

## POLAR LUNAR POWER RING - PROPULSION ENERGY RESOURCE

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**ABSTRACT** - A ring shaped grid of photovoltaic solar collectors encircling a Lunar pole at 80 to 85 degrees latitude, is proposed as the primary research, development and construction goal for an initial lunar base or development in general. The Polar Lunar Power Ring (LPR) is designed to provide continuous electrical power in ever increasing amounts as collectors are added to the ring grid. Initial lunar base function is suggested as production and distribution of power system components, most importantly the photovoltaic cells. Upon completion of phase 1, the LPR can provide electricity for any purpose indefinitely, barring a meteor strike. Capable of acting as the foundation for diverse Lunar developments ranging from agricultural life support systems to plasma based refinement and fabrication techniques (seamless CELSS), the associated rail infrastructure and inherently expandable power levels place LPR as an ideal tool to power an innovative propulsion research facility, and perhaps a trans Jovian Fleet. The basic polar power ring has utility on asteroids, and could suggest Earthly rectenna receiver positioning as well. Proposed initial output range 90 Mw to 90 Gw.

## INTRODUCTION

The moon can figure prominently in propulsion research in terms of energy and facilities for R and D testing, however, in order to achieve this goal as well as overcome the solar energy problem of the long Lunar Night, a rapid single minded development from an initial lunar base is required. The assumption is that in order to be able to pursue propulsion Research and development, all other potential energy users would likely need to be satisfied in order to reduce competition for energy. Although it is common knowledge that human demand is insatiable, this situation is limited to Lunar access, so we assume a limited set of users of energy including mining and benefaction, power sat component manufacture, and perhaps direct energy export from moon to earth, as well as many other worthy energy uses. The following concept is an attempt to design a power system that is capable of generating sufficient continuous electrical energy to satisfy all users in a profitable manner so energy consumption trade-offs do not generate a negative impact on advances in propulsion required for deep space exploration. The power of the polar Lunar power ring could also be used to facilitate current propulsion requirements. Some problems are identified, unfortunately the initial lunar base would be dominated by the need to produce photovoltaics, the power ring could be very difficult to turn off even in the event we wished it would cease output, also the adventure of independent Lunar development would be limited to the ring builders, as later developments would probably tie into the established electrical grid upon landing. An adventurers point of view. Upon completion of the 90 Gw upgrade the ring would present a solid 300 foot high face of glittering amorphous silicon as the sun comes around. The ring would stretch off into the horizon, like a grey ribbon on edge. From space an almost invisible silver thread or Tiara, yet ring shade would be clearly visible from a polar orbit.

## Philosophical Introduction

In the course of designing strategies for the exploration of the Galaxy, number of philosophical drivers were identified and developed as possible fundamental principles or skills for Space Exploration. One key strategic area is the initial phase of gaining access to space from a fully colonized hospitable planet to our moon(our current situation). If one considers as a fundamental principle of Space exploration the learning of skills in the application of light to pursue space related objectives as transportation, life support, and construction, one can abstract the process and frame it in the context of Life and reality as it now exists. To digress, at Stars, light is a certain resource, the usefulness of matter as it may be found will depend on our light skills. If then one considers that Terran life as it now exists depends on the light skill of photosynthesis and its associated 4 billion years of developmental biochemistry, and that the conditions and residents of the biosphere are almost entirely dependent on photosynthesis, the sentient species Humans should realize that to space is to learn new light skills. If one considers photosynthesis as the key light skill in the hands of life and its final success in building the biosphere of Earth, what extensions to the biosphere are possible, now that sentience( Humans) have appeared within the biosphere, how will photosynthesis be applied, and what are the next logical light skills that may be employed in the hands of life? In simpler terms can sentience apply photovoltaics to support photosynthesis, and what new light skills can be developed that can augment the life/light relationship? For example optimizing photon pressure devices. In addition the photoelectric effect, compton effect, reverse FEL, and inverse Cerenkov offer challenges. Perhaps even testing laser sails as resonators will produce some surprising results. Conceptually- In space, images of New habitats, distance, journey, inertia, momentum, travel, with light as the common thread, and light in transportation emerge, with a question regarding photon pressure, and the potential for optimization, with links to reaction mass. Since most new habitat for life lies in orbit around other stars the application of light in regards to access to those stars suggests a driver for research and development. There clearly is a challenge to sentience to make itself useful. A possible retribution for the extinctions one species is inflicting on the community of the biospheres. A valid question- Are we capable of sustaining life? We go to the moon to face the Galaxy. The Polar Lunar Power Ring will keep the lights on, but it will likely fall on Space Exploration Engineers to prove someone is home. A corollary is that if we create such vast and powerful devices, we must prevent their misuse through the application of new goals as a species. These goals, with education, can do as much to turn around the human conditions as any new power system. Ingenuity can give rise to new hope. A tremendous future lies ahead for this solar system, provided we apply new resources for the long term. We can conquer the moon by a simple circle of Photovoltaics, but this can only spell disaster unless the victory is used to lay the foundation for address greater challenges. I strongly urge discussion on these matters.

### Electricity During The Lunar Night

Electricity stands out as a key tool in the tool chest of a space able civilization both on the surface of the planet and beyond. Photovoltaic cells for the conversion of light energy into electrical energy allows us to generate electricity in space from the energy

resource of light from the star. Nevertheless, as usefull as electricity is, we are dependent on the foodstuffs resulting from photosynthesis. Plant growth is dependent on continual or diurnal irradiation. The following power system was designed with a mind to providing photosynthetic light to an environment that is subject to a 354 hour night (The Lunar Night), utilizing photovoltaic cells, as simply as possible. The purpose of growing plants was to make a lunar base self sufficient in life support systems.

Once life has established a foothold on the moon using photovoltaics to supply adequate photosynthetic light to support a population of Humans, a portion of those humans can consider the next logical light skills to be used in expanding the domain of life keeping in mind the best habitats represent the greatest challenges - habitable planets at other stars. The authors personal R&D fascinations tend towards photon pressure devices, light sails, laser propulsion, laser resonator propulsion, Reverse Free Electron lasers, Reverse Cerenkov effects, The Compton effect, free space photovoltaics, the photoelectric effect, and ultimately the Light drive. The Polar Lunar Power Ring however has many other usefull and interesting applications.

#### Origins of the Polar Lunar Power Ring

Many years ago I did a calculation to find the height of a tower, the top of which, when situated on the pole of the moon would remain constantly exposed to sunlight for the purpose of supplying electricity below to run electrolysis equipment to produce LH2/LOX fuel. The tower height was over 11 kilometers. The power tower had the disadvantage of being difficult to expand the electrical output and could be rendered useless by collectors assembled on the horizon. I examined placing Photovoltaic collectors on the horizon of the tower top, especially on those hills about 200 kilometers away and concluded a ring of collectors was better than the tower and easier to construct than a equatorial power ring. The horizon was about 6.5 degrees and is now proposed to be about 10 degrees due to uncertainties regarding the lunar terrain and the Lunar "winter". The power output is phenomenal, expandable and has the advantage of being continual. After reading Ref. 3 by J.D Burke regarding Polar power systems the ring concept was written up as a paper. Renewed interest in the polar regions of the Moon for its potentially cold trapped water, and renewed interest in Large scale Space Power projects as a solution to biosphere destruction, as well as the need to continue the exploration of space has led to this revised version of the polar power ring.

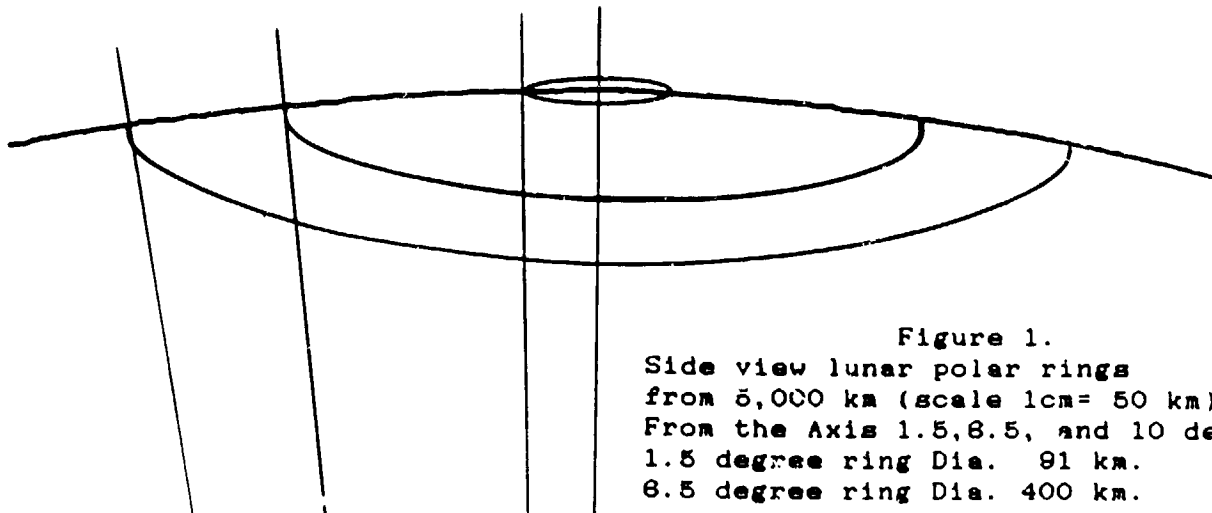


Figure 1.

Side view lunar polar rings  
from 5,000 km (scale 1cm = 50 km)  
From the Axis 1.5, 6.5, and 10 deg  
1.5 degree ring Dia. 91 km.  
6.5 degree ring Dia. 400 km.

## Terraforming analysis

The moon is a slowly rotating body under about 1.4 kilowatt/ square meter solar irradiation, the period of rotation is about 708 hours relative to the sun leaving 354 hours of time during which no solar irradiation is available to a given collector on the surface. Maximal axial tilt to star is about 6.5 degrees, lunar radius is about 1740 km equatorial. The Moon is oblate. if we calculate the distance from the axis at 6.5 degrees from the pole a rough figure of 380 kilometers is found, or a ring almost 800 km in diameter is described around the pole. The pole of the moon is not a smooth surface. Nevertheless from a terraforming theory point of view, a ring beyond 6.5 degrees axial would at any given time including lunar seasons, be under solar irradiation continuously except under conditions of eclipse. This is a situation in common with the equatorial regions and defines the Arctic Circle in Terran terms for survival purposes. Although it could be argued the Moon has 2 types of Arctic circles we seek a permanent location outside either, and this interesting situation will affect the shade cooling potential of the Power system. Having defined the rough minimum circumference of a ring under constant solar irradiation we then compare the boundaries against the topography of the polar surface as valleys outside of the ring allow the boundary to move towards the pole as do high ridges, promontories and crater walls, however these same high promontories outside the ring may force the power collection boundary outside towards the equator as they would eclipse the collectors. In this case the boundary moves to the equatorial face of the topographical feature to ensure adequate irradiation.

Collectors are preferably photovoltaic, amorphous silicon, and produced on the Moon(Landis ref #2)at the base in production facilities, and would be placed in amenable locations alongside pathways cleared by long distance rovers or Sun-Following Lunar bases(Landis Ref #1). Baseline collector size is 10 meters by 10 meters for 14 kw per collector at 10% conversion efficiency. The collectors are fixed for calculation purposes, therefore if we assume optimum collection efficiency to occur along a portion of the ring equal to 1 radius of the ring, at a collector spacing of 100 meters the output of the 400 km of ring would approximate 56 megawatts. This is a conservative figure. Use of foil reflectors and optimizing terrain advantage should bring the figure in at about 90 megawatts. a fully optimized ring to a height of 100 meters solid photovoltaics would put out 90 gigawatts continuous.

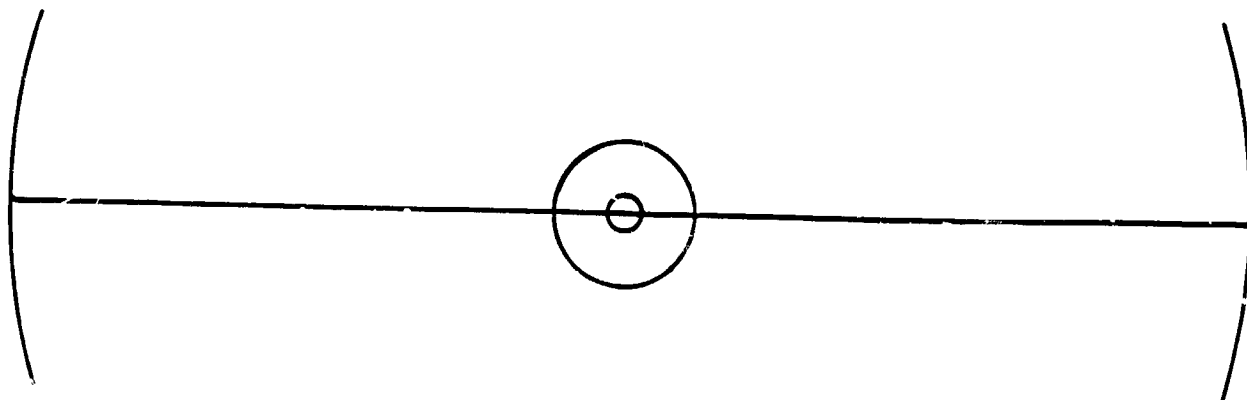


Figure 2. Relative Ring Sizes-Equatorial, 1.5 and 6.5 Degrees  
Scale 1 cm = 200 km Line represents 1738 km Lunar diameter

Note - The actual power ring will be irregular due to topographical opportunities- ridges, crater walls, highland and mountains. Exploration beckon. Will Lunar Prospector map out 1:50,000 topographical?

Regarding the initial construction of the Ring,

As the polar data from the Lunar Prospector spacecraft or Muses-A(Japan) becomes available, topographical features of extreme interest should become part of plans for initial bases and landing of development missions. In the case of the LPR 3 parameters come to mind: 1. Polar light mountains or ridges( Mountains of Perpetual Sunlight) are key features. 2. Clean landing areas near the light mountains ( or at a low enough latitude to avoid lunar winter darkness if Light mountains do not exist) 3. Line of sight telerobotic communications with Earth. From there our search begins.

If one considers the concept of Landis- A Sun-following Moonbase(Ref. 1) and applies it to tracing the path for construction of the Polar Lunar Power Ring, construction of a Ring will inevitably result. It is my experience that explorers, if repeatedly travelling over the same path, will increasingly break trail and improve the trail as best as time and equipment permits, and at some point a smooth trail bed cleared of rocks with numerous resource caches to the side will exist, and eventually equipment caches will result as well. If the excess production of solar cells is made available the cells will be emplaced along the path and inevitably be linked together to supply stopover points at scenic areas, and as power transmission resources become available a ring will take form. I would expect power transmission cable sooner than extra solar cells, nevertheless I for one would enjoy the initial trail building

#### Polar Lunar Power Ring #1 initial and final Specifications

Scenario #1(no storage of power)- The initial Power system would be a rag-tag affair rigged up on the slopes of the most accessible mountain of perpetual sunlight or Polar Light Mountain(PLM). On the slopes of the PLM, photovoltaic collectors would face every sunward direction and be cable connected to a power conditioning unit to transmit the power back to the base. If the PLM is high enough to see sun during Lunar winter, the base will shift to the PLM from the Landing spot and a new landing spot or Port will be cleared and constructed. A manufacturing plant for the Lunar Production of Solar Cells(Landis and Perino ref. #2) would be assembled and operated using the output of the PLM cells. The next step is to identify other topographical features that are amenable to solar irradiation in excess of 14 days per lunar cycle and clear travel pathways to those features, gain access to the irradiated slopes, emplace newly produced collectors and run transmission cable back to PLM base. At some point these other collector points would be laterally connected and portions of a ring could take shape similar to a spiders web. In this scenario we are stressing gaining access to continuous output over building a ring. Its key advantage is less reliance on storage, its 2 key disadvantages are a. the Polar light mountain must be proven to exist b. the aggressive development in polar regions is bound to be extremely hazardous. In such darkness the craft and crews would literally be working off an extension cord to the PLM power base. The extent of lunar winter may preclude this scenarion and force the following at a 6.5 degrees latitude.

Scenario #2(reasonable amount of power storage) The Initial power system would be a trio of collectors at about 83 degrees north, with expansions to the south as terrain dictates, eventually outlining a circular power grid. A landing would be made in the plains north of Goldschmidt crater. Just west of the meridian, with a good line of sight to Earth.

Full deployment of solar Cells and construction of a metal surfaced port facility would ensue to ensure dust free landing and takeoff of visiting craft. A road would be constructed to Gioja crater, to the north. From there the road would branch west to the nearside of Hermit crater and the East branch would travel to Nansen Crater passing just north of DeSitter, with a further branch there, with one road heading south south east to Schwarzschild's North Wall (an outstanding collector slope) and a westward branch headed to Cr. Plaskett. On the other road an extension to the west wall of Cr. Rozhdstvenskiy affords access to an excellent collector surface provided the surface is not shaded by the next destination, the northwest wall of cr. Plaskett. The road building should provide access to sufficient crater walls to provide continuous solar output as PV cells become available from the main base. The shape of the ring is dominated by Craters, the height of the north compared to the south walls and whether the East or West walls form high or extended ridges. Cr Nansen and Hermit are within 300 kilometers of Gioja. Initial power output would be 90 Mw continuous excluding losses. As the Ring took shape output would increase to 90 Mw continuous at any point along the travel path continuous. Feeder lines could be run away from the ring in any direction to supply various forms of lunar enterprise, and eventually to the equator. This output represents 10x10 meter collectors spaced 100 meters apart along a 2000 km collector ring assuming about 600 km of collectors will be facing the sun. This is where proper utilization of terrain can increase power and fill up the troughs in output. It is actually better to have an assortment of steep slopes than have a smooth surface in terms of collector density per given length of stretch.

Scenario #3- A Lunar Base is established far from the pole and as extra equipment and solar cells become available, investors pay for construction of a ring as a lunar power utility venture.

Use of Output- Electrical output may exceed other users demand and the excess output can be used to attempt the following:

Plasma refinement techniques, there may be large fragments of nickel iron meteorites that could be refined to extract the platinum group metals.

Plasma based construction techniques could be developed to construct metal chambers rather than fabricating from sheets of metal.

Certainly excess output could be applied to fabricating components of Power-Sats. If the power were used to run a large magnetic field, would we be able to deflect solar wind to concentrate and focus for collection of ions H and He, much like a Bussard scoop? This may evolve from Ion deflection radiation shields.

One form of output we do not want to see is misuse of the energy to run energy weapons. Additionally, this power system would hold some attraction to a Rogue AI. and may be a target of some suicidal hackers.

Linear accelerators(Linac) may be operated to enrich thorium and uranium for use in Mars missions. there may even be the possibility of the production of Tritium and Helium-3 by Linac. A market may exist for modifying nuclear waste to make it more useful for deep space missions.

Antimatter production for research purposes would be possible when the ring reaches full upgrade. This would complement plans to build a fleet of vessels to explore the Jovian system and Asteroids. The Jovian moons have ample water resources for Martian developments in the future. Antimatter may be in demand.

A Laser-Sail facility could slow incoming craft thereby saving on fuel.

A laser resonator facility could test high energy lasers for transportation uses, and to study photons in general.

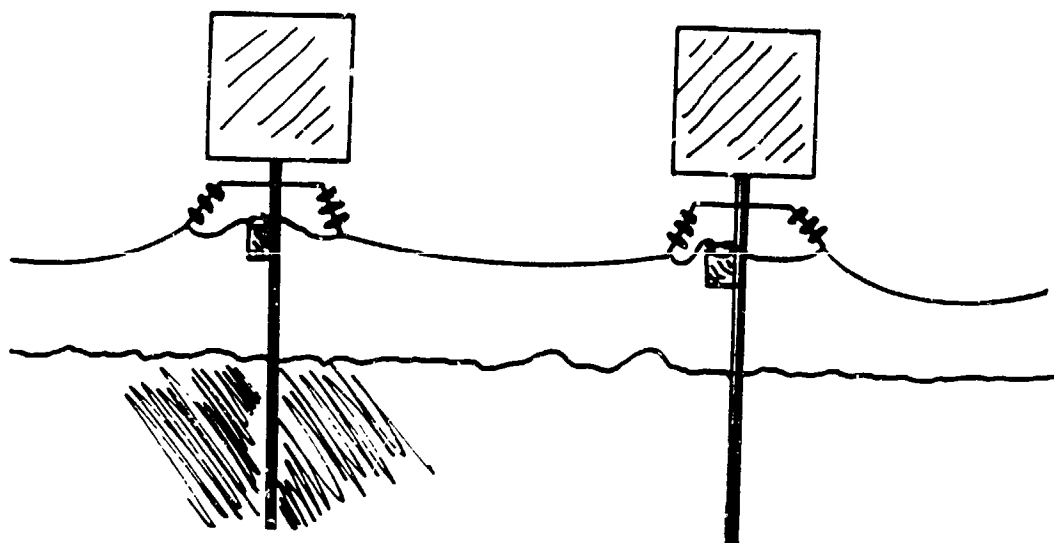


Figure 3. Solar Collectors on Glass composite poles simply tamped down holes augered into regolith. Tower spacing 20-100 meters, Scale 1cm = 5m

### RAIL LINE

Eventually a rail line would have to be constructed along the initial power ring. A rail line would allow the movement of components as large as portions of the 100 meter towers (for the 90 Gigawatt upgrade), power conditioning devices and spools of cable. A large gauge railway would allow radiation shielded human living quarters to travel to construction areas. Habitations would be quite massive, and thick-walled, rail alone would make them continually accessible. Ideally all or part of the line would be dual tracked to allow two way movement of personell and materials. Railways may seem primitive, however, they represent a mature technology with relatively easy guidance requirements. In addition it is reasonable to assume railways will eventually need to be constructed in order to conduct mining operations, and long term travel between bases as equatorial regions will dominate transportation. Rail transport is compatible with Lunar development as most lunar development will, in the long term likely be very large scale, serving Global needs. Lunar dust problems are avoided by using rail transport. The Iron for the rails could be cast from free iron via magnetic seperation from the lunar soil. This Iron would represent a resource cache previously refered to. A solar furnace could be used to melt the iron. It may be advisable to coat the Rails with Chromium refined from the lunar soil. The rail ties could be either Glass soil composites or cast composite Calcium metal. The calcium is assumed to be a by-product of Magnesium production.

LifeCredit Section- One of the best uses of electrical output during the lunar night is lighting Closed Environment Life Support Systems(CELSS). The Life Credit may assist in financing the LPR because the ring can provide sufficient energy to support photosynthetic light chambers. Why is this usefull for Earth and Space Exploration? There are fundamental rules regarding extinctions and Galactic Exploration:

1. an extinct life form(species) cannot be used to colonize a planet, repair, augment or support a CELSS. Its genetic life code is also lost. The individual diversity within the population of the species is lost and cannot be used for breeding desired characteristics. The rapid population increase that may be required is not possible as the reproductive methods

are non-existent. Even ideal conditions will not bring needed species back from the dead, and the humans at risk may not have time to wait for evolution to develop solutions to colonization problems, therefore conservation of existing life is essential and is equivalent or better than producing CELLS space technology. To expect biotechnology to produce wilderness or species demand is perhaps an extreme act of faith, and would require an effort greater than conserving existing candidates from a (for now) functional biosphere now in its 17th circumnavigation of the Galaxy.

2. Evolution is the only offsetting factor against extinctions, as such it must be allowed to proceed on Earth, therefore wilderness must exist on Earth so that evolution can proceed unhindered and beyond the human intervention, just as it will also proceed under human direction.

3. It follows then that since some extinctions are a natural process in the long term, Humans can conserve the "naturally deleted" life forms for later use, (In addition to species endangered by humans), for although the life form may no longer be suitable for current habitat on Earth, it may be useful for the more recent and primitive barren habitats presenting in space. A Space Exploration insurance. IE-that which has outlived its usefulness in biosphere earth may be needed in new biospheres, and should not be discarded as new applications and niches will result from space travel. We are the sentients, not the plants, our eyes should be open to the potential of life in the larger picture of the Galaxy.

4. Life originated on Earth, the best insurance against extinctions and to insure availability for use in space is a healthy habitat on the planet Earth, therefore to conserve habitat on earth is to conserve the biological resources that will assist in galactic exploration.

5. In the event other life is encountered most trade will initially be information. Our technology may be interesting for historical studies. Much more valuable the genetic information relating to biochemical functions, and life morphology from enzymes to the diversity of species. Especially so if the customers are DNA based. We may be destroying a treasure house of enzyme designs, worth the price of a Star Drive a dozen times over. For what in the Galaxy is rarer than life? Life truly is an interstellar class technology. As we travel further from our home star, we will quickly appreciate how valuable genetic data can be as we buy it to survive, colonize or sell back some diversity lost. Also- genetic information can be sent at the speed of light and would represent the beginnings of interstellar trade. (Ref.4 Feoktistov) Many reasons to conserve life.

The final argument for a large continuous power supply on the moon, and the LPR as worthy design, is simply this: Since humans must conduct agriculture to sustain themselves on the lunar surface and since this is a relatively inefficient use of energy, necessary nonetheless, large amounts of extra energy must be made available for growth of plants. Some plants may exist on earth that can readily adapt to the Lunar day cycle, but it is doubtful those species will produce oxygen and food in the dark. In the meantime the LPR can supply light, and the power to produce large Closed Environment Life Support Systems.

In conclusion the Polar Lunar Power Ring provides a permanent, long term, almost trouble free, solid state solution to the lunar night energy problem. It requires a initial lunar base capable of producing amorphous silicon Photovoltaic cells, power transmission cable and long distance rovers. The benefits include an eventual rail infrastructure, large scale plant growth capabilities, and plenty of power to conduct propulsion research. The cold traps on the Lunar pole can be enhanced to passive



cryogenics levels. The power output is inherently expendable and limited only by the output of solar energy conversion devices. Once constructed the electrical output can enable most of the lunar developments proposed. The ease and extent of potential space activity due to the capabilities of this power system may force a re-evaluation of Human goals that will place education, Conservation and the challenge of interstellar travel as 3 working surfaces of a single tool to carve a new future for Mankind. The dangers of the power system or the systems potential to alleviate environmental destruction are uncertain. The forecast for lunar power systems is certain- sunny.

We were born to go  
as far as we can fly.

-Hawkwind (In Search of Space)

#### Acknowledgements:

The author would like to thank Dr. Geoffrey A. Landis for his assistance in preparation of this paper by volunteering Ref 1. and 2. and providing comments which led to extensive revisions of the concepts as originally presented at the Lunar Bases and Space Activities in the 21st Century symposium April 7, 1988 Houston Texas. Also Dr. Robert L. Forward, for volunteering papers on daring propulsion concepts requiring power systems of this magnitude and Space Studies Institute for the tools to build with. A future version of the Polar Lunar Power Ring will include concepts by D. Criswell and J. Burke, and will be available from the Author in late 1990. Also of assistance was the Report of NASA Lunar Energy Enterprise Case Study Task Force July 89.

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