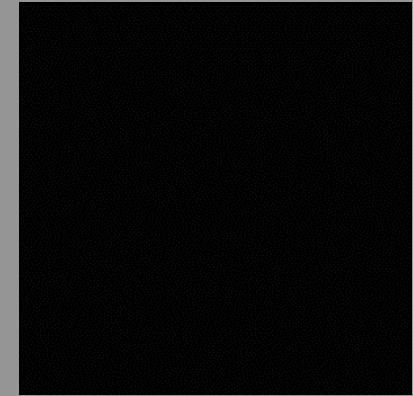
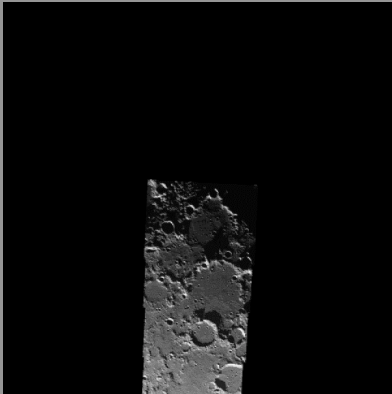
Develop rover technology to enable missions for many destinations and latitudes

Beyond Moon and Mars...

Spiral the surface of Mercury - the ultimate circumnavigation venue



Takeaway



Poles are unexplored opportunities for science, resources, and habitation that are accessible by solar means

Lunar circumnavigation is the achievable, affordable first step

Prioritize polar exploration – Go for the Poles