

INFRASTRUCTURE

09 – Power System (Solar Drapes)

SUMMARY

This chapter discusses solar and nuclear power on the Moon. It highlights the Solar Drapes concept which uses the maximum Starship payload capacity to deliver a whole array of thin film PV drapes suspended by a line of telescoping poles. In this way, an average of 5.1 MWs is produced from a single payload delivery. This is industrial scale power providing enough for any of the following: Ongoing food for 230 people, or 37 tonnes of propellant per day, or 29 tonnes of iron per day, or 8 tonnes of aluminum per day. These high-power products would be produced at the poles and the results shipped overland within three days to anywhere else on the Moon. Nuclear power would be useful during brief times of shading or during the long nights away from the poles.

PEAKS OF ETERNAL LIGHT

Because the Moon always points its face at the Earth, it rotates on its axis only once a month as it orbits the Earth. For this reason, towards the equator, the Moon's day lasts for two weeks, and its night also lasts for two weeks. If an initial base was located near the equator it would have to have a power system such as nuclear power to provide the base with enough power to survive the two-week night.

Fortunately, the Moon is barely tilted compared to its orbit around the Sun. As a result, there are locations near the north and south poles where sunlight shines for greater than 80% of the time. These have been originally given the term, "Peaks of Eternal Light (PELs)". Additionally, these locations tend to be close to certain regions where the sunlight never hits the ground. We call these, "Permanently Shadowed Regions (PSRs)". In 2009, NASA's LCROSS mission conclusively demonstrated the presence of water ice and organic chemicals in one of these permanently shadowed craters in useful concentrations.

SOLAR DRAPES

The Space Development Network puts forward a concept for solar power at the lunar poles which represents what we believe would be the least mass, maximum power system for the PELs.

The concept of operations is that a lander would land away from a specific PEL. The lander would lower a robotic tractor pulling on a wagon filled with telescoping poles and rolls of thin solar drapes. As the wagon drives to the PEL and then drives along its ridge. It would tilt up telescoping poles and deploy long footings. Precise adjustments would be made to ensure that these telescoping poles remained directly vertical. As the wagon pulled forward, a suspension line connected between the tips of the poles would be pulled out of the wagon until the next telescoping pole was erected. This process would continue until all poles and drapes were placed on the ground.

After this set-up was complete, all poles would simultaneously start telescoping vertically causing the suspension line between them to raise up and the thin film sheets would unroll. The result would be a very large wall of solar drapes arising up to 60 meters high which would be perpendicular to the incoming sunlight. Motors between the suspension line and the drapes would ensure that the drapes are always pointing directly at the sunlight as it moves across the horizon during the month.

We have calculated that a 100 metric ton payload of solar drapes delivered by a cargo Starship would provide industrial levels of power. It would be enough to electrolyze 37.6 metric tons of water each day for propellant, or 28.8 tonnes of iron per day, or 7.9 tonnes of aluminum each day. And that is from a single Starship payload! Alternately, that much power could be used to grow enough food continuously for 230 people. See our poster below.

TRANSMITTING POWER

For ice-harvesting operations, vertical solar drapes could be set up outside of the periphery of the PSRs while ice-harvesting vehicles operate within. So, how could the power from solar panels get down to the ice harvesters? There are several possible solutions which people in the field have discussed. Small robots with a spool could lay out a wire from the drapes to a base station that the vehicles would periodically return to recharge. That part of the wire in the permanently shadowed areas could be superconducting tape given the very low temperatures there. Alternately, power could be beamed from the drapes to the vehicles using

either microwaves or lasers. The advantage of this approach is the savings of the mass of the wire.

Some have proposed placing a transparent tent over icy regolith and then using mirrors on neighboring ridges to redirect sunlight onto the tent to heat the regolith to steam out the volatiles into rovers with tanks where the volatiles could be condensed. But this approach seems to be complicated when it comes to laying out the tent over uneven ground, sealing the periphery, and then uncovering and moving the tents. Given the LCROSS results showing fairly high concentrations of water, it would probably be simpler just to transmit the power to excavating vehicles and to use electrical power to steam out the volatiles within the harvesters themselves.

POWER STORAGE

Most lunar advocates along with NASA recognize the great value in starting the first base at the southern lunar pole where there are both the so-called Peaks of Eternal Light and high concentrations of volatiles. But even at these peaks there will be nights lasting for several days. And as one establishes a base anything more than a few hundred kilometers away from the poles, very quickly the nights become 14 days long. If each facility doesn't have its own nuclear power source, there will need to be an energy storage solution.

Types of Power Storage

Perhaps the easiest and most straightforward storage solution would be to simply use batteries. But they have significant mass and may be difficult to produce cheaply using local materials. Alternately, electricity during the day electrolyzes water into hydrogen and oxygen and then runs them back through a fuel cell during the night. Alternate forms of power storage could include flywheels (using local material) or thermal wadies where heat is stored in the regolith during the day which then powers equipment that produces electricity at night.

Reducing Power Consumption

It is likely that one wouldn't run operations during the night at the same level of energy consumption that one does during the lunar day. So, during the night, energy intensive operations would come offline and activities would turn from operations to low-power activities such as maintenance, cleaning, food processing, and recreation.

SOLAR CONCENTRATORS

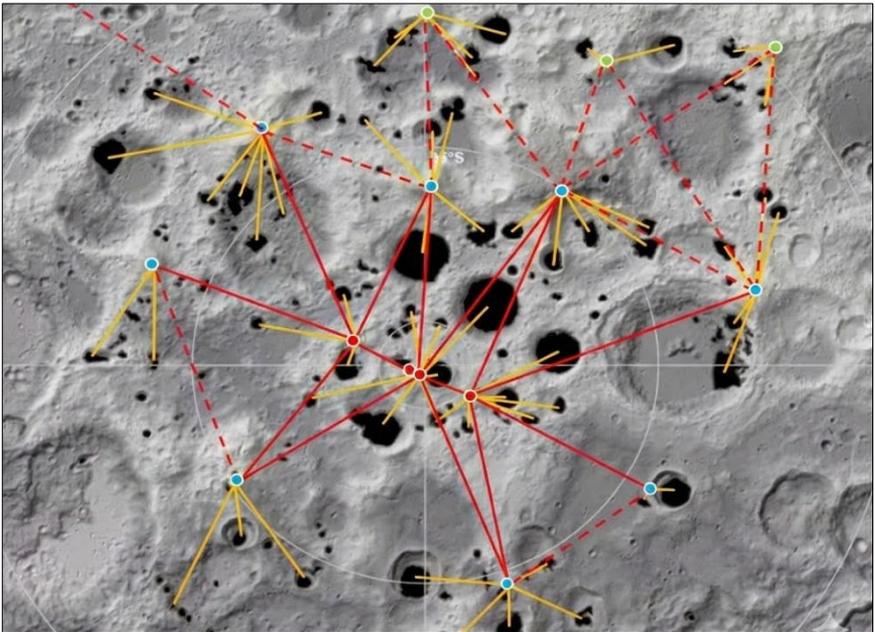
Solar concentrators are parabolic mirrors that concentrate sunlight to a point or line. This concentrated sunlight can heat a liquid which transmits that heat to an engine that can produce power or electricity. Since they are just mirrors, they could be somewhat thinner than solar panels and, more importantly, they could be constructed using local aluminum found in the rocks of the lunar highlands.

The concentrated sunlight can be used directly for certain processes including melting, sintering, cooking, and in support of some chemical processes.

These solar concentrators could be connected to Stirling engines which are highly efficient. These engines could be connected to electrical generators to produce electricity.

REGIONAL POWER GRID

The PELs are limited areas even in the polar regions. There are many areas at the poles that don't have these peaks. One could imagine setting up, over the long term, a network of towers on regional peaks that would use microwaves to transmit power between them. Alternatively, aluminum is abundant in the lunar regolith whereas there are no known copy ore bodies on the Moon. On Earth, high tension, high-voltage, long-distance wires tend to be made of aluminum not copper. By using connecting different PELs, each pole region could supply power 24/7 including operations down in the permanently shadowed craters.



NUCLEAR POWER

Different types of power systems will be needed for the different phases of development at different locations. Starting at the lunar poles, photovoltaics and concentrated sunlight will be the dominant source of power.

Later, facilities will be established away from both poles perhaps at sites that are frequently visited (e.g. tourism sites), a people group has established a settlement, or where specific elements are being mined. In this case, the lunar nights would last for about 14 Earth days during which no solar power could be produced on the surface. Nuclear reactors would be ideal for providing power especially during the long nights.

Shipping nuclear fuel from Earth to non-polar areas would be the obvious thing to do initially as a whole lot of power could be shipped as a small amount of mass. Fissile material can be launched safely from Earth but would need to overcome politically driven pushback. With time, nuclear fuel could be produced from resources on the Moon. In particular, there are a few locations on the Moon that are known to have higher concentrations of thorium which can be used as a safe source of nuclear fuel. NASA is developing the Kilopower system which would be very useful for powering habitats.

Concept of Operations for the Establishment of Solar Drapes at the Lunar South Pole

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Introduction

It is well recognized that the lunar south pole would be a good location for the establishment of an initial permanent base due to the presence of permanently shadowed regions near locations with nearly continuous solar illumination. If a permanent base is established and grows into a large international base, high energy activities will require the maximum exploitation of the solar power available at these high sunlight locations. These high energy processes could include: the electrolysis of lunar polar ice for propellant, the growth of food, the production of surface structures, and the extraction of metals from the lunar regolith. The concept of solar drapes is here proposed along with a method for how they could be erected.

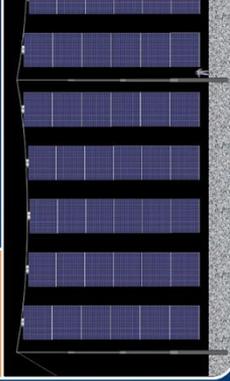
Delivery & Set-out



A large payload is delivered to the lunar surface via a reusable lander. A motorized wagon with the solar drapes packed within drives out of the lander to the deployment site. An auger located at the back of the wagon drills vertical holes to a depth of approximately 20% of the height of the drapes. Automated mechanisms tilt up the first telescoping pole and places it into the hole. The holes will need to be dug as vertical as possible.

Between the tips of each telescoping pole is a suspension line onto which approximately five solar drapes are attached in series. As the wagon moves forward, the solar drapes are pulled out of the wagon and onto the ground at regular intervals. The wagon then drills the second hole, tilts up and drops the second pole and moves forward, and so on until the entire solar drape payload is set out.

Erection



The erection of the solar drapes would be as simple as activating the telescoping poles at the same time. The suspension lines between them would begin to pull up and hence deploy all solar drapes at the same time so that a long wall of solar drapes arises simultaneously. Each drape would track the sun by means of a motor between the top of each drape and the suspension line.

Power Uses

Assume 100 metric ton Starship payload with 50 tons for solar drapes including support and electrical management, 30 tons reserved for surface deployment, and 20 tons of margin during design. We estimate a specific power of 150 W/kg. The total power delivered would thus come to 7.4 MW. Starting at the best lunar south polar peak of persistent light with an average of 83% illumination through the solar year and 20% loss due to self-shading brings the power to 5.1 MW. This amount of power would be able to provide any one of the following capabilities:

The total energy to electrolyze water comes to 17.8 MJ/kg at 90% efficiency, meaning we can electrolyze 37.6 metric tons of water to hydrogen and oxygen per day. If certain metals were to be extracted directly from lunar rocks or regolith then iron can be produced in a molten oxide cell for 15.25 MJ/kg plus heat yielding 28.8 tonnes per day, or aluminum can be produced in a molten salt cell for 55.33 MJ/kg plus heat yielding 7.9 tonnes per day.

Each person consumes about 4.42 kg of food each day. It has been estimated that it takes 22 MW of lighting to produce that amount of food. So, we calculate that the full payload of solar drapes would provide enough lighting to produce food for about 230 residents.

REFERENCES & CALCULATIONS: DevelopSpace.info/drapecalculations