



# Lunar Solar Power Station

Lecture 35

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# Why Are We Interested in a Lunar Based Solar Power System (LSPS)?

- General Features of Extraterrestrial Solar Power Systems
  - The Sun is a dependable energy source that supplies high quality energy
  - Concept utilizes passive and low mass equipment to collect and generate electricity
  - Can be operated while repairs are made

## Why Are We Interested in a Lunar Based Solar Power System (LSPS)? (cont.)

- Why the Moon vs. GEO?
  - Stable and predicable platform (low gravity, no wind, few moonquakes)
  - The Moon contains all the materials needed for solar cells and structures (reduces transportation over SPS)
  - Less intrusive than GEO positioning
  - Improved worker safety

# Solar Energy From Space

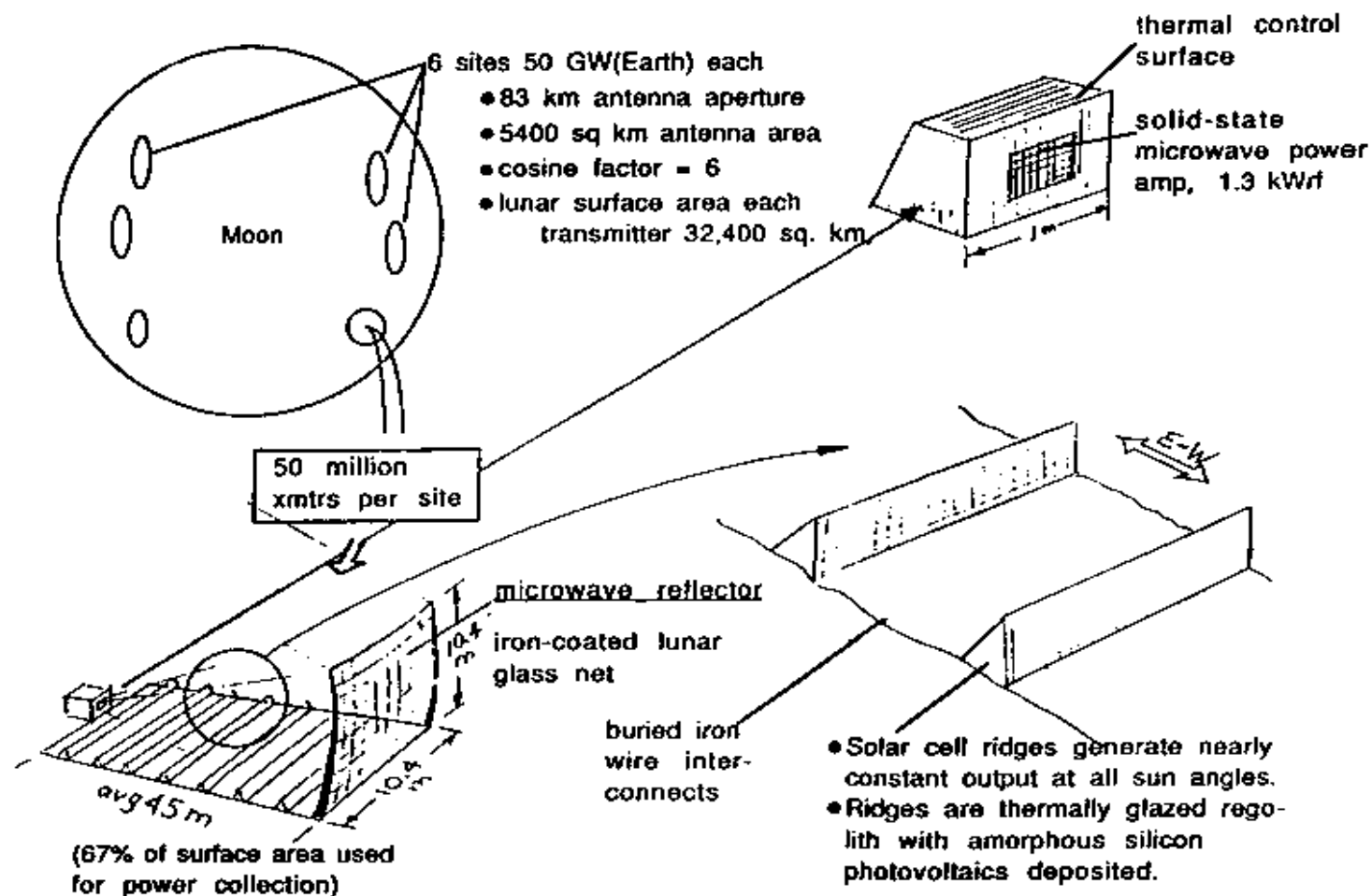
## Solar Power Satellites

- Pioneered by Peter Glaser
- Originally proposed 1968
- Subjected to scrutiny by NASA, DOE, and National Academy of Sciences

## Lunar Power System

- Pioneered by David Criswell
- Originally proposed 1985
- Subjected to analysis by NASA and U. of Houston

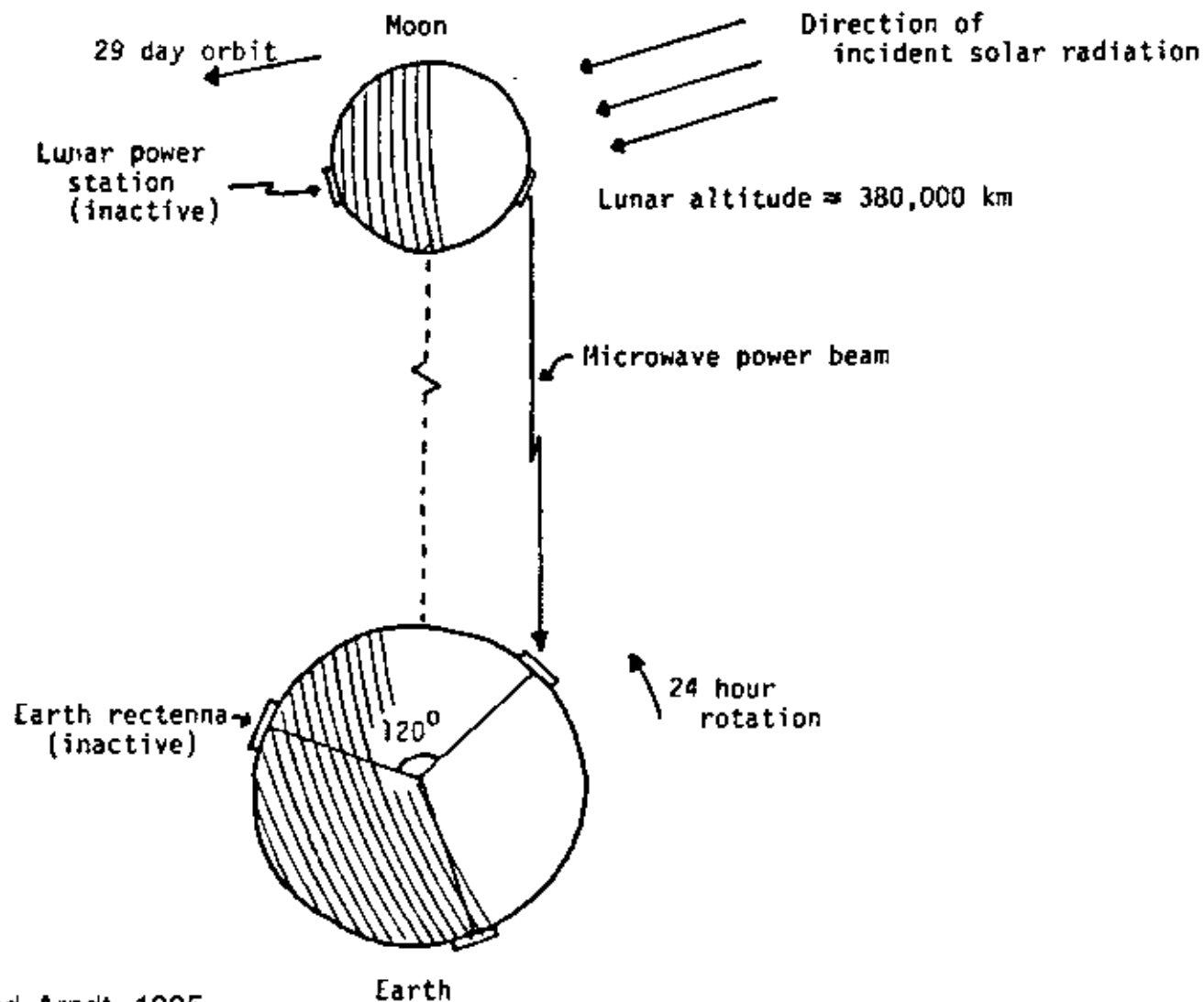
# Lunar Power System Concept



# Concerns About the LSPS

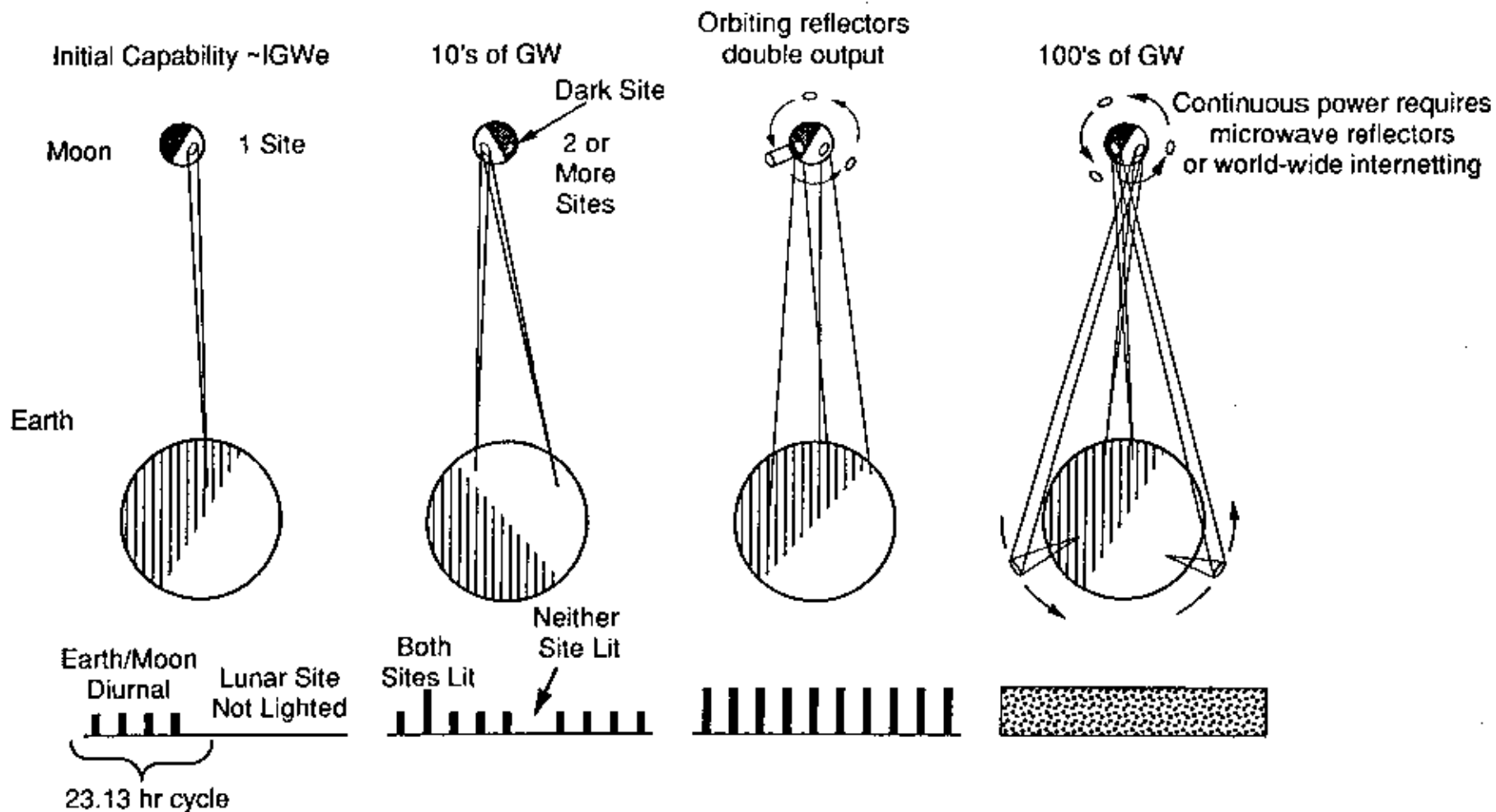
- Lunar base only receives solar energy 50% of the time (need multiple collection bases)
- Rotation of the Earth means multiple receiving stations are required
- Fixed collectors do not collect optimum solar flux
- Si cells are about 1/3 the efficiency of GaAs cells
- Larger transmitting distance requires bigger transmitting antenna

# The Rotation of the Moon and Earth Requires Multiple Collection and Receiving Units



After Kerwin and Arndt, 1985

# Evolution of Lunar Power System to Continuous Baseload Power Requires Auxiliary Reflectors at Earth and Moon





## The Collection Area of a Lunar Power System Must be Much larger Than That for a SPS

- Factor of 2 because of day/night cycle
- Factor of 2 because of fixed oblique solar incidence angle
- Factor of 3 because Si converters are 1/3 the efficiency of GaAs.

The total area of LSPS is  $\approx 12$  times that of a SPS

# Transmitting Antenna Sizing Criteria

Coherent Microwaves

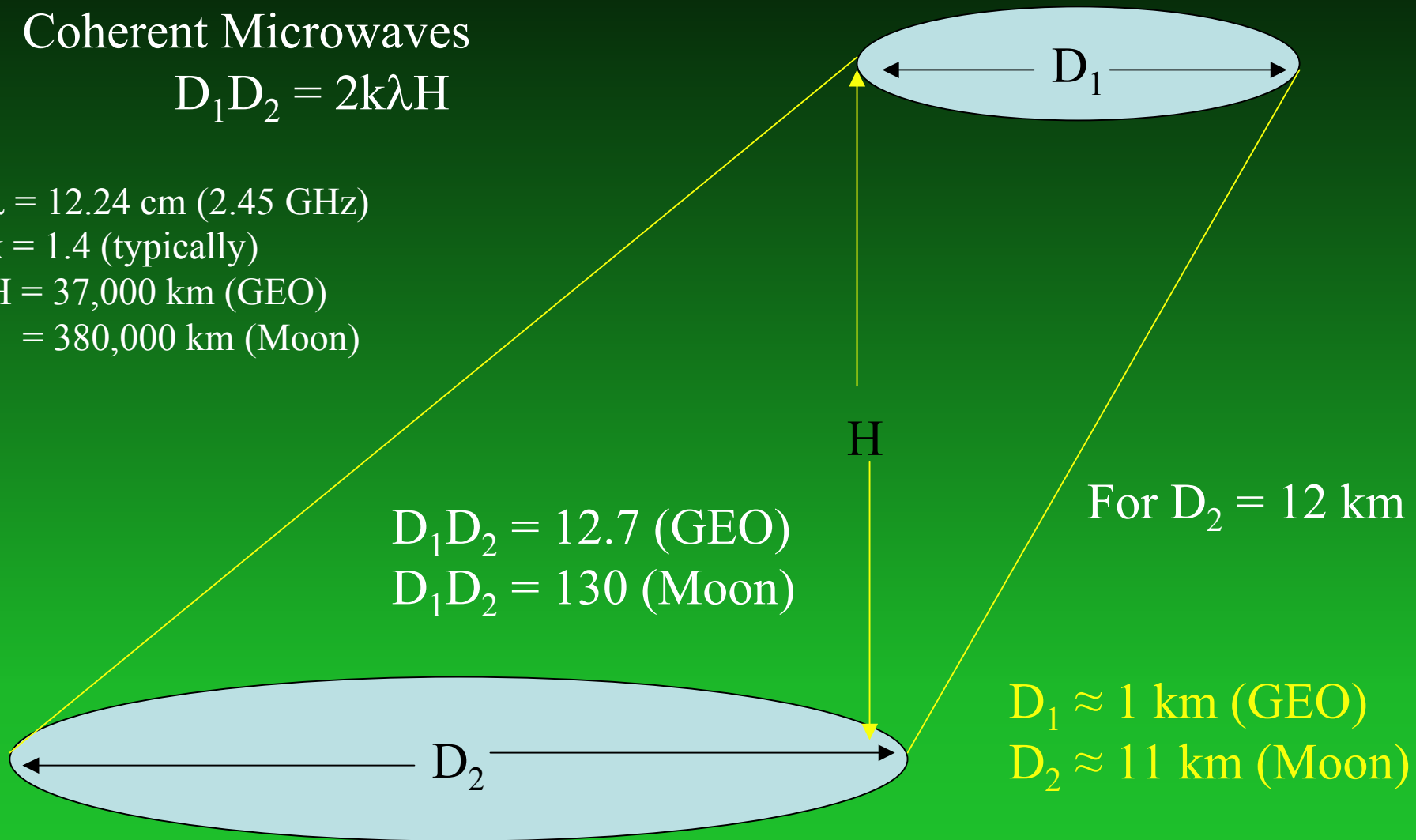
$$D_1 D_2 = 2k\lambda H$$

$\lambda = 12.24 \text{ cm (2.45 GHz)}$

$k = 1.4 \text{ (typically)}$

$H = 37,000 \text{ km (GEO)}$

$= 380,000 \text{ km (Moon)}$



$$D_1 D_2 = 12.7 \text{ (GEO)}$$

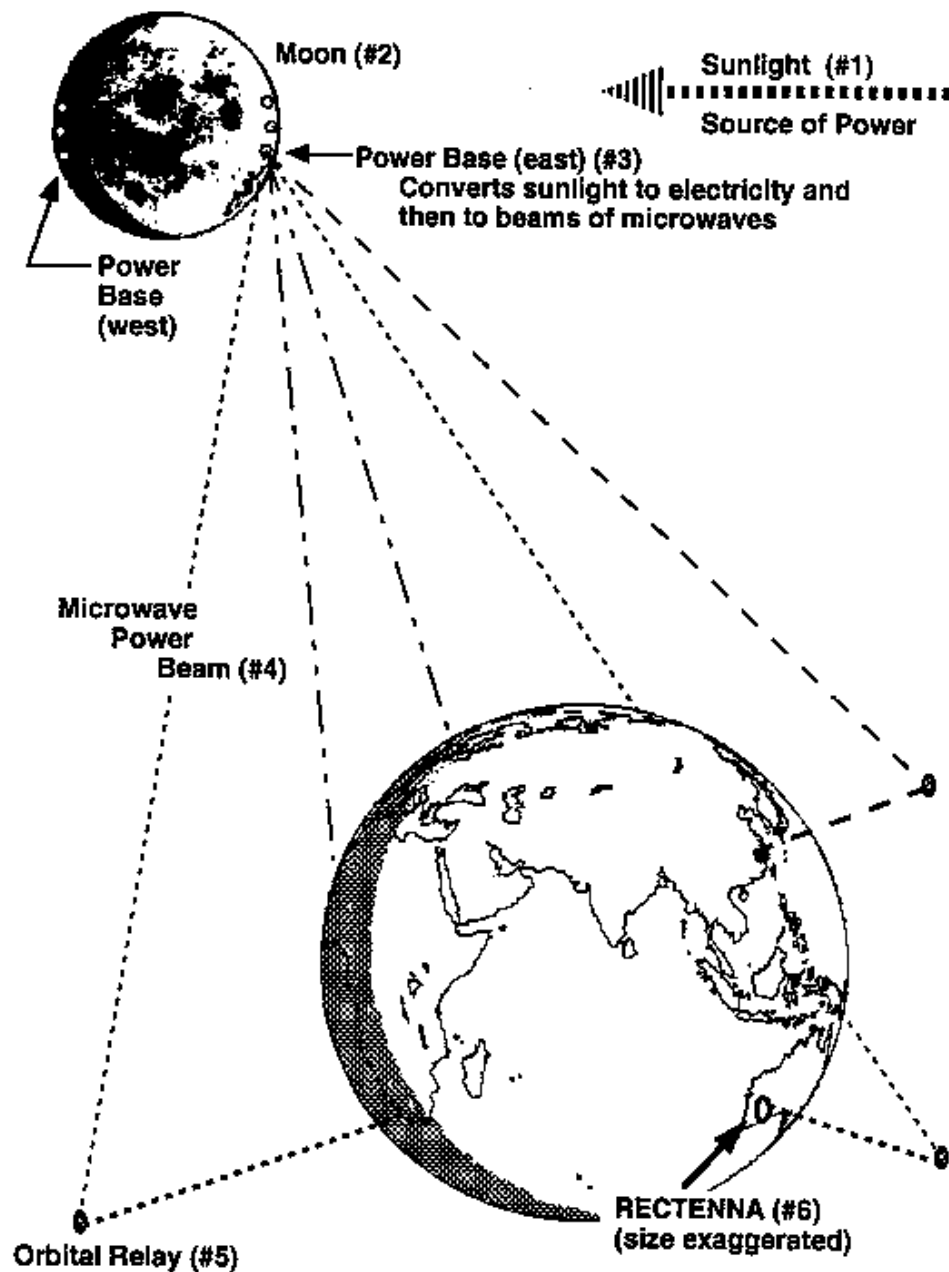
$$D_1 D_2 = 130 \text{ (Moon)}$$

For  $D_2 = 12 \text{ km}$

$D_1 \approx 1 \text{ km (GEO)}$

$D_2 \approx 11 \text{ km (Moon)}$

# LSP SYSTEM



# Lunar Solar Power Reference Design- 20,000 GW<sub>e</sub>-(Criswell 1996)

World Installed capacity -1999-3,180 Gwe

Illumination of one cell (geometry)	32%
Fill factor (ground cell area/base area)	20%
Solar cell efficiency	10%
Collection efficiency	90%
Electricity to microwave	85%
Transmission to Earth	73%
Earth atmosphere transmission	98%
Rectenna collection efficiency	89%
Microwave power conditioning	88%
Electric grid conditioning	97%
<b>Overall efficiency for 1,368 W/m<sup>2</sup> (electricity to Earth grid/lunar solar watt)</b>	<b>0.266%</b>

## **Lunar Solar Power Reference Design- 20,000 $\text{GW}_e$ - (Criswell 1996)- Continued**

- For a 0.266% overall efficiency and to produce 20,000  $\text{GW}_e$ , one would need to cover 15.3% of the lunar surface.
- Number of bases required would be 12 (pairs)



# Lunar Solar Power Reference Design- 20,000 GW<sub>e</sub>- (Criswell 1996)- Continued

• Total regolith handled	2 billion tons/y
• Lunar equipment	
mining	12, 739 tons
processing	428,481 tons
support	48,171 tons
• Transport to Space	
from Earth (ave. for 10y ramp-up)	70,314 tons/y
from Earth (parts, consumables, > 10 y)	172,687 tons/y
from the Moon (LO mirrors)	336,181 tons/y
• People	
on the Moon	5,000
in LLO	395
in LEO	486

# Lunar Solar Power Reference Design- 20,000 GW<sub>e</sub>-(Criswell 1996)- Continued

• Costs (\$1995 billions)	
Space	4,926
Earth (mainly rectennas)	17,040
Total	21,966
• Capital Costs	1,098 \$/kW <sub>e</sub>

It is Claimed That the Total mass Investment for  
Electricity from Solar Energy is Less Than for  
Terrestrial Systems

	Tons/GW <sub>e</sub>
Terrestrial Thermal Power Systems	310,000
Terrestrial Photovoltaic	430,000
Lunar Solar power System	52,000

After Criswell and Thompson, 1996

# What if the SPS was Constructed of material from the Moon?

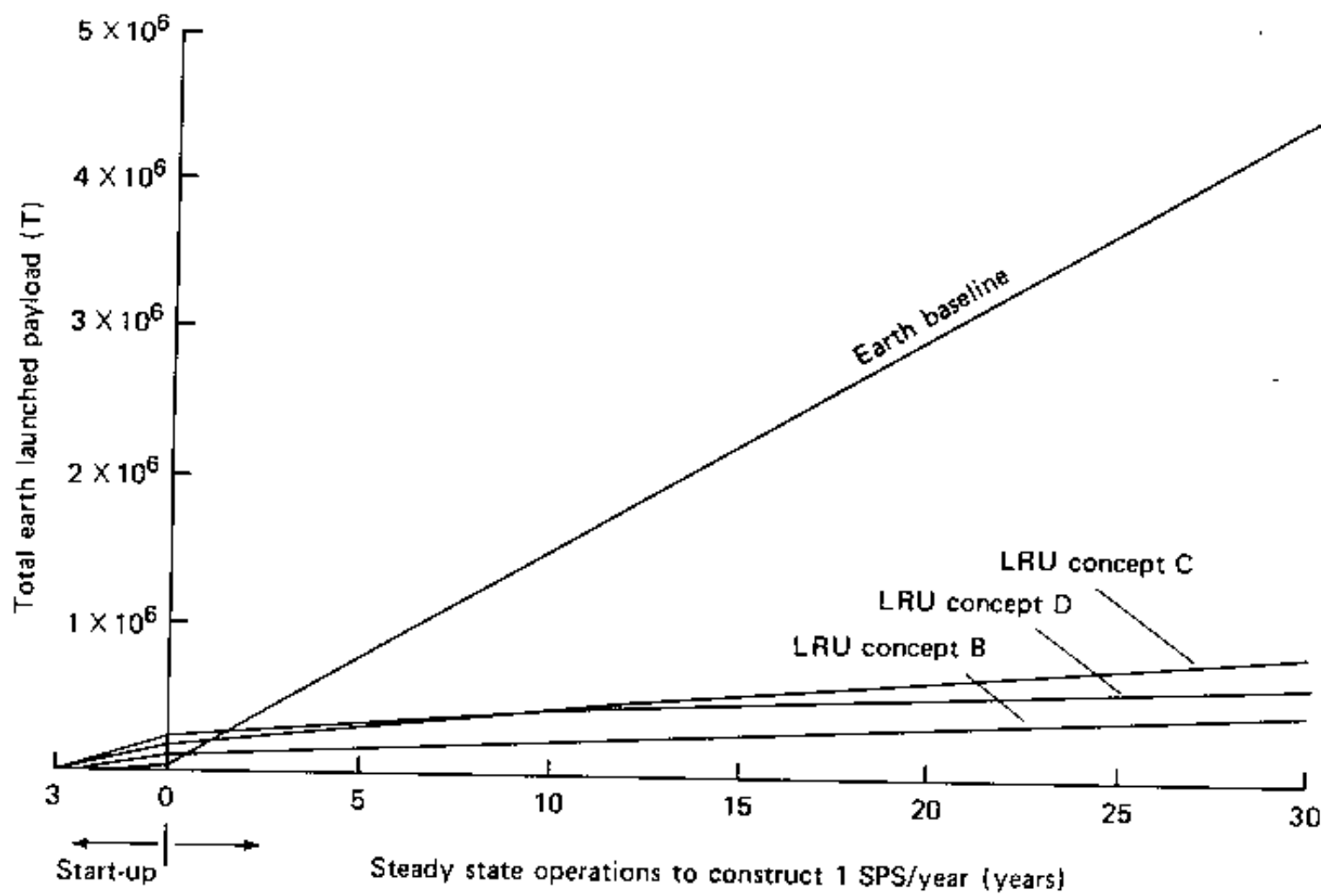
- First proposed by G. O'Neill, 1974
- General Dynamics and MIT completed the analysis in 1979
- Conclusion was that 90-96% of the SPS mass could come from the Moon
- Would require mass drivers on a Lunar base to send material to a Space Manufacturing Facility





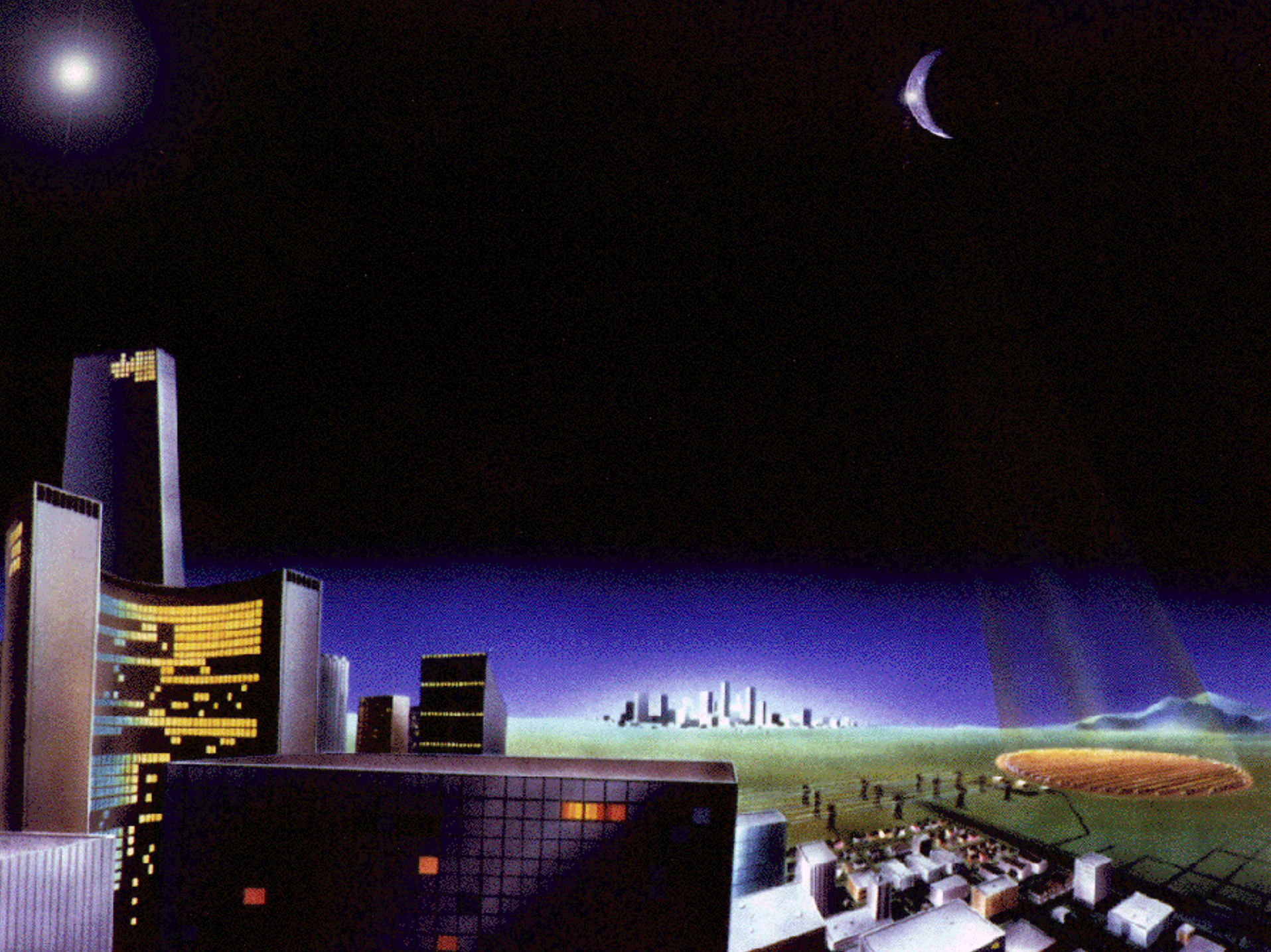


# Using Lunar Resources Can Greatly Reduce the Mass Launch Rates From Earth



After G. E. Marvniak and G. K. O'Neill. 1993



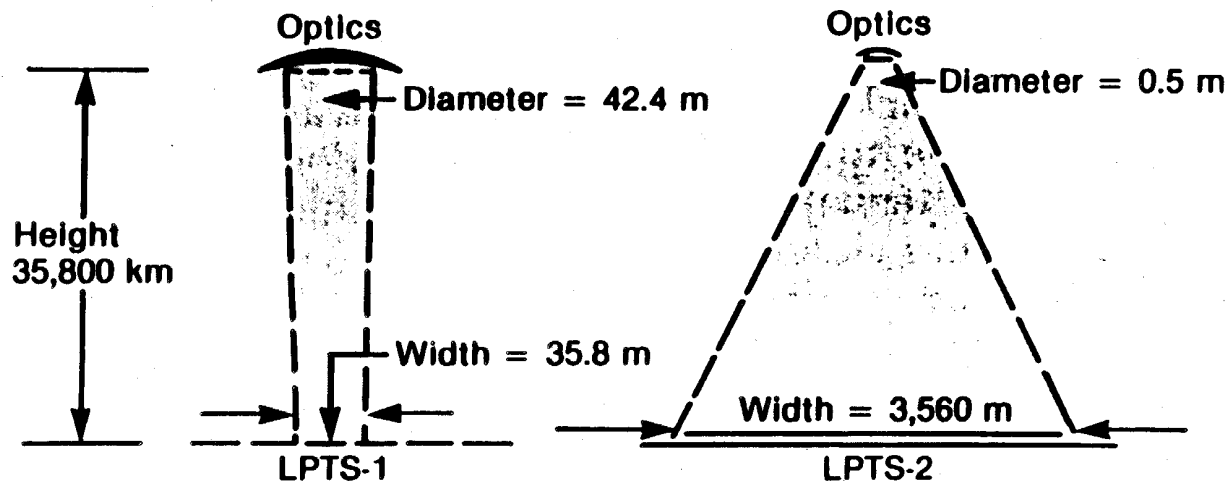




# Conclusions-LSPS

- The Lunar Solar Power Satellite would require a substantial return to the Moon.
- The LSPS would only make sense if it produced most of the projected electricity use in the World.
- A major factor in the ultimate COE from the LSPS will be the launch costs from Earth

# Solar Power Satellites Could Also Use Lasers For Energy Transmission



SOURCE: Claud N. Bain, "Potential of Laser for SPS Power Transmission," report No. R-1861, PRC Energy Analysis Co., DOE contract No. EG-77-C-01-4042, September 1978.