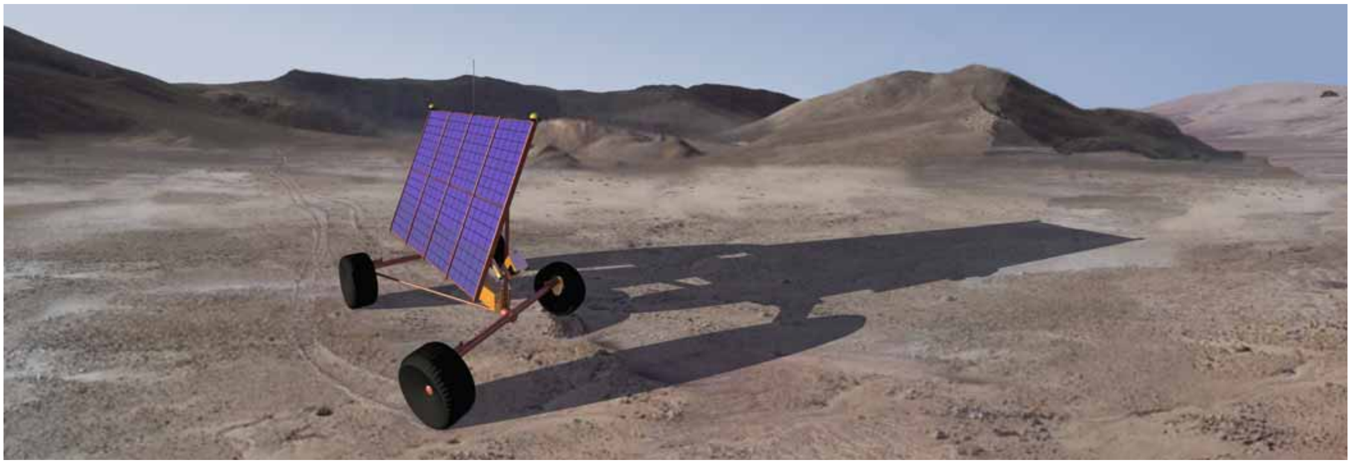
Sun-Synchronous Robotic Exploration



Robotic exploration of planetary surfaces is restricted by the availability of solar power and implications of thermal conditioning to survive extremes of hot and cold, of midday sun and overnight hibernation. Power and thermal cycling are fundamental reasons why exploration ambitions and accomplishments are compromised. With a constant energy source and moderate ambient temperatures, surface exploration missions could last for months or years. The number of daily accomplishments would be multiplied by remaining longer in sunlight and, in some cases, never experiencing nightfall. New mission concepts that dramatically expand operational goals and time frames will revolutionize planetary surface exploration.

We advocate sun-synchronous navigation as a mission concept for planetary surface exploration. With the robotics technologies necessary to enable it, sun-synchronous navigation will provide the capability of persistent, in some cases perpetual, presence to explore, dwell in, and develop resource-rich regions near the poles of planets and moons.

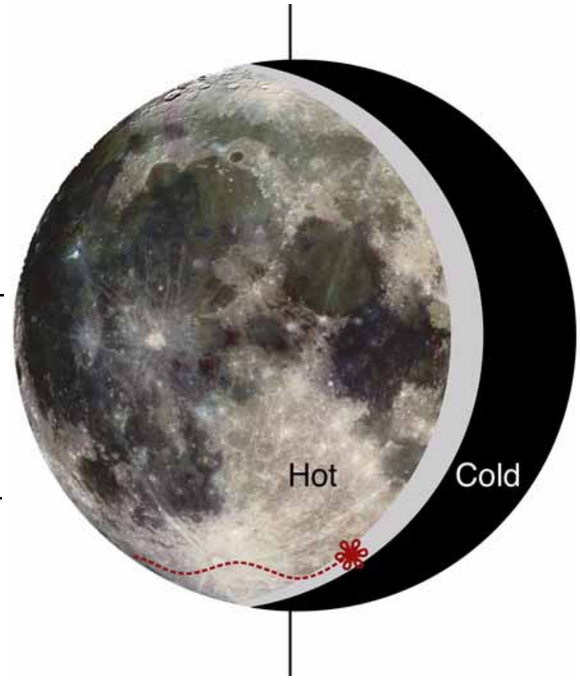
Sun-synchronous navigation is accomplished by traveling opposite to planetary rotation, navigating with the sun, to remain continually in sunlight. At appropriate latitude and speed, rovers can maintain continual exposure to solar insolation sufficient for sustained operation. Furthermore by lagging the night-to-day terminator by the appropriate phase angle, these rovers can regulate their temperature, seeking the transient region between nighttime cold and daytime hot. Power and thermal limitations can thus be overcome on destinations like the Moon, Mars and Mercury.

At mid-latitudes sun synchrony results in global circumnavigation but at polar-latitudes, during periods of continual sunlight, the sun synchronous route can be a circum-feature circuit. Energy-efficient, solar-powered rovers can operate, even on Earth, in the persistent sunlight of the polar summer by tracking the sun with the orientation of their vertically-oriented solar panels. They must navigate around terrain features to avoid shadowing or seek locations of unobstructed sunlight.

Sun-synchronous navigation makes possible an innovative class of planetary rovers notable for their lower mass, reduced complexity and cost, and freedom from nuclear power and overnight hibernation. These rovers will manage the collection of solar power, so that power storage requirements are minimized. This translates into further reduced rover mass, complexity, and cost.

The objective of this research is to discover, express, and exhibit the importance of reasoning about sunlight as it pertains to robotic exploration. At the Robotics Institute of Carnegie Mellon University we are developing the algorithms, technologies, and experiments that will fulfill the vision of sun-synchronous navigation

- We are developing power-cognizant path and temporal planning software for rovers to dodge shadows, seek sun, and drive sun-synchronous routes. This requires planning capable of autonomous navigation in partially known, time-varying environments with additional considerations of power and thermal management.
- We are investigating algorithms that incorporate scheduling and temporal reasoning, modeling of light and ephemeris with autonomous navigation.
- We are prototyping a robot, named Hyperion, to exploit the advantages and meet the challenges of sun-synchrony. We have conceived Hyperion as a vehicle physically capable of speeds of about 1/2 meter per second at a maximum locomotive power consumption of 150W. It has a wheel-base of approximately 2 meters by 2 meters to provide stable support for its 3 square meter, vertically mounted solar panel. The vehicle and power system have mass of approximately 90 kilograms with the sensors, electronics and computing payload adding 50 kilograms and a steady power consumption of 75W. Design refinements and component tests are currently underway.



Polar Circumnavigation

- We intend a field experiment in a polar planetary-analog setting in a location of continual direct sunlight. We will collaborate with the NASA/SETI Haughton-Mars Project and conduct experiments on Devon Island, Nunavut, Canada in July 2001. Our aim is to verify the algorithms for combining sun-seeking with autonomous navigation and to validate the parameters that will allow sun-synchronous explorers to be scaled for other planetary bodies.
- We will scale and generalize results of studies and Earth-bound experiments to other planetary bodies.

Hyperion Concept Rover

The great explorers of history went beyond their own backyard, to follow rivers, cross mountain ranges, reach the poles, and circumnavigate the globe. The ambition then and now is to discover the unknown: to explore regions, not just sites; to analyze, not just observe; and to operate effectively and reliably without excessive support. Robotic explorers capable of sustained operation will perform rigorous in situ science, detailed surveys, resource characterization, and exploration on a vast scale.

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