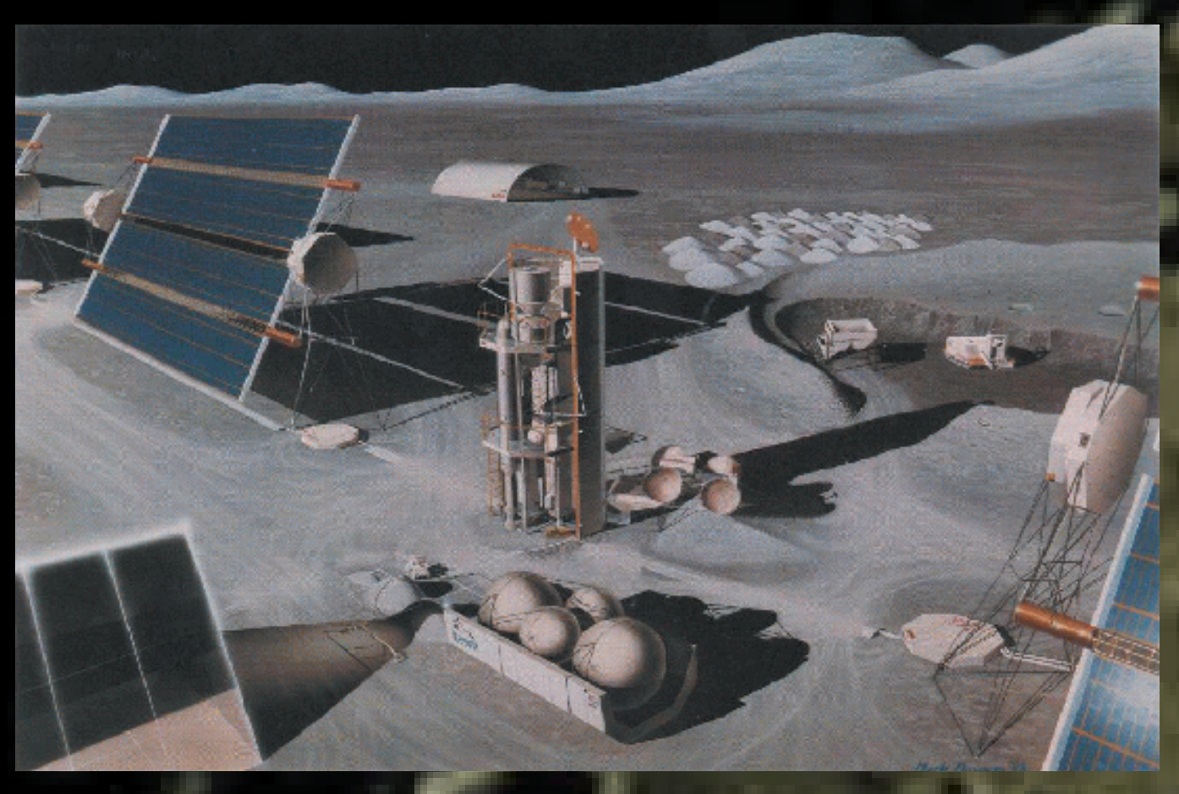
Moonlight Project

The Moonlight Project was awarded with a Special Prize in the 1st Aurora Student Design Contest (Barcelona, 8th-9th September 2003)

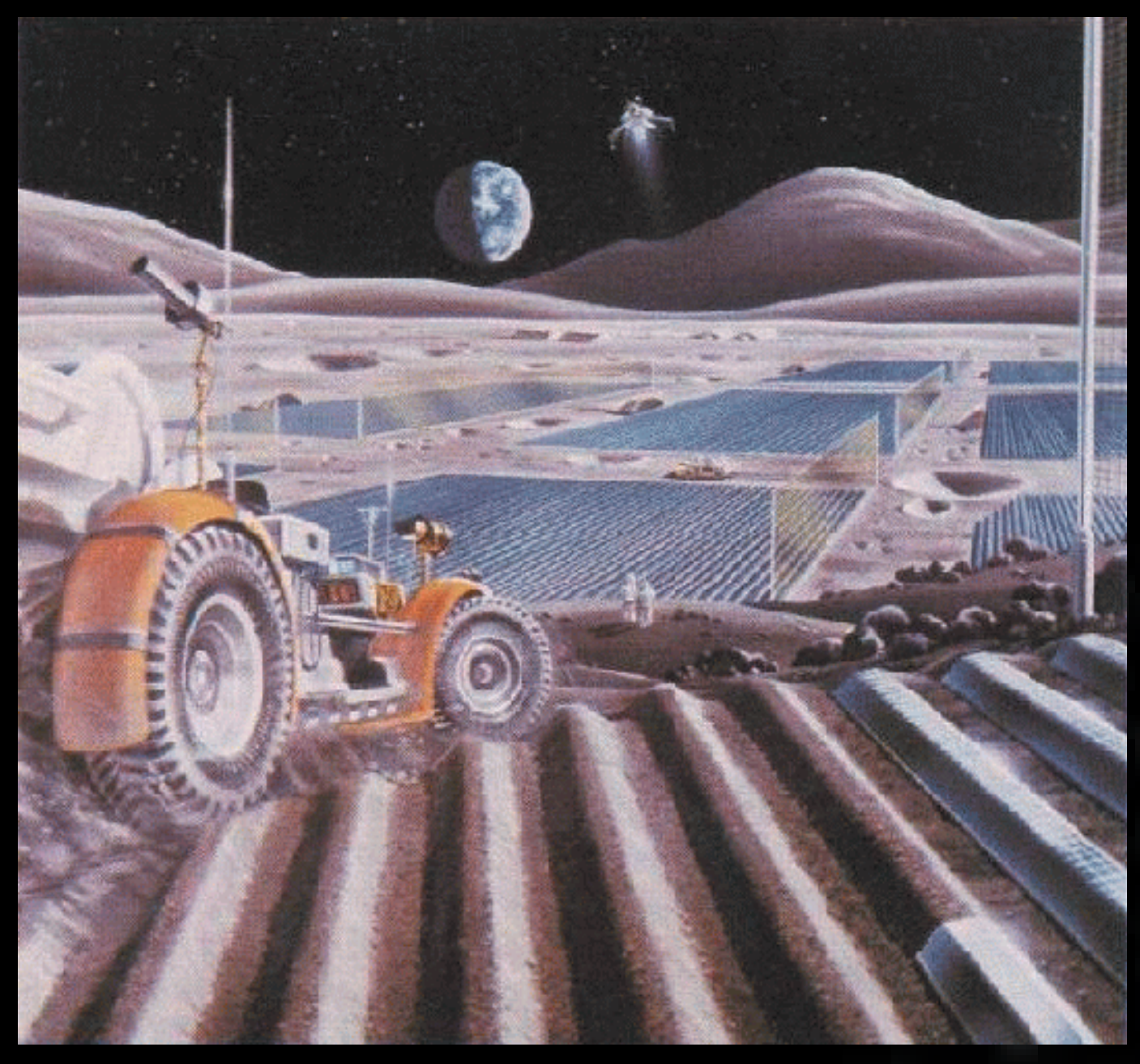
In collaboration with:

Rationale



The establishment of a permanent base on the surface of the Moon is one of the next steps in space exploration. One of the reasons this hasn't been made yet is the extreme hostile environment found there: lack of atmosphere, omnipresence of regolith, lethal solar radiation, wide thermal amplitude,...

Because of this hostile environment, it seems logical that the first lunar colony is run by robots. But even a robotic colony will encounter many difficulties once established on the Moon. Most of these difficulties are related to lunar night.



As the rotation period of the Moon is almost 28 days, lunar night results to be 14 days long in non-polar areas. This fact becomes a problem if we plan to establish a base that depends on solar energy. In addition, the temperature of the surface of the Moon can drop to -170°C in shadow areas, while illuminated points can reach +130°C. This thermal amplitude has negative effects on the equipment, specially on batteries and fuel cells. If we also consider that in order to carry out surface operations we'll need artificial light, the power issue becomes critical.

The situation we just described would be a lot easier if sunlight was available on the Moon like on Earth. Surprisingly, this has a relatively simple solution: to place a satellite in orbit around the Moon that reflects sunlight to the lunar surface.

Background

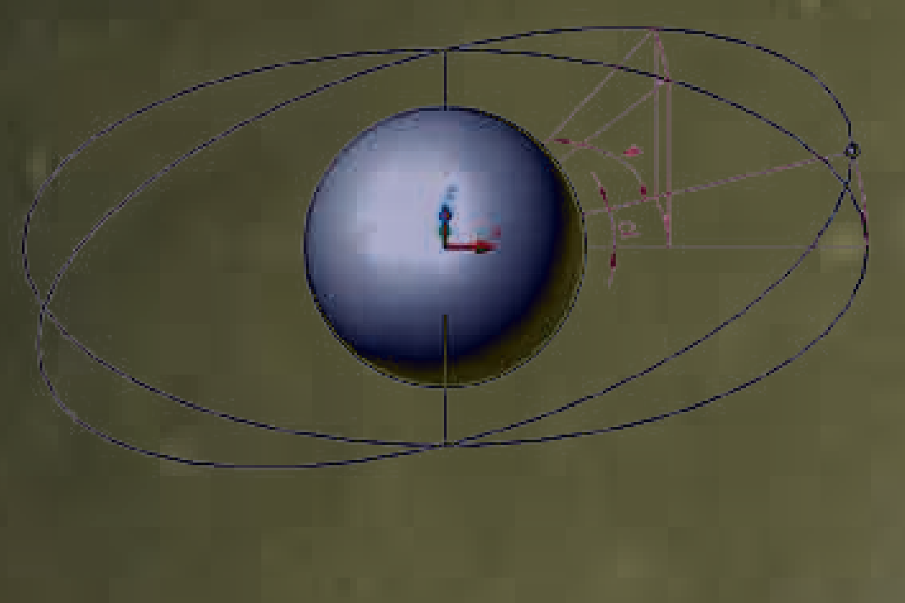
The idea of using a space reflector to provide light at night isn't new. In the decade of the nineties the Russian Space Agency carried out the Novey Svet project. The goal of this project, whose name means "new light", was to develop the technology to deploy and control large space reflectors to illuminate some polar regions on Earth.

The Novey Svet project included a series of experiments called Znamya. Znamya 2 was conducted in 1993 and consisted in the deployment of a 20 meter solar-sail. It was followed by Znamya 2.5 in 1999, but this time the 25 meter reflector failed to deploy due to the drift of the Progress M-40 spacecraft. The Znamya 3 experiment was scheduled for the year 2001, but it was canceled after the Znamya 2.5 failure. The Novey Svet project was abandoned and it hasn't been undertaken again.

Scenario selection

Before starting to design our satellite, we have to determine in which scenario we are going work. The scenario of a satellite is defined by its orbit parameters. The optimal scenario will be the one that answers the following question: "Which orbit around the Moon provides the best illumination conditions for an hypothetic base on its surface?".

1) The orbit problem



The orbit problem is divided in two parts:

- determining the orbit parameters in function of the revolution period
- calculating of the movement of the satellite around the Moon

2) The optic problem

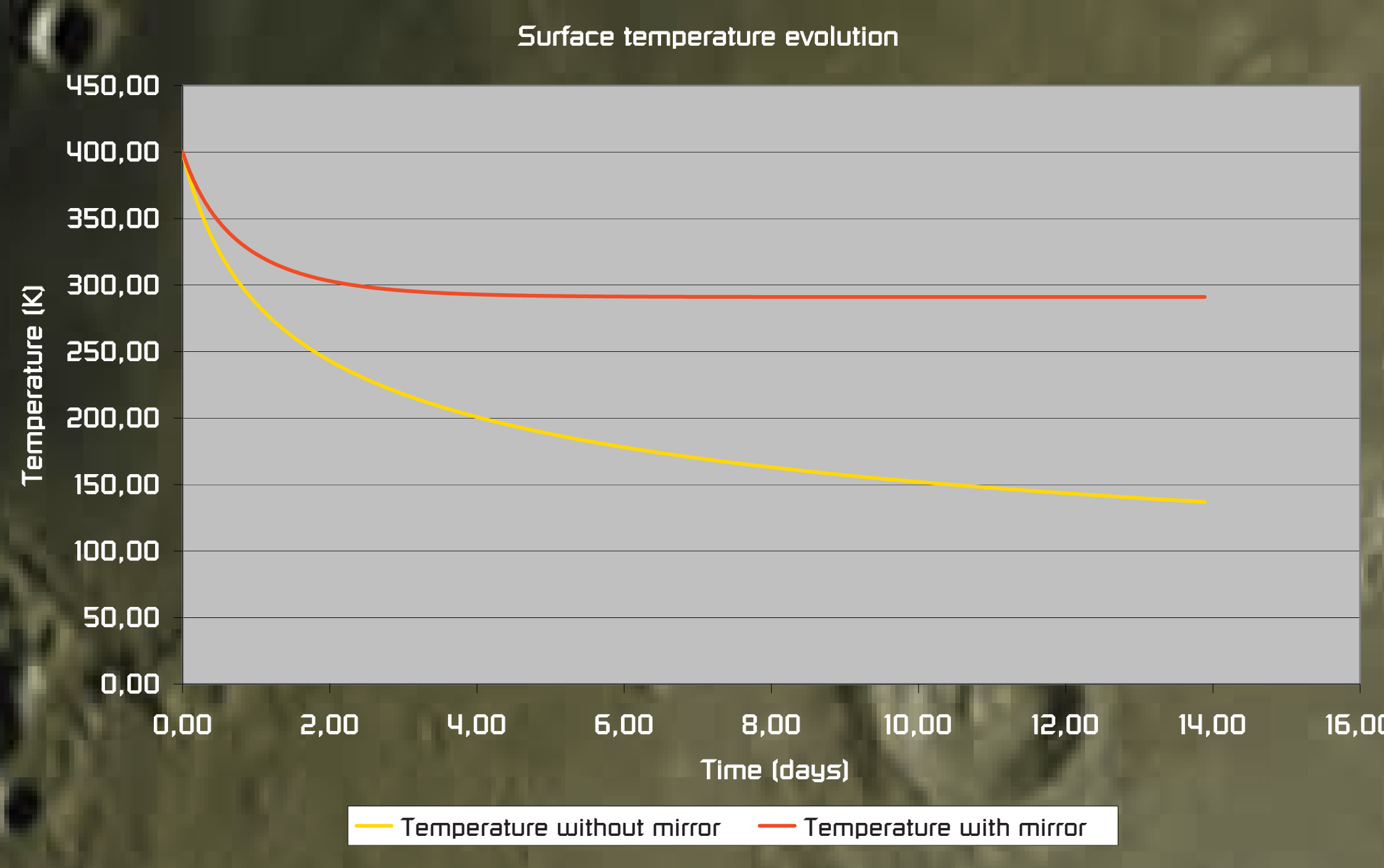
The optic problem consists in estimating the gain that we can obtain in terms of artificial illumination with a given orbit. We must emphasize that artificial illumination is not always possible, but it is determined by the position of the satellite and the base on the Moon. In order to determine if it is possible or not to reflect light from the Sun to the base first we need to establish the conditions of artificial illumination. These conditions are three:

- *condition of light:* the first condition to use artificial illumination is that no natural illumination is available.
- *condition of visibility:* the second condition to use artificial illumination is that the satellite has direct visibility of the base on the surface of the Moon.
- *condition of reflection:* the third condition to use artificial illumination is that the satellite is able to redirect light in the proper direction from the Sun to the base.

3) The thermal problem

The thermal problem consists in finding the evolution of the temperature of the surface of the Moon in function of the incident power. Then we can determine the temperature T at any given time t.

The graph next to this illustrates this temperature evolution.



4) Scenario simulation

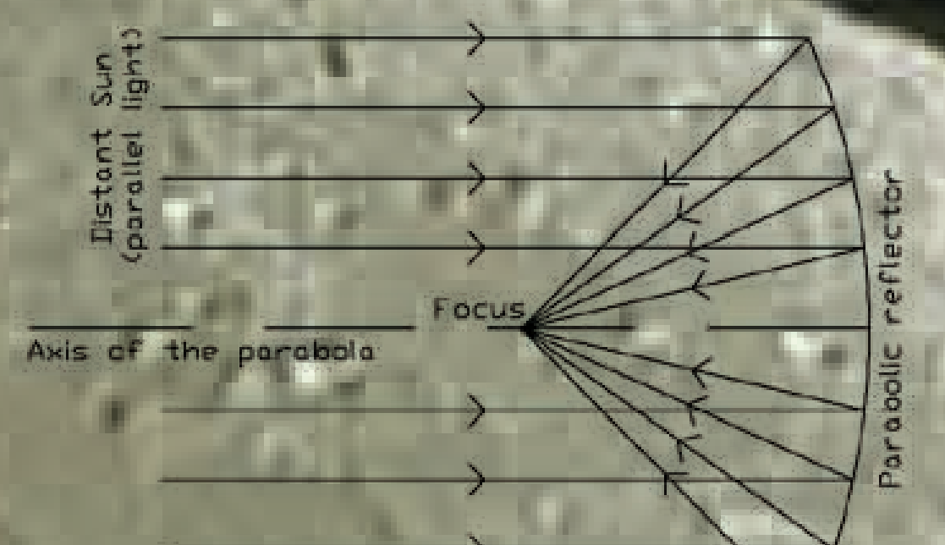
We can see that greater revolution periods provide longer illumination conditions. However, the higher the satellite orbit is, the lesser power we are able to reflect to the Moon due to light dispersion. Thus we need to find an equilibrium between reflected energy and illumination period.

We think that 12-hour orbit gives the best compromise between reflected energy / illumination period.

Revolution period	Satellite altitude	Satellite inclination	Artificial illumination	Total illumination	Gain
3h	701 Km	45,44°	1.616 hours	5.162 hours	19,35%
6h	2.133 Km	26,67°	2.416 hours	5.767 hours	33,34%
12h	4.406 Km	16,43°	2.727 hours	6.022 hours	39,26%
24h	8.014 Km	10,26°	2.935 hours	6.166 hours	42,57%
48h	13.742 Km	6,44°	3.071 hours	6.253 hours	44,58%
72h	18.547 Km	4,91°	3.125 hours	6.286 hours	45,34%
96h	22.836 Km	4,05°	3.158 hours	6.317 hours	46,06%

Large Deployable Reflector (LDR)

The Large Deployable Reflector consists in a reflective surface with a paraboloid shape. The paraboloid (as a revolved parabola) has the property to reflect all rays parallel to the axis to one point called focus.



To avoid the Znamya 2.5 deployment problem, we have based the design of our satellite in a rigid but still lightweight structure. The reflector itself is based on NASDA's ETS-8 large deployable antenna experiment. Each LDR module contains 7 hexagonal 2 meter side panels. These panels are composed of a thin reflector rigidified with ribs that deploys like an umbrella.

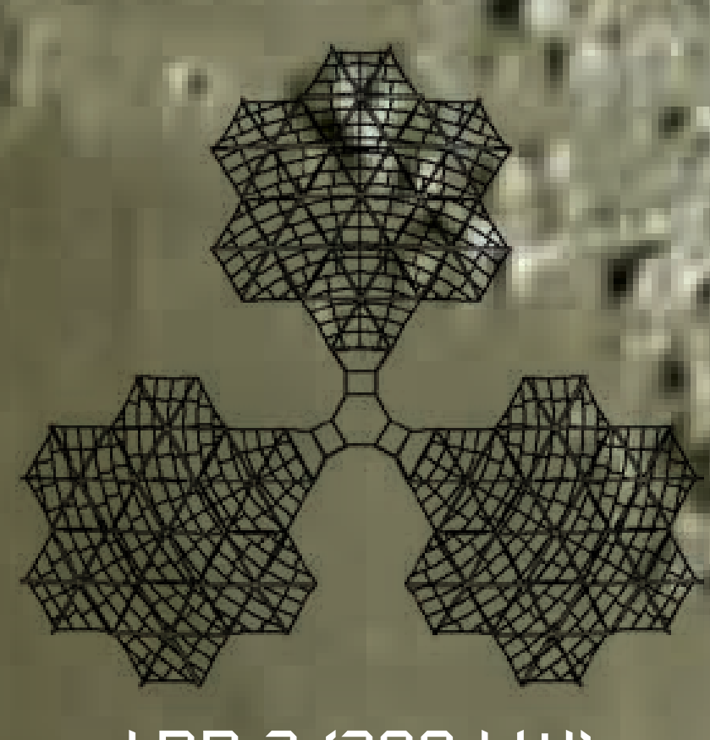
LDR - Deployment Phase 1

LDR - Deployment Phase 2

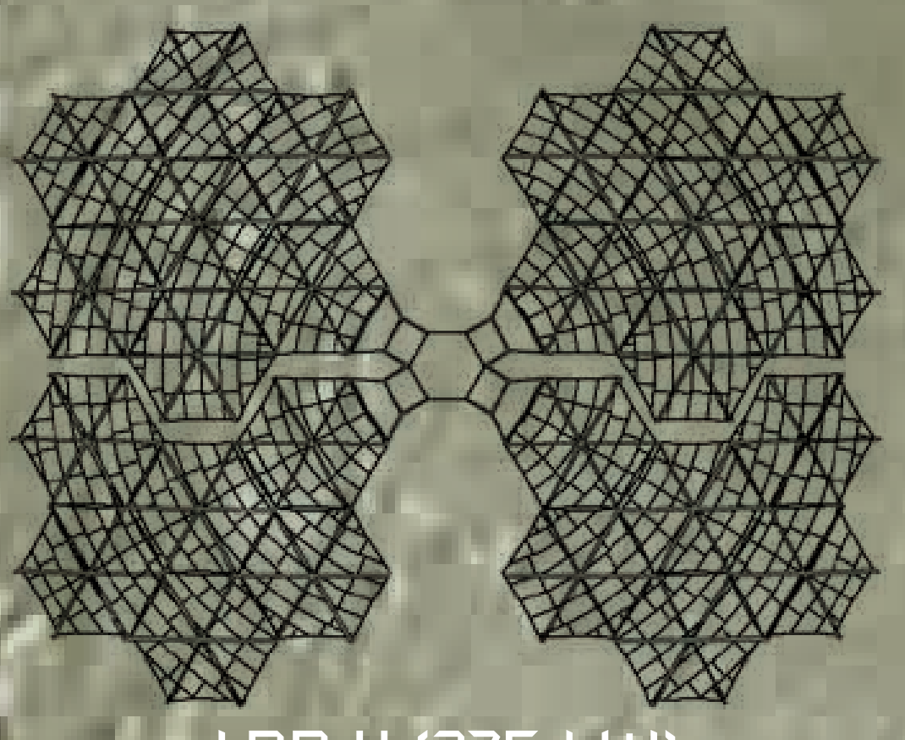
LDR - Deployment Phase 3

LDR - Deployment Phase 4

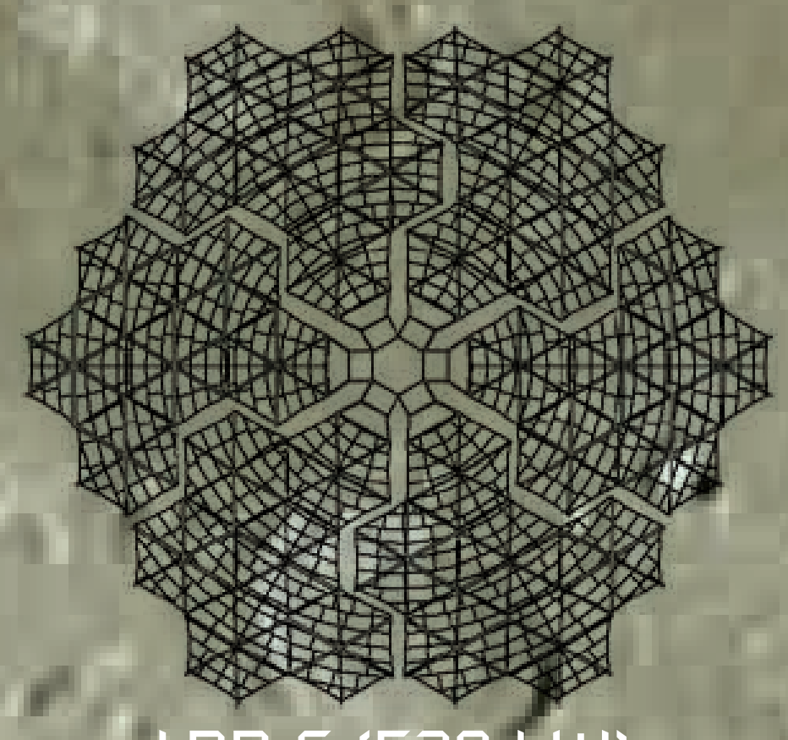
Each LDR module provides near 75 square meters of reflecting surface. Considering that the solar constant is 1350 kW/m², this is equivalent to 100 kW of reflected power.



LDR-3 (300 kW)



LDR-4 (375 kW)



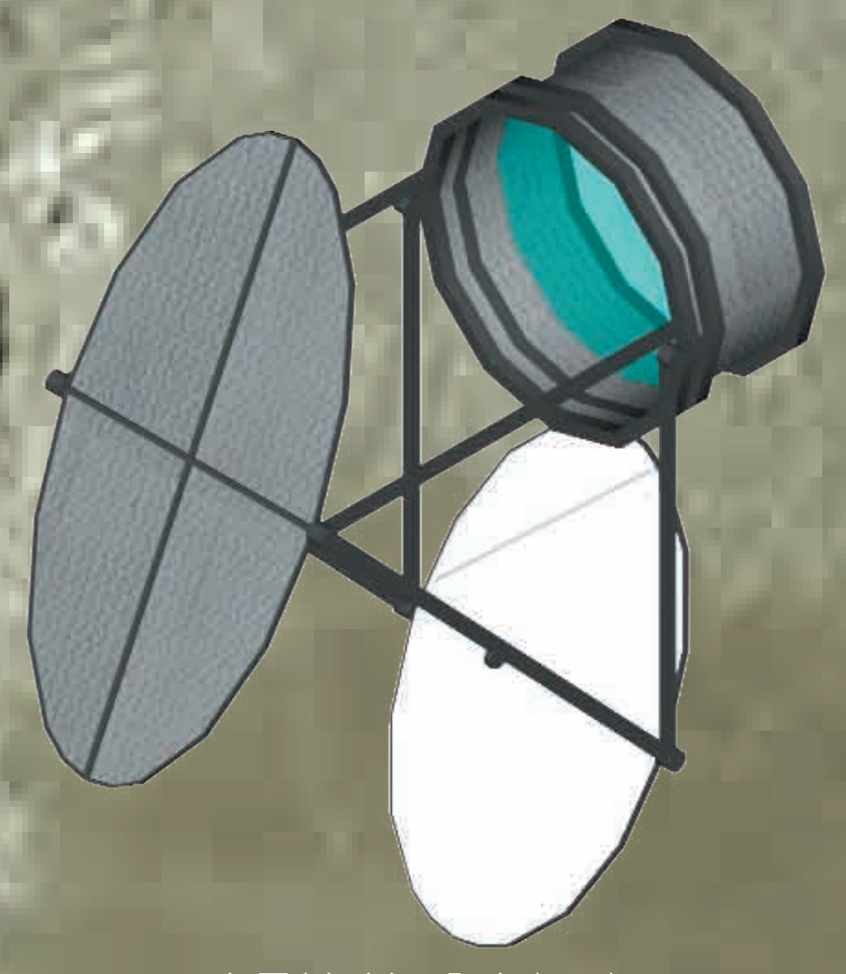
LDR-6 (520 kW)

Light Processing Unit (LPU)

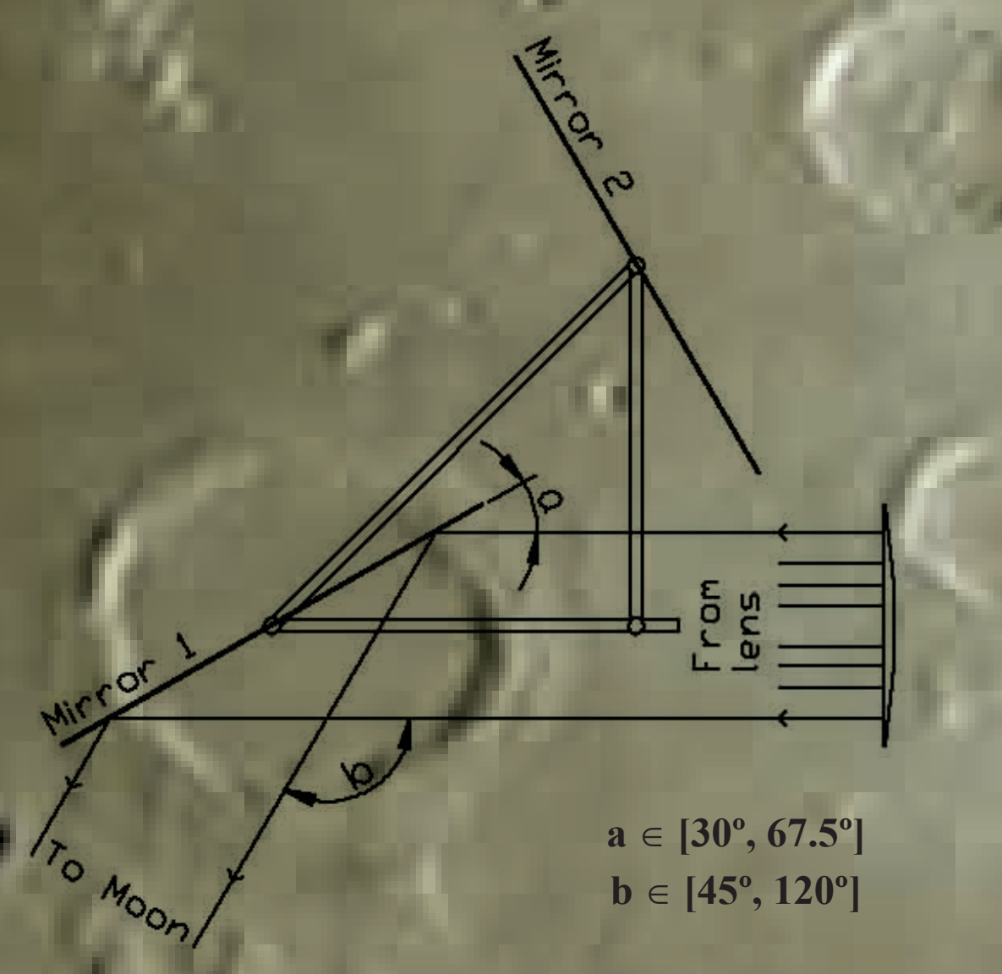
The Light Processing Unit is placed near the focus of the LDR. The LPU is composed of two elements:

- a converging lens that restores parallelism to the rays.
- two rotating mirrors that can combine to reflect light in any angle between 45° and 180°.

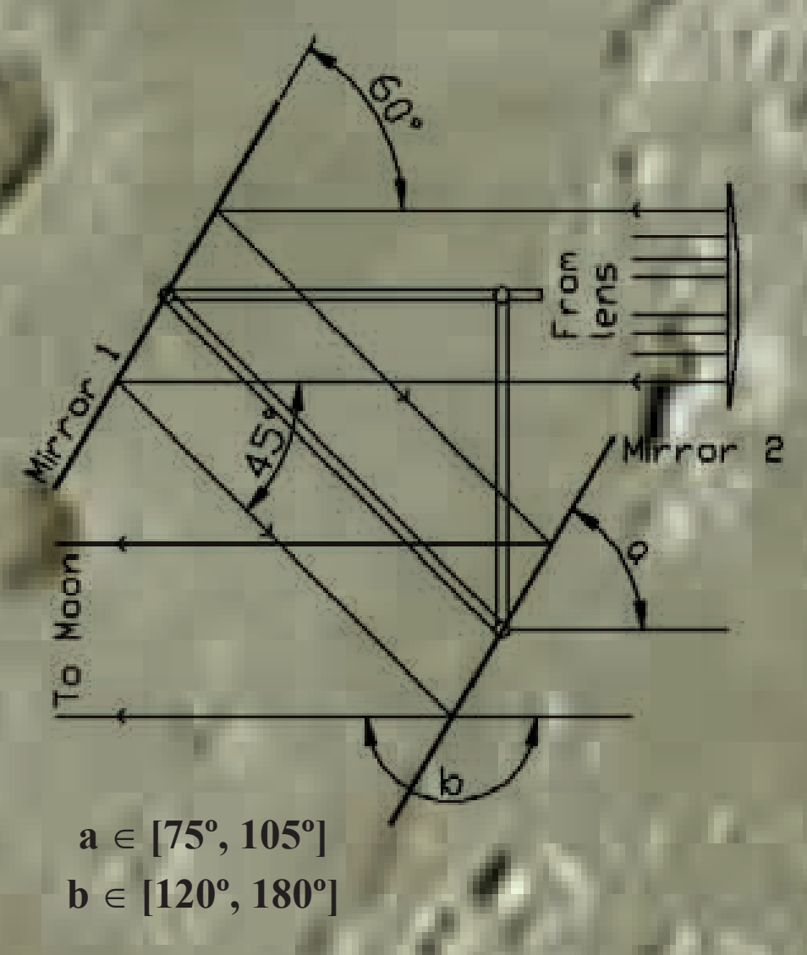
The LPU itself can rotate 360° in the satellite main axis. This gives it the ability to direct light in any direction of space between ±135°.



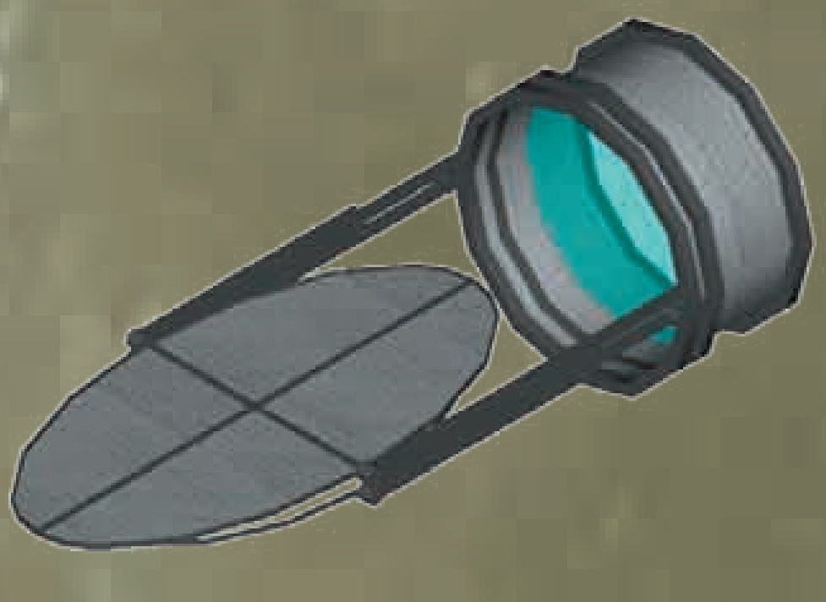
LPU Unfolded



$a \in [30^\circ, 67.5^\circ]$
$b \in [45^\circ, 120^\circ]$

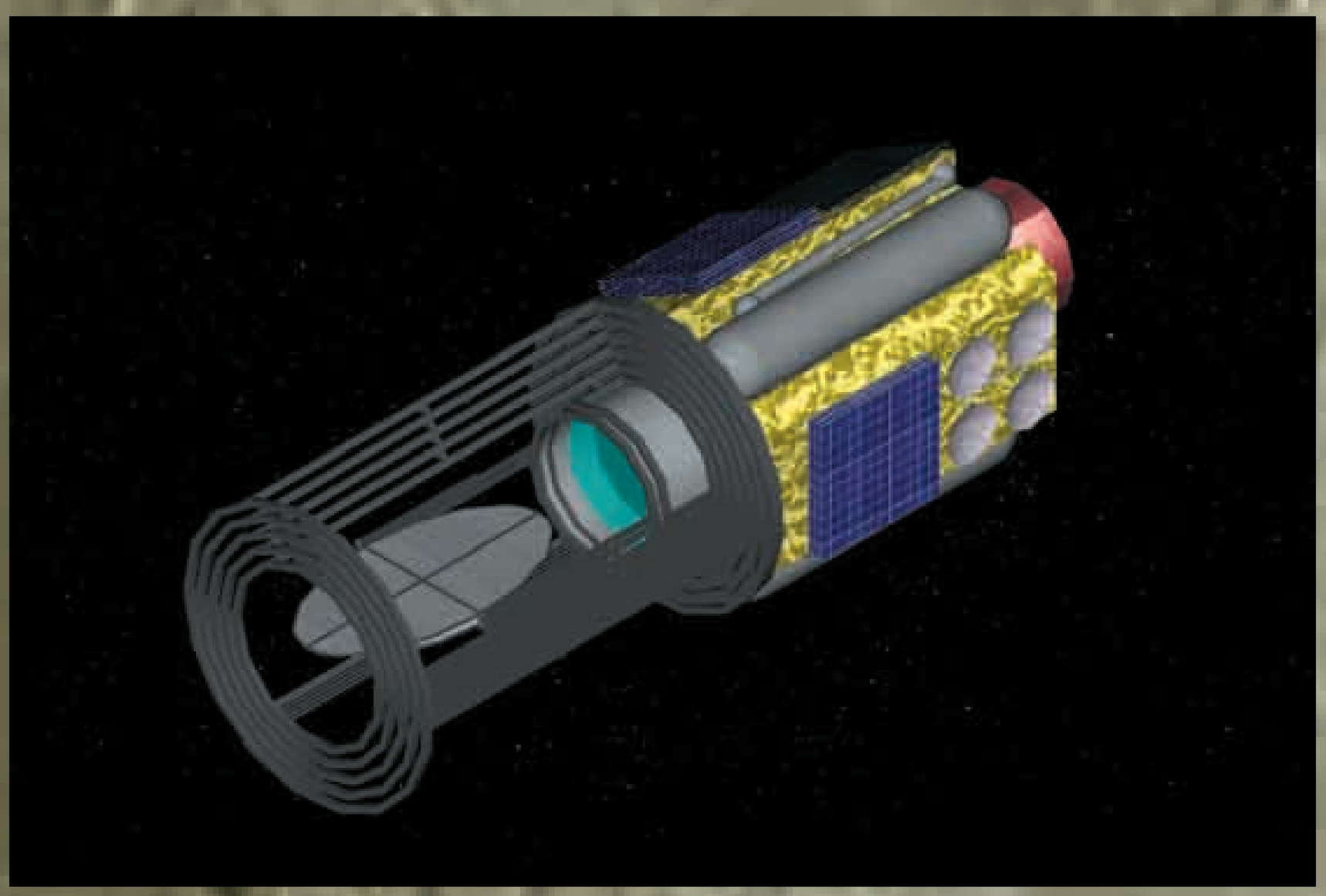


$a \in [75^\circ, 105^\circ]$
$b \in [120^\circ, 180^\circ]$

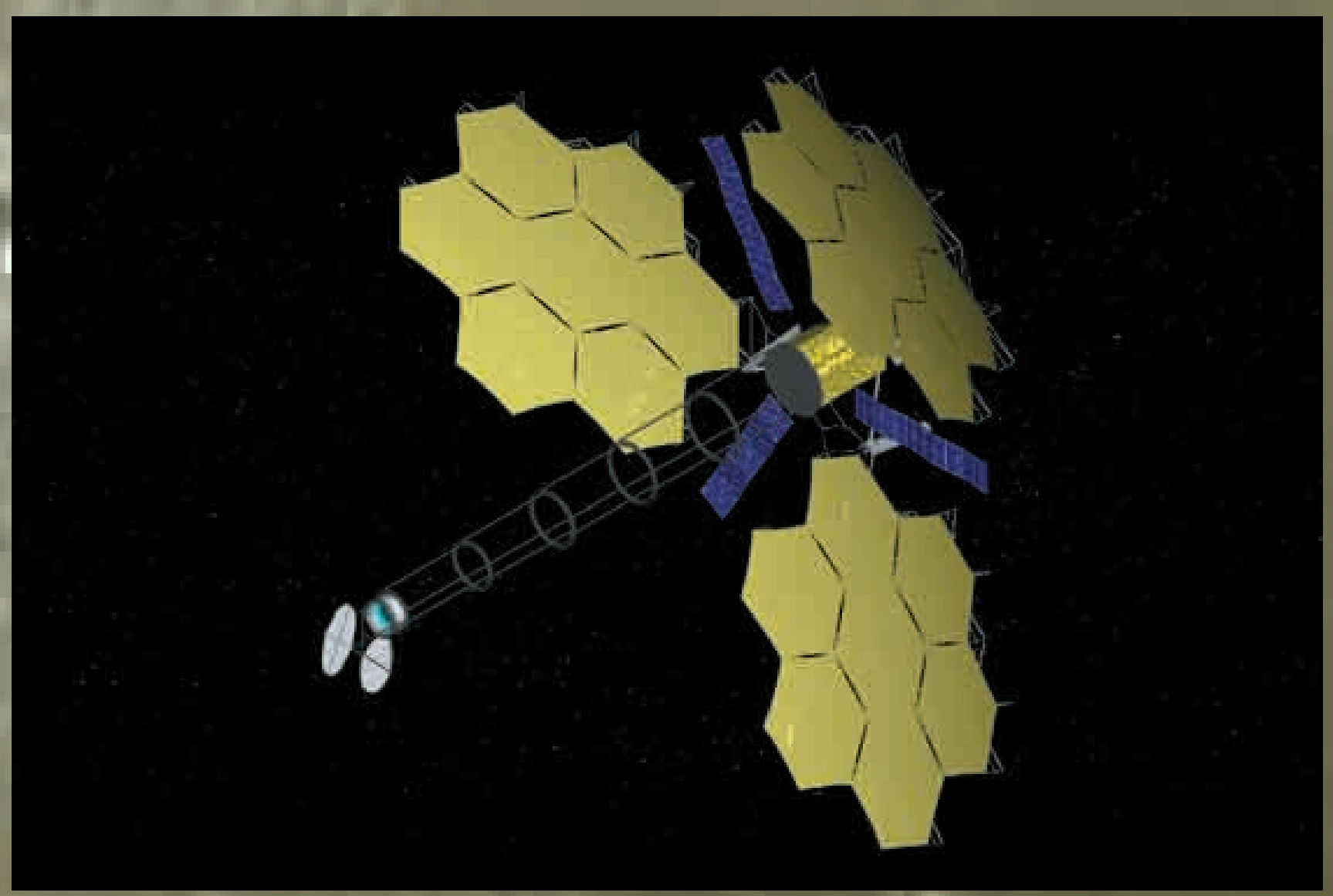


LPU Folded

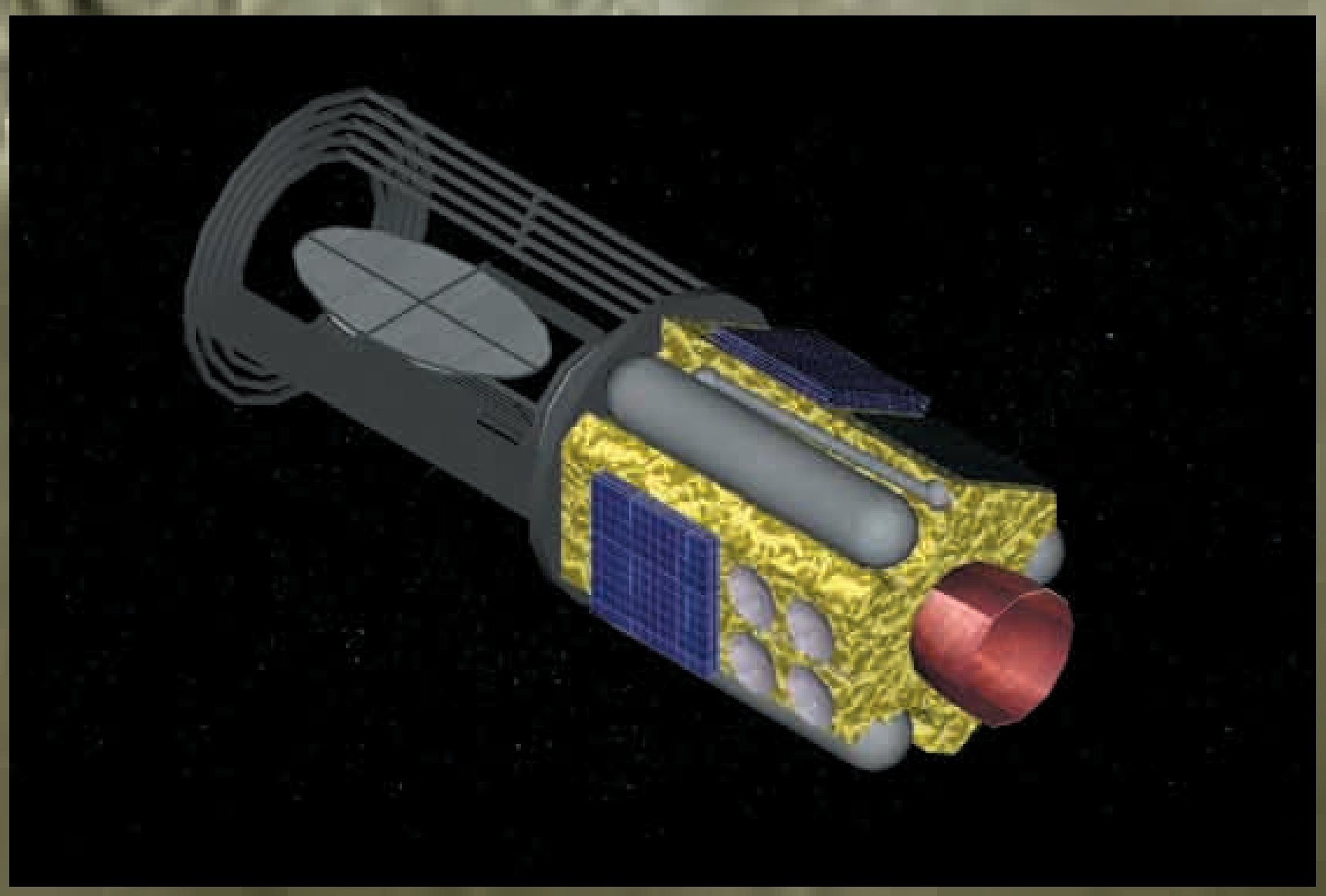
Final design



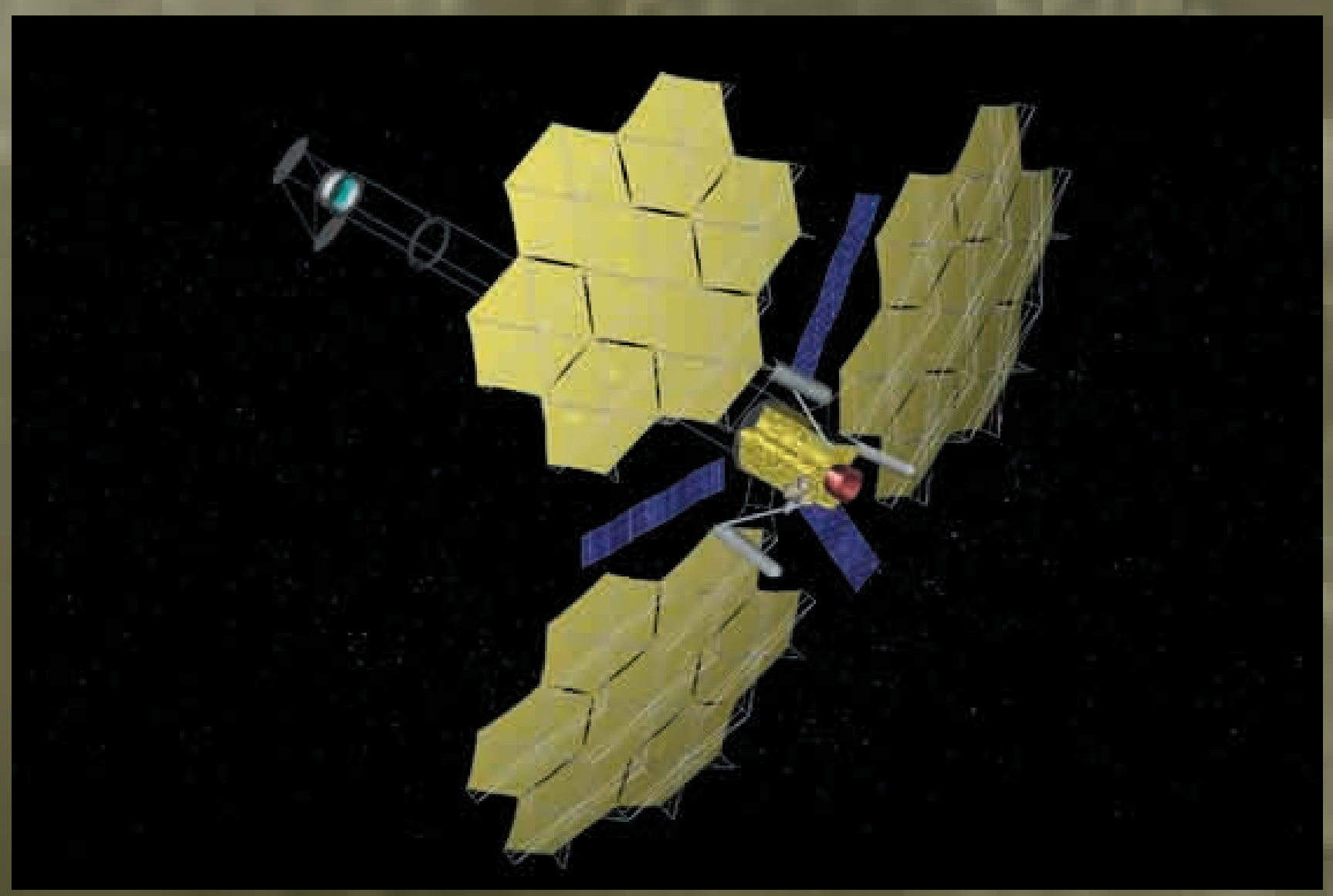
MOM Folded (forward view)



MOM Unfolded (forward view)



MOM Folded (backward view)



MOM Unfolded (backward view)

The Moonlight Team

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