Special Equipment Which Uses Concentrated Solar Light for Earth Protection against Asteroids-Advanced Design and Technology

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Abstract

This paper presents the advanced design and technology of special equipment (here called SECSLEP) which uses concentrated solar light for destruction of dangerous asteroids.

According to Einstein General Theory of Relativity, elliptical orbit of any cosmic body is rotating around the ellipse center (i.e. the perihelion of orbit is moving continuously). On the other hand, the trajectories of cosmic bodies are permanently affected by the gravity of other cosmic bodies which are also moving. In the case of asteroids (which have relatively small masses), orbit changes can be important leading to the danger of collision with Earth. At this moment our civilization has practically no efficient and reliable mean to destroy or divert dangerous asteroids form their collision trajectory with Earth. The idea of SECSLEP is a new one. It is a 'canon' which uses concentrated solar light for deviation or vaporization of dangerous asteroids. This idea was presented for the first time by the authors of this paper in 2014. The present paper presents an advanced design and technology of such equipment. Mainly, this equipment is composed of one large and one small parabolic mirror having the same focal point and coincident axes. The mirrors are positioned face to face i.e., the concave side of the large parabolic mirror is oriented to the concave side of the small parabolic mirror. The light rays coming from Sun are focalized by the large parabolic mirror in its focal point. The light rays are then reflected by the small parabolic mirror (which has the same focal point as the large parabolic mirror) in parallel rays along the parabola axis. The beam of concentrated light having diameter 'd' equally to the diameter of small parabolic mirror passes through one hole having diameter 'd+' placed in the center of large parabolic mirror. An articulated mirror tube is fixed on the convex side of the large parabolic mirror by means of a spherical articulation. This mirror tube is used for directing of the concentrated light beam toward the asteroid. This equipment is practically an 'electromagnetic cannon' having power of the order of terawatts. It can vaporize for example an iron asteroid of 100 tones in seconds. If asteroid is too heavy, the concentrated light beam can vaporize only locally the asteroid matter and the reaction force created by vapors will deflect the asteroid from the collision trajectory with Earth. Due to the high speed of light, this type of canon can hit the asteroid when it is still at a great distance from Earth. This canon can hit the asteroid an indefinite number of times until the asteroid is deviated or vaporized. This equipment can be built on Earth orbit and then placed on a solar orbit as Kepler telescope. Canons having relatively small power (several thousands of kW or more) can be used for feeding with high electromagnetic power the magnetoplasmadynamic thrusters of spacecraft traveling in solar system, particularly to Mars. In this way, intense space traffic within the solar system becomes sustainable. Other application is debris from near Earth space. Debris are vaporized or melted for faster disintegration in atmosphere, feeding of LEO satellites with additional power for increasing the period of operation or Mars terra-forming.

This paper evaluates the equipment mass, power requirements and heat transfer for small and large parabolic mirrors having various diameters. The paper presents advanced design of mirrors based on hexagonal, square or triangular cells and new technologies for manufacturing reflecting mirror foils (plates). The resistance structure of mirrors is made from multiple triangular, hexagonal or square cells built from tubes made from titanium or graphite fiber composites. The reflective material of mirrors may be gold plated foil/plates made of graphite fiber. The gold has a high reflectivity and the graphite had a high heat transfer coefficient and strongly dissipates heat in space through radiation. In this way, both parabolic mirrors are efficiently cooled. The gold plated foil is stretched on the hexagonal, square or triangular cells of mirrors. The gold plated plates are directly applied on the cells.

This equipment which will operate near Earth will be subject to natural bombardment with particles of so called unorganized matter of Universe (meteors, meteorites, interplanetary dust and gas, solar

wind, cosmic radiation). The effect of unorganized matter on equipment integrity and operating capacity is also analyzed in order to evaluate the equipment period of active operation in space. The advanced design and technology presented in this paper forms the basis for the development of designs and technology of operational equipment which will be placed in space for Earth protection against asteroids, cleaning debris from space and feeding future LEO satellites and spacecraft with high power electromagnetic energy or terra-formation of planet Mars.

Key words: anti asteroid, magnetoplasmadynamic thruster, spacecraft, LEO satellite, debris removal

Nomenclature:

d, distance from Sun, [m]
e_c, emissivity, dimensionless
E, energy, [J]
E_e, irradiance in proximity of Earth, [W/m^2]
E_s, irradiance at 0.1 AU distance by Sun, [W/m^2]
M, mass, [kg]
P, power, [W]
r, radius, [m]
R, reflectivity, dimensionless
t, temperature, [^{o}C]
T, absolute temperature, [K]
c, heat capacity, [J/kg·K]
c_f, heat of fusion, [J/kg·K]
c_v, heat of vaporization, [J/kg·K]
σ, Stefan-Boltzmann coefficient for black body radiation, [W/m^{2}K^4]
δ, thickness, [m]
λ, thermal conductivity coefficient, [W/m·k]

1. General

Currently, there is no reliable or efficient system for destroying or deflecting asteroids or comets on a collision trajectory with Earth. Such a system is necessary because it seems the danger of asteroid impacts exceeds any anticipation. For example, the trajectory of asteroid Apophis will pass below the orbits of LEO satellites when on April 13 2029. It is not known when it will return and how close will to Earth will get then.

According to Einstein General Theory of Relativity, the elliptical orbit of any cosmic body is rotating around the ellipse center (i.e. the perihelion of orbit is moving continuously). On the other hand, the trajectories of asteroids are permanently affected by the gravity of other asteroids and planets. Due to these reasons asteroids can be involved in collisions causing sudden trajectory changes. Asteroids have relatively small masses and may suffer significant orbit changes leading to the danger of collision with Earth. According to estimates, there are over 150 million asteroids in our solar system. Most of them are grouped in the asteroids belt (fig.1) but some have trajectories passing close to Earth (fig.2). WISE (Wide-field Infrared Survey Explorer) (NASA) revised the estimated population of near-Earth asteroids. The infrared-sensing telescope performed the most accurate survey to date of a slice of this population as part of project called NEOWISE. This allowed the science team to make new estimates of the total numbers of the objects in different size categories. NEOWISE observed more than 500 objects larger than 100-meters which can be considered medium to large-size asteroids. Near-Earth asteroids smaller than these sizes were not studied and near-Earth comets will be analyzed at a later time.

For the largest asteroids, larger than 1,000 meters, NEOWISE data revises the total population down to 981 from a prior estimate of about 1,000. While this is not a dramatic difference, the findings show that NASA has met the goal of an initial survey of near-Earth asteroids agreed with Congress in 1998, calling for the detection of at least 90 percent of the largest objects. There are an estimated 911 objects of this size known, which means that NASA has found 93 percent. That leaves roughly 70 such bodies to be found.

Current studies indicate about 19,500 asteroids, instead of the previously estimated 35,000.

The study does not apply to objects smaller than 100 meters, but according to previous studies, there are more than a million in this size range.
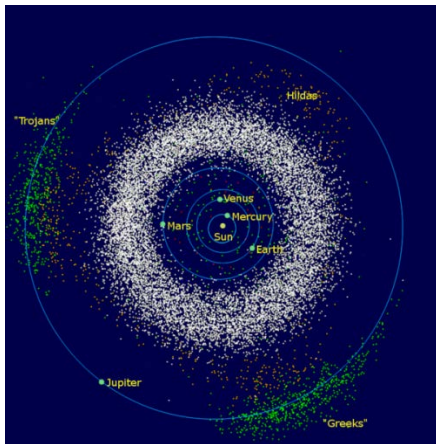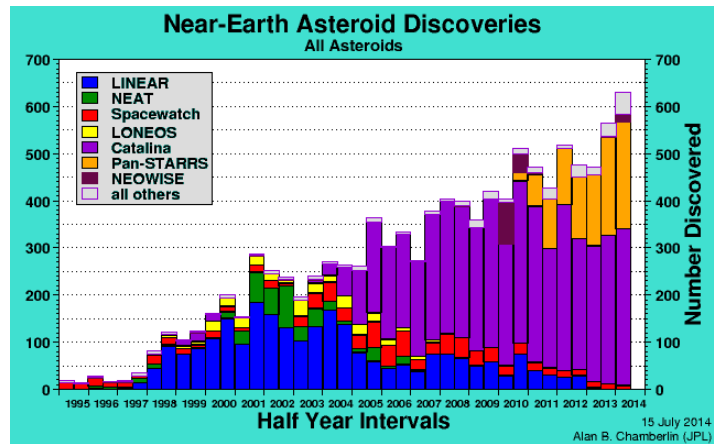

Fig.1-Asteroid belt

Fig.2-Near-Earth asteroids

On the other hand, the number of asteroids which disintegrate in atmosphere is incredible high (see fig.3). This demonstrates again that the problem of asteroids impact is very serious.
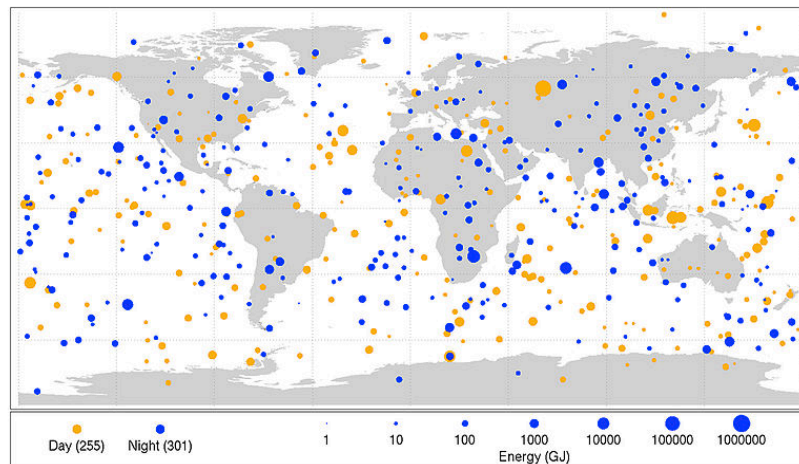

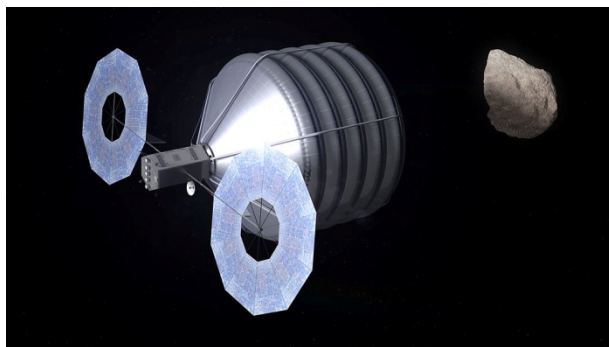Fig.3-Small asteroids that disintegrated in Earth's atmosphere
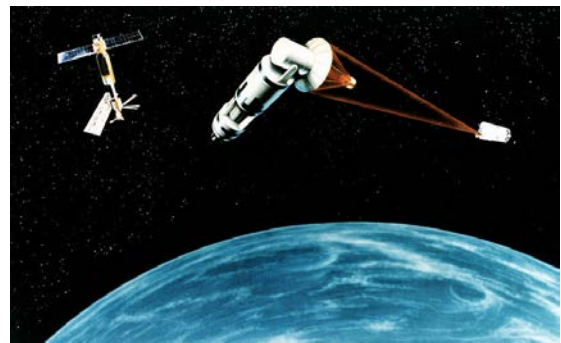

Fig.4-Asteroid capture

Fig.5-Asteroid deflection using a laser ray

In [1] one can see a synthesis of all means of Earth protection against asteroids.

Fig. 4 and 5 present two proposed solutions for Earth protection. One protection method is the capture of small celestial objects (fig.4). Fig.5 presents a solution using a laser powered by a nuclear reactor which deflects the asteroid through forces produced by local vaporization of asteroid material (laser ablation). Other solutions propose asteroid gravity tractor, kinetic impact, nuclear explosive devices etc. It is clear that such solutions are not completely satisfactory. Asteroids can be very large objects. Most of asteroids rotate and are conglomerates formed through accumulation of debris after collisions between other asteroids.

Measurements of rotation rates of large asteroids located in the asteroid belt yielded no upper limit. No asteroid with a diameter larger than 100 meters has a rotation period smaller than 2.2 hours. However, a solid object formed through accumulation of debris after collisions between asteroids should be able to rotate much faster.

Due to these issues, the problem of Earth protection against asteroids has no satisfactory solution yet.

2. Special Equipment Which Uses Concentrated Solar Light for Earth Protection against Asteroids

The Special Equipment Which Uses Concentrated Solar Light for Earth Protection against Asteroids proposed in this paper could preferably be placed on a solar orbit, close to Earth or even on Earth's orbit at a small distance from Earth. The system includes one large and one small parabolic mirror made from thin reflective foils sharing the same focal point. The reflective foils (plates) are stretched on light parabolic supports (the large and the small parabolic supports). The light rays coming from Sun are focalized by the large parabolic mirror onto the focal point. Then the light rays are reflected by the small parabolic mirror as a group of parallel rays which passes through a central hole located in the center of the large parabolic mirror. A mirror-tube attached to the large parabolic mirror by means of an articulation permits the orientation of concentrated light beam as requested by the consumer (fig.6).
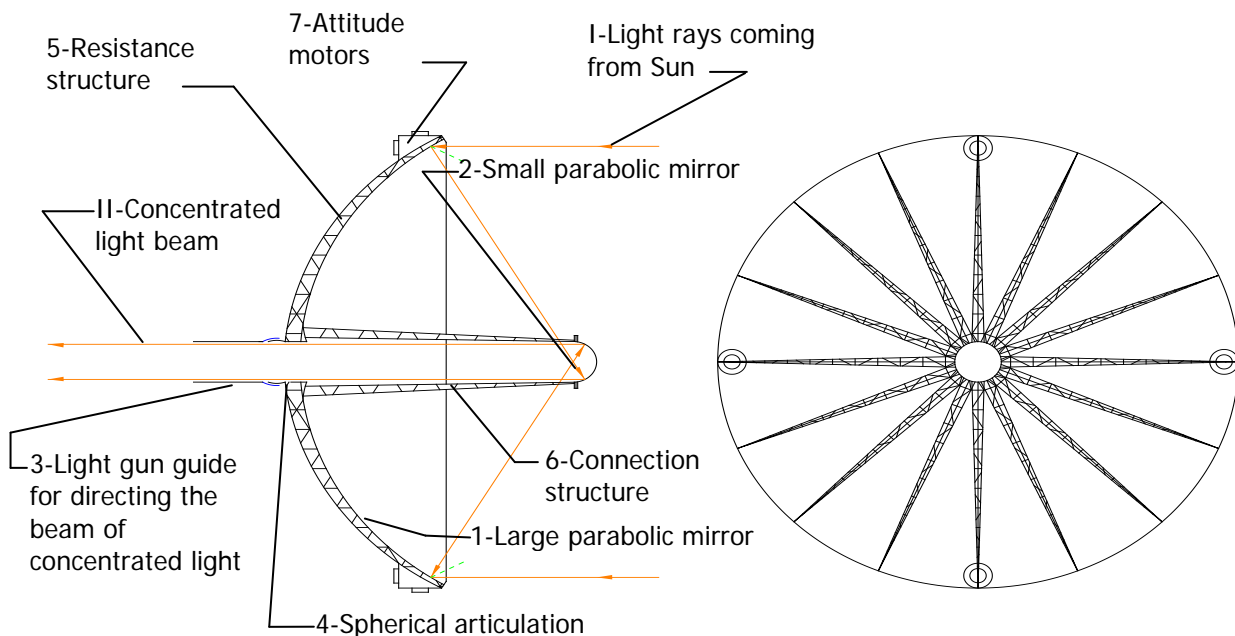

Fig.6-Main design features of SECSLEP

The role and functions of the main components are:
1-The large parabolic mirror. Role: Capture and focus Sun light onto common focal point.
2-The small parabolic mirror. Role: Receives the light rays coming from the large parabolic mirror and reflects them forming a beam of concentrated parallel rays of light

3-The mobile mirror-tube or 'light gun'. This component is linked to the resistance structure of large parabolic mirror with an articulation. Role: Directs the light beam according to the consumer request.

4-Articulation for the 'light gun'. Role: This articulation permits the rotation of light gun around one point as to the consumer needs.

5-Resistance structure. Role: It keeps in position the foil forming the large parabolic structure. The foil is stretched on this structure.

6-Connection structure. Role: Aligns the large and small parabolic mirrors (i.e., the axes of the two mirrors are kept parallel and a common focal point is maintained).

7-Positioning engines. Role: They keep SECSLEP in the correct position

[I-Parallel light rays coming from Sun; II-Concentrated light beam sent to consumer].

For a better understanding of the solution principle, fig.7, presents the photo of a low scale SECSLEP model. Another photo of such equipment can be seen in fig.8. This time, the surfaces of parabolic mirrors are generated by lines.
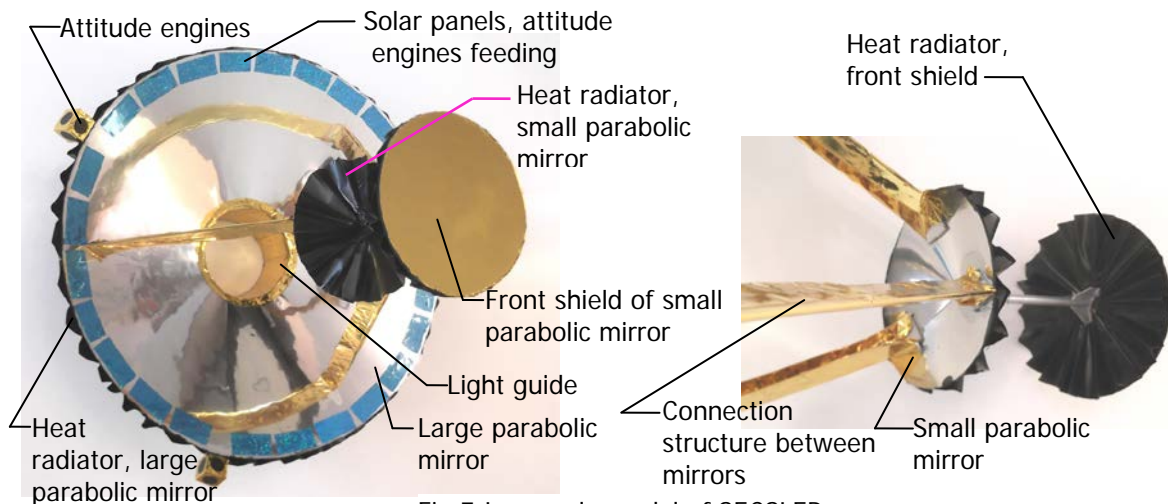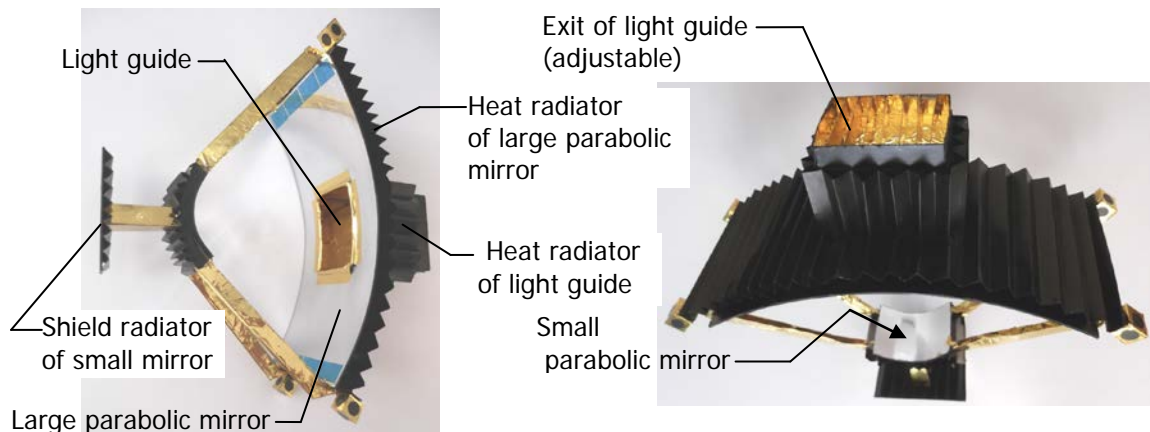

Fig.7-Low scale model of SECSLEP

Fig.8- Low scale model of SECSLEP having surfaces
of parabolic mirrors generated by lines

For a clear understanding of cannon operation, see fig.9.

Normally the SECSLEP is stable in space because according to the law of momentum conservation the sum of all light impulses is zero. However, when the light beam is directed toward a target this balance is broken and compensation forces must be applied to keep SECSLEP in position (i.e. with the concave side of the large parabolic mirror oriented toward the Sun).

3. Calculations
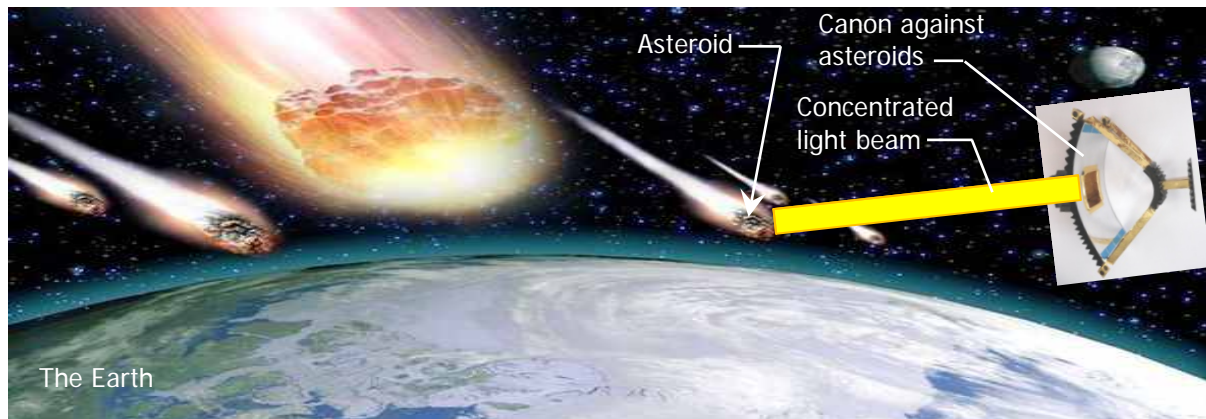
3.1 Calculation of SECSLEP power

Fig.9-Combined image showing action of canon against asteroids

The solar power is the key of future expansion of our civilization in space. The main component of this power is electromagnetic radiation. The spectrum of solar radiation is the spectrum of a black body having temperature of 5800 K [2]. The electromagnetic radiation is emitted in a broad band of frequencies. As a result of fusion nuclear reactions, the electromagnetic energy is initially emitted in the range of Gamma rays. However, during travel from the Sun core to surface, these rays are converted in lower energy photons then emitted into space. This is the reason for which the Sun does not emit Gamma rays. The Sun emits only X-rays, ultraviolet light, visible light, infrared light and radio waves. The spectrum of nearly all solar electromagnetic radiation striking the Earth's atmosphere ranges from 100 nm to 1mm.

This spectrum of Sun is shown in fig.10. The power emitted in the X and ultraviolet range is low. Most of the power is emitted in the range of visible light. Infrared and radio frequencies have less power. Assuming the SECSLEP is placed near Earth, the irradiance can be assumed to be E_e=1360W/m^2.
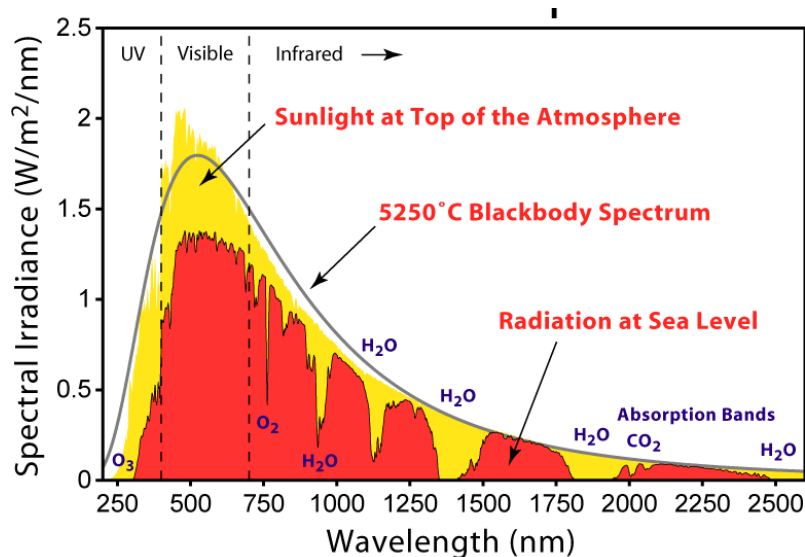

Fig.10-The spectrum of Sun

Assume that both mirrors are made from Mylar foil plated with gold [3]. The reflectivity of such a foil is remarkable. Figure 11 shows that gold has a coefficient of reflectivity R_g=0.98 for most frequencies. In the case of SECSLEP, the best foil should be made of gold plated fine/thin graphite fabric both for the high reflectivity of gold, high heat transfer coefficient and high emissivity coefficient of graphite.

Assume that the large parabolic mirror is oriented with the reflective (concave) face toward the Sun, in order to maximize the amount of captured energy.
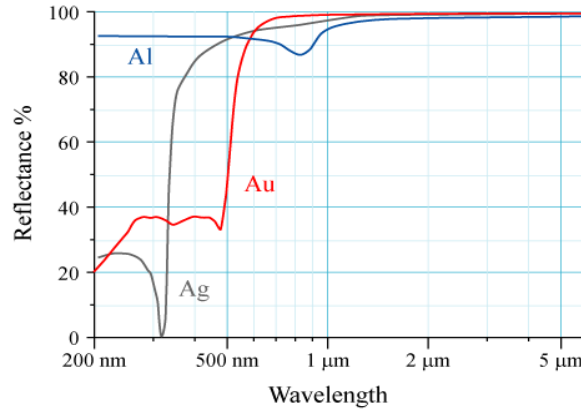
Fig.11-Reflectivitivity of metals

For example, if the large mirror has radius r=10 m, and solar irradiance E_e=1360W/m², the total collected power is:

$$P = E_e \cdot \pi \cdot r^2 = 1360 \cdot \pi \cdot 10^2 = 427.2 kW \qquad (1)$$

This is a significant amount of power. However, when this radius increases the power collected from Sun becomes very high. Table 1 shows the correlation between the SECSLEP mirror diameter and the amount of collected power. As shown in table, when the radius of the large parabolic mirror r= 50 m the collected power is P=10681.4 kW. Such a mirror is relatively easy to be built in space due to the absence of gravitation.

Table 1- Sun power collected by the large parabolic mirror of SECSLEP

Crt. no.	Radius of large parabolic mirror, r[m]	Collected solar power, P[kW]	Crt. no.	Radius of large parabolic mirror, r[km]	Collected solar power, P[terawatt]
1	5	106.8	13	1	0.004
2	10	427.3	14	2	0.017
3	15	961.3	15	3	0.038
4	20	1709.0	16	4	0.068
5	30	3845.3	17	6	0.154
6	40	6836.1	18	8	0.273
7	50	10681.4	19	10	0.427
8	60	15381.2	20	12	0.615
9	70	20935.6	21	14	0.837
10	80	27344.4	22	16	1.093
11	90	34607.8	23	18	1.383
12	100	42725.7	24	20	1.708

Assume that a SECSLEP having the radius of large parabolic mirror, r=50 m is focused on an iron asteroid for 10 second. Consider iron properties listed in the literature [5]:
Melting temperature: t_m=1538 °C; T_m=1811 K;
Boiling temperature: t_b=2862 °C; T_b=3135 K;
Heat capacity: c=0.45 kJ/kg·K (considered about the same for solid and liquid iron);
Heat of fusion: c_f=247.3 kJ/kg;
Heat of vaporization: c_v=6088.3 kJ/kg;
The quantity of heat necessary for vaporizing of 1 kg of iron is given by:

$$E_1 = 1 \cdot c \left(T_b - T_o \right) + c_f \cdot 1 + c_v \cdot 1 = 0.45 \cdot 3135 + 247.3 + 6088.3 = 7746 kJ/kg \qquad (2)$$

(heat capacity is considered about the same for the solid and liquid state)

Taking the power from table 1 for radius r=50 m, in 10 seconds the power beam into the asteroid is:

$$E = 10 \cdot 10681.4 = 106814 \text{kJ} \tag{3}$$

Such energy can vaporize a mass of iron given by:

$$M = \frac{E}{E_1} = \frac{106814}{7746} = 14 \text{kg} \tag{4}$$

The asteroid is continuously hit in this way (hundreds or thousands of times) until deflected from a collision trajectory with Earth. Thus even the trajectory of massive asteroids can be changed. Local vaporizing of asteroid mass leads to apparition of a reaction force produced by expanding vapors.

However, in space gigantic construction having a radius of kilometers can be built easier than on Earth due to the absence of gravitation. Calculations done using the above data show that an SECSLEP having the radius of large parabolic mirror r=10 km can send beam into the asteroid at the (huge) power of 0.427 terawatt. Such a power can vaporize an iron asteroid having the mass of 100 tons in 8 seconds.

The time required to destroy or deflect an asteroid using the SECSLEP system is reasonable low. Practically, the asteroid can be destroyed in a few minutes because obviously the SECSLEP beam hits the target with the speed of light.

In the case of very large asteroids as the Dinosaur killer (dimension 37 km, see fig.19) which could destroy our civilization, a special SECSLEP should be built in future. Such a SECSLEP could have the radius of large parabolic mirror r=20 km and it should be placed at 0.1 AU distance from Sun. The power of such a SECSLEP will be 170.8 terawatts. Such a SECSLEP should be completely automatic due to the great distance from Earth.

3.2 Heat transfer calculations

Simple calculations show that SECSLEP work properly both near Earth (where irradiance E_e=1360 W/m^2) and at 0.1 AU distance from Sun (where irradiance E_s=136000 W/m^2).

Assume a SECSLEP placed near Earth having the large parabolic mirror radius r_{LPM}=10 km and the radius of small parabolic mirror r_{SPM}=1.25 km (that concentrates Sun light by a factor of 64). The most stressed piece of SECSLEP is the small parabolic mirror because the power supported by 1 m^2 is $64 \cdot E_e$. Consider reflectivity of gold plated foil (plate) $R_{gf/p}$=0.98 and emissivity of carbon fabric/plate $e_c \approx 1$.

Assuming that the whole power absorbed by god plated foil (plate) is radiated according to Stefan – Boltzmann law,

$$E_e \left(1 - R_{gf/p} \right) \cdot \left(\frac{r_{LPM}}{r_{SPM}} \right)^2 = \sigma \cdot T^4 \tag{5}$$

where σ=5.67x10-8 W/m^{2}K^4, is the Stefan-Boltzmann coefficient for black body radiation. Using the given data, thermal balance is achieved for T=419 K (t=146 ºC). This temperature is under maximum allowable working temperatures for carbon composites (t=280-300 ºC) assuming carbon fiber composites with polymeric matrix.

Considering that gold plated foil (plate) thickness is δ=0.05 mm, and average thermal transfer coefficient is for graphite working at 146 ºC is λ=80 W/m·k, the temperature difference needed for transferring of heat from the golden face to rear carbon face of fabric Δt is given by thermal balance equation:

$$E_e \left(1 - R_{gf/p} \right) \cdot \left(\frac{r_{LPM}}{r_{SPM}} \right)^2 = \lambda \cdot \frac{\Delta t}{\delta} \tag{6}$$

For the given data, the thermal difference necessary for heat transfer would be Δt=0.001 °C. This small value shows that the heat is quickly transferred from the golden-plated face to the graphite fabric/plate rear face due to the high value of thermal conductivity of graphite and the very low thickness of foil (plate). As a result, the temperature of SECSLEP would be fairly constant.

SECSLEP works properly even when is placed at 0.1 AU from Sun. In this case, for the same dimensions and values of constants, except irradiance E_s that is 100 times than E_e, using equation (7) we found that temperature of surface is $T_{SPM}=1323$ K ($t_{SPM}=1050$ °C) i.e. under the melting point of pure gold (1064 °C).

$$E_s \left(1 - R_{gf/p} \right) \cdot \left(\frac{r_{LPM}}{r_{SPM}} \right)^2 = \sigma \cdot T^4 \qquad (7)$$

This means that structure of small parabolic mirror and connection structure between the small parabolic mirror and large parabolic mirror should be made of titanium bars having very thin walls.

Using the formula (8) for thermal balance of the large parabolic mirror, we found that surface temperature is $T_{LPM}=468$ K ($t_{LPM}=195$ °C) still under 280-300 °C - the working temperature limit for carbon fiber composite with polymeric matrix.

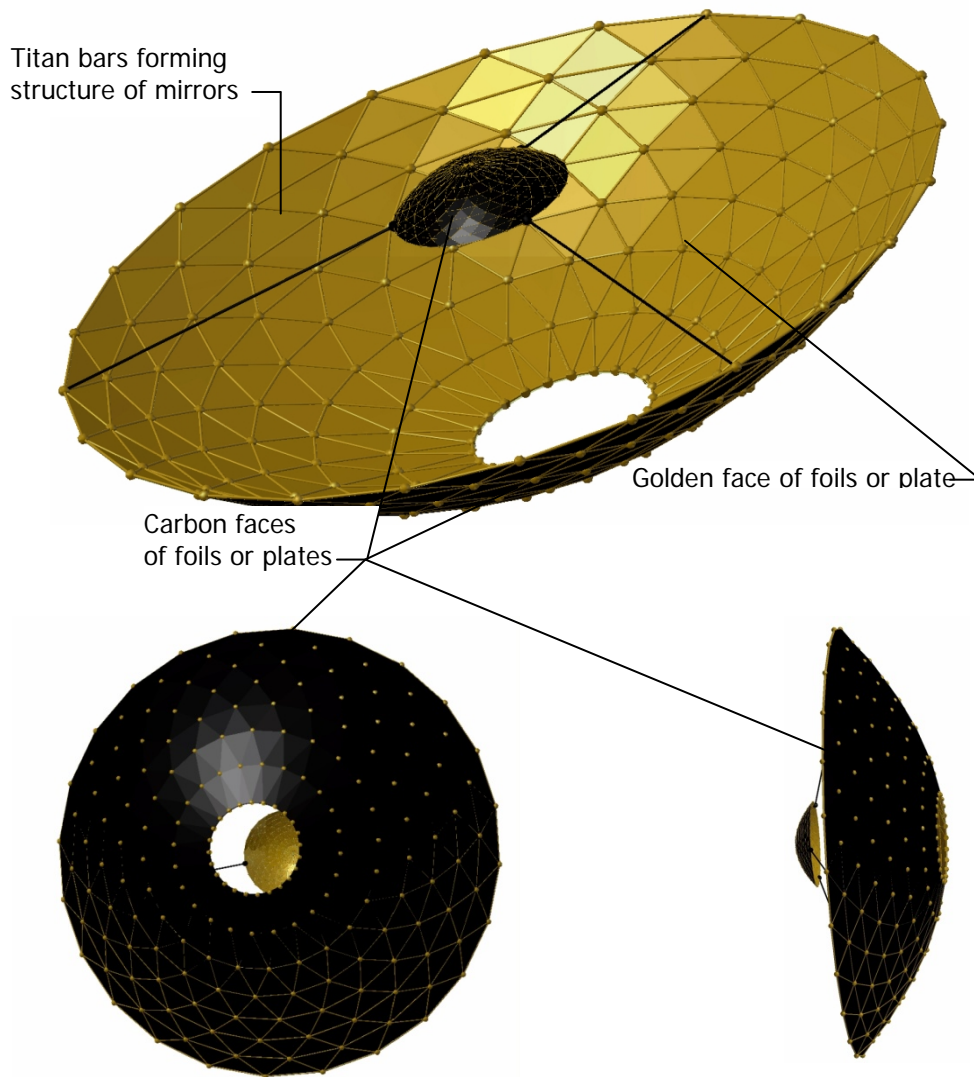$$E_s \left(1 - R_{gf/p} \right) = \sigma \cdot T^4 \qquad (8)$$

Fig.12-SECSLEP built using triangular cells

3.2 Calculation of SECSLEP mass

Fig.12 presents a design based on triangular cells (only the large and small mirrors are presented).

Obviously, hexagonal or rectangular cells are feasible [4]. Use of rectangular cells yields a light structure, but stability is reduced compared to the design using triangular cells.

When gold plated foil is used, the bars can be square and straight. If gold plated plates are used, the bars must be curved according to the parabolic surfaces of mirrors. The advantage in the second case is the higher accuracy of light focusing.

Such a construction can be relatively easily built in space if 'Spiderfab' type robots are used (fig.13) [6]. Calculations show the resistance structure of the large parabolic mirror can be built from 528 bars having length of 9.3 m each. If the bars are square tubes made of titanium having dimensions $L \times l \times \delta$ = 20 mm x 20 mm x 0.2 mm, calculations show that the total mass is 357 kg which is quite reasonable for space transportation. However, if graphite fiber composites are used instead of titanium, the mass of the large parabolic mirror decreases by about three times due to the extremely low density of these materials.
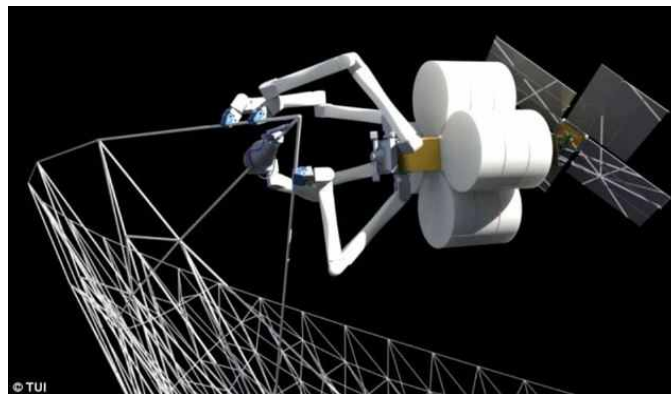

Fig.13-NASA's Spiderfab building construction in space

5. Other applications

5.1 Anti-debris cannon

Another application of SECSLEP is as anti-debris cannon. Such a SECSLEP has adequate dimensions for melting or vaporizing debris located around the Earth. It can vaporize or melt debris before entering the atmosphere facilitating burning in atmosphere and preventing the impact of solid debris with the ground.

5.2 Feeding of ISS, satellites and other space equipment with additional power

Low power SECSLEP can be used for feeding ISS, satellites and other space equipment with additional power as request. The satellite has a parabolic mirror able to focus light received from Sun of SECSLEP on the cold gas tank (tank is placed in the focal point of parabola) (fig.14).
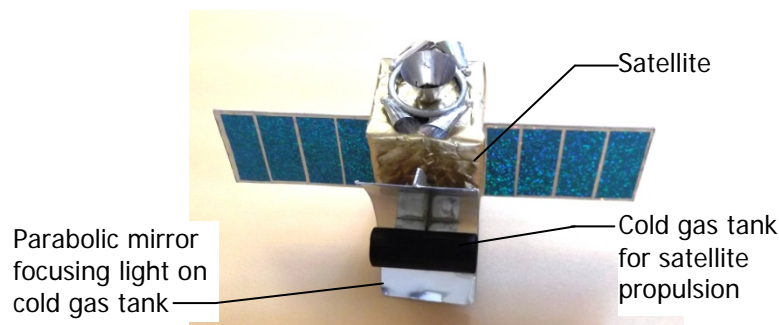

Fig.14-Long life LEO satellite powered by parabolic mirror

When rays coming directly from Sun or from SECSLEP are focused on the cold gas tank (fig.15), the internal energy (pressure, temperature) of gas increases. In this way, the cold gas stored in the tank is heated before every expansion in Laval nozzle for satellite acceleration. Due to this procedure, an increased number of gas expansions are possible without increasing the initial quantity of cold gas and, as a result, the life duration of satellites on LEO orbit increases about 3 times.
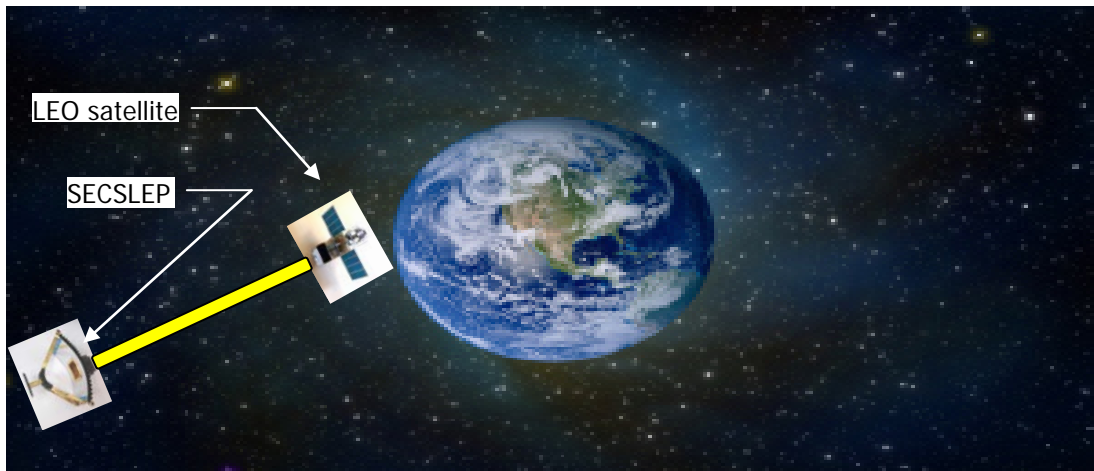

Fig.15-Feeding of LEO satellites with power before acceleration

5.3 Feeding of spacecraft with concentrated solar power

For travel within the solar system at far distance from Earth, supplying a spacecraft with solar energy is a problem due to variation of irradiance as $1/d^2$. For example ESA's Rosetta was asleep for about 3 years due to the low irradiance of Sun at those long distances. Rosetta simply did not have sufficient energy for powering the communication equipment.

The irradiance of SECSLEP beam does not vary as $1/d^2$. It is constant except for slight reduction due to dimensional imprecision of SECSLEP construction. For this reason, SECSLEP can feed spacecraft with high amount of power virtually within the whole solar system. It is known that spacecraft powered by magnetoplasmadynamic thrusters require electrical power of hundreds of kW to work properly. Such a spacecraft having the configuration shown in fig.16 can be powered by a SECSLEP with thousands of kW (fig.17).
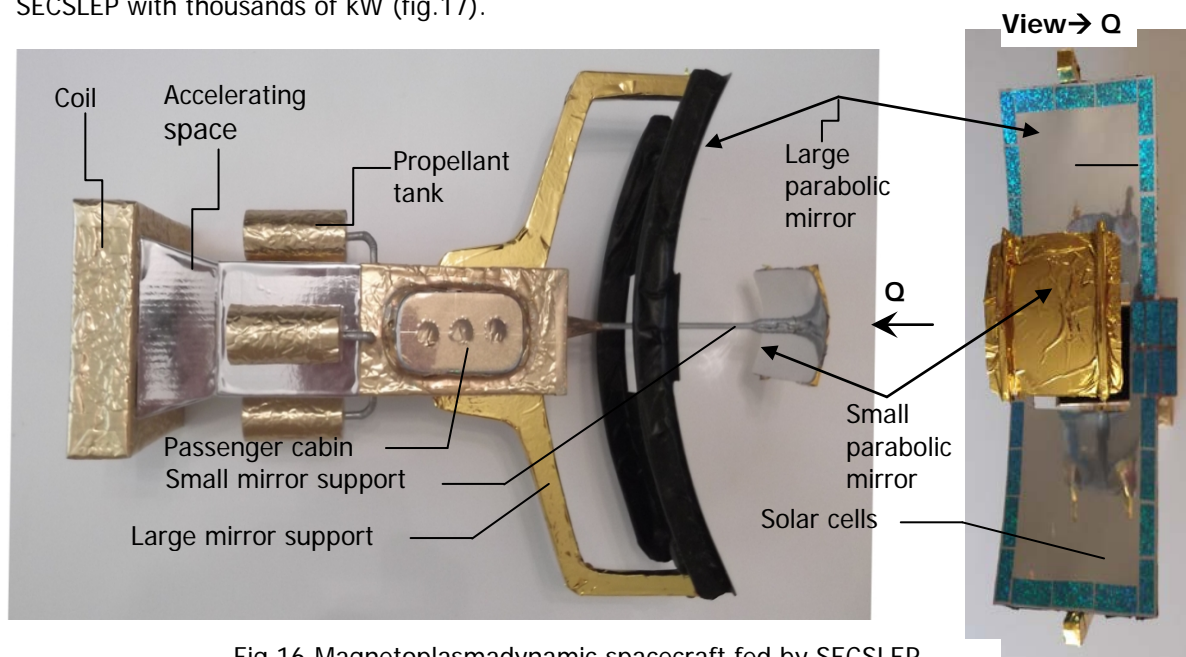

Fig.16-Magnetoplasmadynamic spacecraft fed by SECSLEP

The adjusting head of SECSLEP is tracking the large mirror of a spacecraft powered by magnetoplasmadynamic thruster. The solar cells placed on the large mirror of spacecraft transform a

part of concentrated power received from SECSLEP in electrical power (hundreds, thousands of kW) necessary for working of magnetoplasmadynamic thruster.

The rest of electromagnetic energy is used for increasing plasma energy before being accelerated by the cathode-anode electric field and magnetic field produced by coil. In this way, passenger spacecraft will currently travel between Earth and other planets.
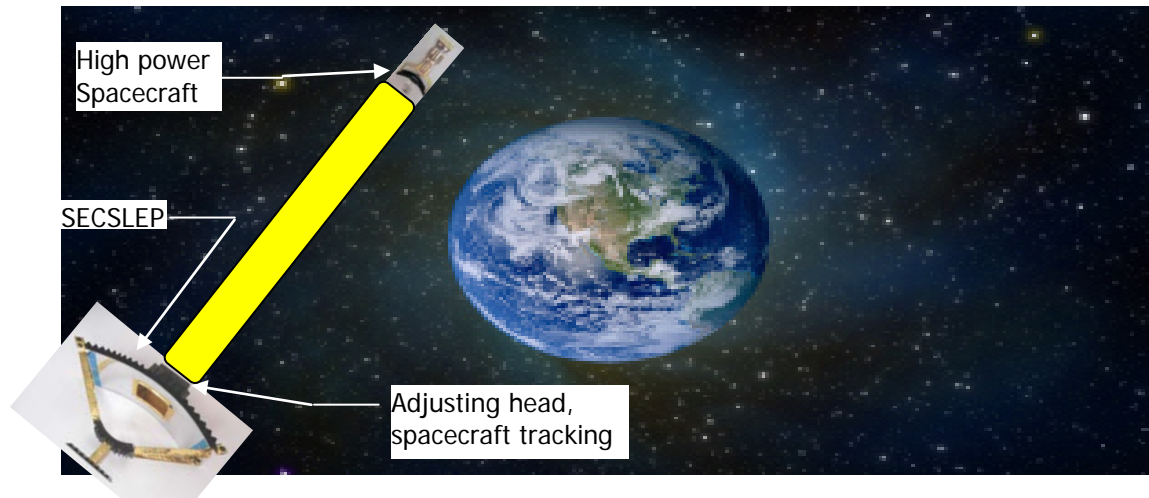

Fig.17-Feeding of magnetoplasmadynamic thrusters of spacecraft with high power electromagnetic energy (concentrated light)

5.4 Terra formation of planet Mars

A SECSLEP placed on Mars orbit can contribute to the terra-formation of this planet (fig.18). The high power light beam can prepare terrain through melting/vaporizing areas of Mars's soil or for delivering high power for water and Oxygen producing.
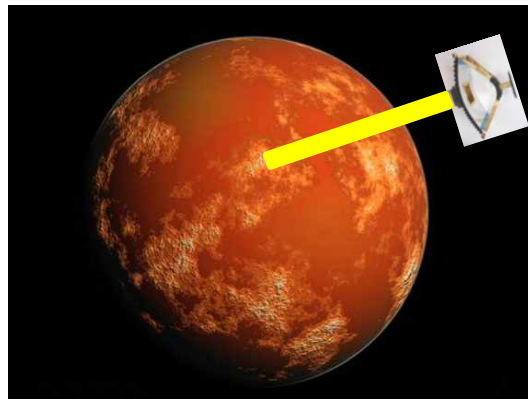

Fig.18-Terra-formation of planet Mars

7. SECSLEP position in space, life duration on orbit, reliability and maintenance

7.1 SECSLEP position in space

The SECSLEP equipment will operate in the Solar system near-Earth or on Earth orbit (fig.19). As known, Earth is subject to a permanent bombardment of natural elements called 'unorganized matter' of the universe: meteors, meteorites, interplanetary dust and gas, solar wind and radiation. Evaluation of effects of unorganized matter on SECSLEP life duration and its operating capacity is of major importance.

For this reason, detailed knowledge of the operating environment and the possible destructive effects on equipment will be useful during the design phase. The greatest danger is posed by meteors.
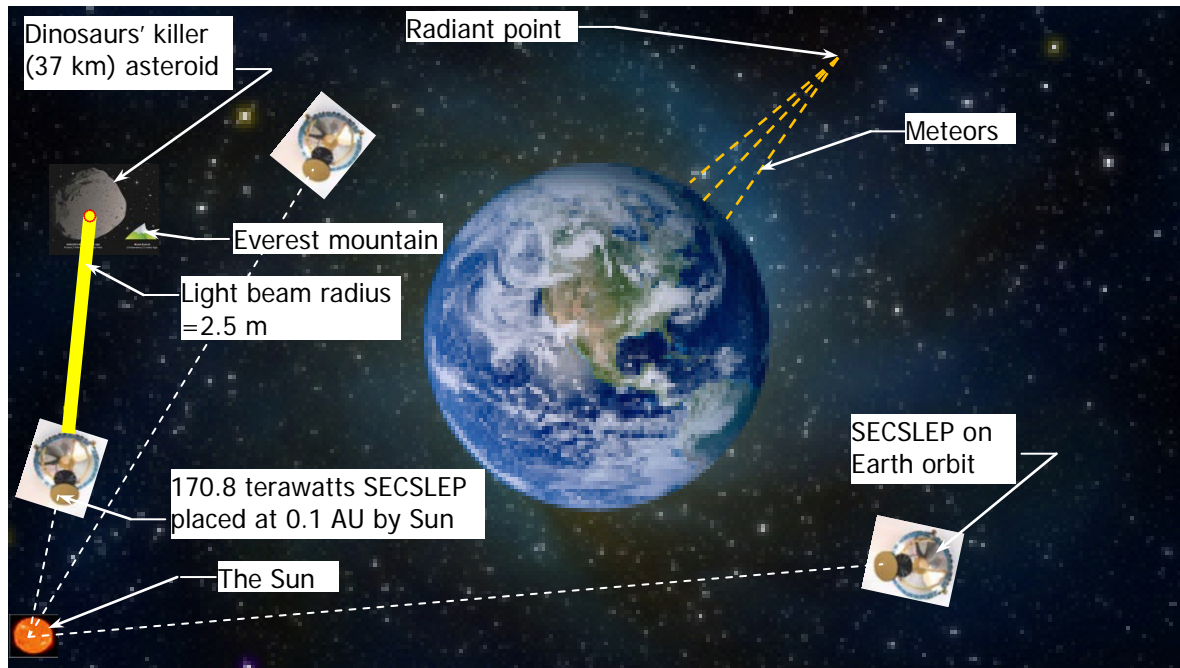
Fig.19-Positioning of SECSLEP for guarding of Earth

Meteors come from interplanetary space, enter Earth's atmosphere at speeds up to 30 to 40 km/s and are consumed by burning at about 80 km altitude. The frequency and distribution of meteors in the sky is not always regular. Sometimes meteor showers occur during a few nights in about the same region of the sky and are coming from the same point called the radiant point. The meteor bodies are porous having the average weight of about 1 g and diameter of 0.15 mm. Their heliocentric speed is about 50-60 km/s. Some of meteorites have a mass of about 3 g and a diameter of 0.3 mm and glow like a magnitude 5 star while burning. Meteoric matter density is of 10^{-21} to 10^{-20} kg /m^3 [7]. Within 24 hours, the Earth's atmosphere is crossed by 10^8 meteors brighter than magnitude 5. Due to these meteor falls, Earth's mass grows by several hundred tons annually.

Obviously the mass flow of meteors outside the atmosphere is higher than specified. For example, major meteor showers in Northern Hemisphere are given in Table 3 [8].

Table 3-Major meteor showers in Northern Hemisphere

Meteoric current meteoric IMO code *	Visibility	Date of maximum intensity	Coordinates of radiant point			ZHR**
			λ ☉	α	δ	No.
Quandrantis QUA)	Dec 28 – Jan 12	Ian 04	283.2◦	230◦	+49◦	120
Lyrids (LYR)	Apr 16 – Apr 25	Apr 22	32.3◦	271◦	+34	18
η-Aquariids (ETA)	Apr 19 – May 28	May 05	45.5◦	338◦	-01◦	65
η-Lidris (ELY)	May 03 – May14	May 08	48.0◦	287◦	+44	3
Bootids (JBO)	Jun 22 – Jul 02	Jun 27	95.7◦	224◦	+48◦	Var
Piscis Austrinids (PAU)	Jul 15 – Aug 10	Jul 27	125◦	341◦	-30◦	5
δ-Aquariids (SDA)	Jul 12 – Aug 23	Jul 29	127◦	340◦	-16◦	16
α-Capricornids (CAP)	Jul 03 – Aug 15	Jul 29	127◦	307◦	-10◦	5
Perseids (PER)	Jul 17 – Aug 24	Aug 12	140.0◦	48◦	+58	100
k-Cygnids (KCG)	Aug 03 – Aug 25	Aug 17	145◦	286◦	+59◦	3
α-Aurigids (AUR)	Aug 28 – Sept 05	Aug 31	158.6◦	91◦	+39◦	6
ε-Perseids (SPE)	Sep 05 – Sep 21	Sep 09	166.7◦	48◦	+40◦	5
Dracinids (DRA)	Oct 06 – Oct 10	Oct 08	195.4◦	262◦	+54	Var
Southern Taurids (STA)	Sep 10 – Nov 20	Oct 10	197◦	32◦	+09	5
δ-Aurigids (DAU	Oct 10 – Oct 18	Oct 11	198◦	84◦	+44	2
ε-Geminids EGE)	Oct 14 – Oct 27	Oct 18	205◦	102◦	+27◦	3

Orionids (ORI)	Oct 02 – Nov 07	Oct 21	208∘	95∘	+16∘	25
Leo Minotids (LMI)	Oct 19 – Oct 27	Oct 24	211∘	162∘	+37∘	2
Northern Taurids (NTA)	Oct 20 – Dec 10	Nov 12	230∘	58∘	+22∘	5
Leonids (LEO)	Nov 06 – Nov 30	Nov 17	235.3∘	152∘	+22∘	15
α-Monocerotids (AMO)	Nov 15 – Nov 25	Nov 21	239.3∘	117∘	+01	Var
Monocerotids (MON)	Nov 27 – Dec 17	Dec 08	257∘	100∘	+08∘	2
σ- Hidrids (HID)	Dec 03 – Dec15	Dec 11	260∘	127∘	+02	3
Geminids (GEM)	Dec 07 – Dec17	Dec 13	262.2∘	112∘	+33	120
Comae Berenicids (COM)	Dec 12 – Dec 23	Dec 15	264∘	175∘	+18	3
Leonis Minorids (DLM)	Dec 05 – Feb 04	Dec 19	268∘	161∘	+30∘	5
Ursids (URS)	Dec 17 – Dec 26	Dec 23	270.7∘	217∘	+76∘	10

Notes:
 * International Meteor Organization
 ** Zenithal Hourly Rate

It is clear that the SECSLEP must not be placed on orbits which are intersecting the meteor trajectories.

7.2 SECSLEP life duration on orbit, reliability and maintenance operations.

If SECSLEP orbit does not intersect meteor showers, its operational life can exceed many tens of years even over one hundred years. Maintenance operations are necessary for replacing damaged components of resistance structure or reflective foil (plates). The reflective foils (plates) are expected to be the most sensitive components of this equipment because they are very thin. In future, the use of multiple graphene foils can lead to an increased life of reflective foils (plates).

SECSLEP placed on Earth orbit would be easier to maintain. Robots can perform repair operations, too, as shown n fig. 13. When the orbit is heliocentric, maintenance is more difficult and costly. However placement of some SECSLEP on heliocentric orbit is necessary for heating asteroids or comets at great distances from Earth.

The reliability of SECSLEP is considered to be high due to the equipment essential simplicity. SECSLEP manage high power using a simple technology.

7.3 Conclusions

The Special Solar Power Supply Systems are composed of two parabolic mirrors placed face to face and having a common focal point. The light concentrated by the small mirror can be directed by a mirror-tube ('light gun') to the asteroide for its deflection from a collison trajectory with Earth.

SECSLEPs having small to medium dimensions are suitable for supplying additional power to LEO satelites, ISS, space hotels, for melting debris around earth or terraforming planet Mars.

Particularly, SECSLEP can feed the sapcecraft powered by magnetoplamadynamic thrusters with hundeds or thousands of kW permitting increased trafic within the solar system.

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