# Re: We can meet all our needs through space development

***Source:*** http://sci.tech−archive.net/Archive/sci.space.policy/2008−01/msg01037.html

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- *From*: Einar <einarbb@xxxxxxxxx>
- *Date*: Wed, 30 Jan 2008 18:11:43 −0800 (PST)

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On Jan 30, 2:44 pm, Willie.Moo...@xxxxxxxxx wrote:

> On Jan 29, 10:52 pm, Einar <eina...@xxxxxxxxx> wrote:
>
>> like
>> expectations of 13% efficiency not 40% as you appear to assume with
>> solar energy. A large difference.
>
> While 13% was the norm in the 1980s for silicon wafers and one can
> actually point to them, they are not the norm for multi−specral
> wafers.
>
> http://en.wikipedia.org/wiki/Spectrolab
>
> NREL has already demonstrated that multi−spectral cells exceed 40%
> efficiency.

But they´re far more expensive and moreover the 40% efficiency you
were using existe only in laboratory, like I think I pointed out to
you earlier.

You should work with what is commonly available.

I have posted this to you before, but these people have an idea of
replasing much of the fossil fule use in USA.

"A Solar Grand Plan
By 2050 solar power could end U.S. dependence on foreign oil and slash
greenhouse gas emissions"
http://www.sciam.com/article.cfm?id=a−solar−grand−plan

They intend to only use cheap 13% efficiency wafers, and have made a
plan which sounds very doable within theyr stated timeframe, i.e. to
2050.

However, the what I keep repeating to you is that, while I think your ideas are potentially workable, the timeframe you have thrown at us is clearly unrealistic.

2100 sounds like a workable timeframe for such extensice ideas. Anyow, by 2050 we will probably be ready to expand solar energy production into space.

I´ll expect that before then there will be a time of experimentation, i.e. small scale experiments with small solar powerstations, experiments with beemed power, etc.

That´s what is allways lacking in your suggestions,,,the inevitable experimental phase. By 2050 the experimental phase might be over and we may be ready to begin your project of building them on a significant scale − the way you suggest.

> Now, when silicon is exposed to light, what happens is determined by the colors of the light striking it. In the case of the sun, this is given by the planck curve of a black body radiator operating at 5800K − through an atmosphere that absorbs some of the energy − principally hydrogen...
>
> http://en.wikipedia.org/wiki/Black_bodyhttp://en.wikipedia.org/wiki/Solar_radiation
>
> So photons that are longer or redder than 1,108 nm − don't operate the silicon cell. They merely heat it.
>
> And, photons that are shorter or bluer than 1,108 nm − contribute only the bandgap energy to the circuit. (if its properly balanced with a load)
>
> What happens to the extra energy? Well, it shows up as ballistic energy in the photons in the conduction band − yep − heating the photocell again.
>
> Then there's the recombination of electrons that get formed but not picked up − this depends on temperature.
>
> And that's not the only source of loss − there are junction losses − resistances in the cell itself that cause current squared times resistance (i−squared r) losses − which also causes heating.
>
> The I−squared r losses can be reduced by reducing junction resistance − in cells like those designed by Bob Swanson at Sunpower − or by reducing current for a given power by increasing number of junctions in series − in cells like those designed by Bernie Sater at Photovolt − or by combining the two together like I do with my cells at Mok Industries.

> Keeping the silicon cool is how to reduce dark current losses.
>
> This leaves you with ineffective photons. The long−wave photons that don't contribute to the cells operation − and the short wave photons that contribute onlty the bandgap energy.
>
> Since the planck curve graphs in the references I gave are energy per wavelength versus wavelength − the area under the curve.
>
> For each wavelength, take a ratio of the wavelength and the bandgap wavelength in the case of silicon 1,108 nm − and multiply the solar output by that ratio. So, for example, the energy in a photon with a wavelength of 554 nm (green) contributes only half its energy to the operation of the circuit. 277 nm (Violet) contributes only one−quarter its energy to the operation of the circuit. Do this across the entire planck curve (its called convolving the silicon response curve and the solar black body curve) − and you get what each color contributes to the operation of the silicon cell. Now integrate the convolved curves to get the area. Then, finally, divide the smaller area of the convolved curve with the larger area of the planck aka blackbody curve − and you get a number − around 23% − with small junction losses and temperature losses.
>
> Now what Spectrolab did − is they combined photocells of different wavelengths and arranged to have bandgap matched light fall on each type − and use the output of all of them. NREL has shown that they operate at 40.7% efficiency with 3 bandgaps. We are discussing building 6 bandgap system (GaAs can be doped to change its bandgap energy) − that is expected to have efficiencies exceeding 60% − the practical limit seems to be 20 bandgaps − with 80% efficiencies
>
> So, 40% has been achieved
>
> 60% is a reasonable near term research target (and the focus of current research, visit my web site, fill out a contact form,and I will send you a white paper)
>
> 80% is a plausible long term achievement
>
> I quoted 40% overall...

That sounds truly like an excellent technology, but how expensive would such cells be when compaired to those that already are in mass production? How quickly can the price be reduced through economies of scale? Do they contain very expensive materials that will result in them staying expensive no matter what?

These are worthy considerations. Remember you intend to use these on a very large scale, presumably first in groundstations. The people with the abow mentioned plan intend to make do with less sophisticated technology, and still think that it will be possible to significantly reduce the use of imported oil over the period to 2050.

> > The program I find believable assumed that it will take some years to achieve that 13% efficiency,

> 40% has already been achieved, I'm funding research to see if we can achieve 60% by doubling the number of junctions, and qualified researchers feel that by increasing the number of junctions further using MEMs technology − it may be possible to get to 80% ...

MEMs are a most important innovation. Clever use of manufacturing techniques originally used in manufacture of chips, is how most of them are made. The airbag of my car probably is activated by such a MEM.

The question will the bee weather the trick of the chip makers can be repeated, i.e. to make enough of them to shrink the prices down to reasonable levels.

But if expensive materials are used, or materials which supply could cause a bottleneck, then they might stay expensive anyhow. Moreover, many of the chips have become so incredibly complex, so expensive to develope that even though they are mass produced in great numbers, they ´re not especially cheap to purchase.

That is importan, the price. If you are to persuate people to use them. Today, older tech solar cells have become cheap enough that average people can affor to use them on a reasonable scale. Solar cells f.e. on the roof of a house can really shrink the electricity bill.

> > as current mass produced solar cells do not achieve more than 10%,

> I am mass producing CPV systems that routinely achieve 18%

At what cost when compaired with cheaper cells?

> > I can only assume that you are expecting what is now only possible in controlled laboratory settings will become practical mass production, which by the way is not an obvious assumption.

Lets do more than quote numbers shall we. Lets look behind the numbers and then we can come to some logical conclusions.

The number you give is an average based on systems that use amorphous or polycrystalling construction. Junction losses are extraordinarily high in these systems. This is deemed acceptable because they can get their silicon at very low cost compared to pure float silicon that is a pure crystal.

What you term − experimental or laboratory − systems have far higher efficiency.because they use float silicon − that costs about $1 per square inch. This is about 3x higher in price than polysilicon systems − but the output is less than double (14% versus 23%) −

I use float silicon − but fabricated in a way and cut into dies that allow me to operate it at 1,000x solar intensity. (see my web pagehttp://www.usoal.com) − this cuts the PV costs per watt way down, and lets me operate at higher efficiencies.

Ditto with the UTJ cells from spectrolab. They have a germanium subtrate − and CVD epitaxially grown − GaAs and InPh layers − whose thickness allows efficient capture of specific colors of light. These are $12 per sq inch in quantity.

So, here's the deal; lets compare the older design, with my current design (Patent #7,081,584 − Mook), and whats in the labs today that I'm expecting to use on orbit tomorrow;

sunlight − 645 milliwatts per square inch terrestrial clear day
881 milliwatts per square inch space earth orbit

mass produced conventional solar panels
14% efficient
1x concentration
645 milliwatts per square inch solar
90.3 milliwatts electrical per square inch
$0.30 per square inch cost
$3.32 per peak watt (PV cost)

Mok terrestrial PV
18% efficient (filtered)
1000x concentration
645 watts per square inch solar
116 watts electrical per square inch
$1.00 per square inch cost
$0.01 per peak watt (PV Cost)

Spetrolab 6J PV (research)
55% efficient
5,000x concentration

4,405 watts per square inch solar
2,422 watts per square inch electrical
$12.00 per square inch cost
$0.005 per peak watt (PV Cost)

I simply must disbelieve your figures until you can give some idea how you are arriving at them.

I have not only given you pointers to research results from one of my vendors independently verified by government laboratories, I have given you an insight into my current research efforts.

Thank you for that. But as your figures clearly demonstrate the newer technologies are more expensive per square inc over to far more expensive per square inc.

That matters a lot, when you intend to use them on a large scale. However, there is naturally the issue in what setting the planned use is for. I wouldn´t be surpriced, once perfected and shown to be reliable, the high energy per square inch types will dominate installations where cost per square inch is not so great an issue but energy produced per square inch is.

Since you didn't bring it up, I haven't yet addressed the other big issue − the laser efficiency, and then the efficiency of the conversion on the ground. Free electron lasers have achieved 30% efficiencies 20 years ago, diode lasers routinely exceed 10% efficiency − yet are less tunable.

http://www.frascati.enea.it/fis/lac/fel/fel2.htmhttp://www.alfalight.com/press−detail.asp?articleid=24

The military has focused on lightweight compact applications for years. But both teams believe for sound and valid reasons that 80% to 85% efficiencies are achievable with a dedicated effort over the next five years.

So, I have used those figures for my estimates here.

sunglight −−−> DC electricity 55% 55%
DC electricity −−−> laser energy 85% 47%
laser energy −−−> DC electricity 85% 40%

That´s a bit of an assumption.

> By the way, the asteroid project you appear to be assuming sounds really seriously expensive.

> Cost is only one aspect, value created is the other. So, it is important to create more value than you spend in order to achieve your goals.

Now, this asteroid operation is clearly an operation in which the will inevitably have to be a testing period. This will necessiate a large trained cadre of astronauts. This will moreover also necessiate quite bit of EVA training of those astronauts. This will in addition necessiate the development of deepspace vessels, I´d say preferably nuclear powered. Now, I know you have suggested beemed power over the distance from the Sun. But that´s another development project with a testing period all of its own, and expenses, potential bottlenecks, etc, etc.

Beemed power will require years of testing, first small scale then large scale all of its own. Now, today we may not foresee any great difficulties. But there allmost allways are difficulties, especially when working in an environment humans stichtly speaking still have got very litle experience in working within.

But, if we accept nuclear power for at the very least the first generation of deep space wessels, then at least that operation´s initial successes will not depend on the rate of development of the other program you apparently intend to run at the same time. So different development scedules, unforseen bottlenecks need not harm that operation as well.
You need allways to be able to take such in stride.

Now again about the asteroids, a test will have to be made with capture and moving an asteroid. Now, an easy in the relative test operation might be to attempt to move one of the asteroid that orbit close to the Earth/Moon system around the Sun. Now, such tests are very important, as you need to know weather you assumption are really reasonable, i.e. that shining a laser can tell you enough about the rock to be hauled in to be a practical method for future use, which was one of the methods you mentioned. You need also to test the capture operation itself, if for no other reason that your personnel will need such training. But also in order to develope that operation itself.

Most likely several such tests at the very least will be necessary in order to hone the methods used. In addition as they will be necessary for training purposes of the personnel, and therefore will need probably to continue.

Naturally, there are several different problems. It would require quite a different operation to attempt to capture an asteroid which is only a looselly bound rubble, than an one which is solid through. Each type will need testing and training of its own.

I expect this beginning phase to take from 15 − 20 years, a concervative expectation. All through that time these personnel would have to be maintained, the scientists paid theyr salaries, etc...something you are familiar with. The ships themselves would also be expensive.

> > It would be cheaper to send small ion powered probes to check on the asteroids.

> Cheaper than what? Please explain how you analysed the program and come to this conclusion. Recall, that we precede dispatching the probes with a terrestrial program of observation, and follow it up by dispatching crews to the selected asteroids for processing.
>
> What powers the ion engines in your suggested approach? I use beamed laser energy.
>
> What makes you think an ion engine is superior to a laser engine of the same specific impulse but higher thrust to weight?
>
> I am building an infrastructure to carry out a program. Does the use of ion engine technology assist in that? If so how? Why is it superior to laser propulsion systems that have equal specific impulse and higher thrust to weight?

The ion engines using solar cell power, are a tried and tested system. That´s what they have going for them. Thus they will clearly be relativelly cheap, especially if massproduced. So many could be made. That means theyr use will not depend on the development scedules of all the other systems you intend to be developing. Remember, you are planning to do this all in the incredibly short period till 2050. So, I presume that all developmens scedules more or less have to run at the same time.

So, to safe time ion engined probes can be put into production right now,,,for all what it´s worth.

In addition, you idea for Earth observation necessiated apparently the construction of number of sites. Those are not cheap. Depending though on the size of the observatories you have in mind. But, as you intend them to give the best idea possible from over here, they sound like expensive large mirrors to achieve the necessary resolution of such tiny at that distance objects. Now, such observatories can cost several billion apiece.

So, ion engined probes while slow can be a cheap in the relative option. They, I emphasize, may be means to grant your project the necessary capability of surviving unatticipated development bottlenecks...that when designing completelly new space based systems are considered allmost inevitable by reasonably zynical space people.

Remember, laser propulsion is a separate developmen program. Most certainly, it would be one of the necessary tests of such a system during its development phase to test it on something, so some of the probes might be launched away from Earth by a laser in Earth orbit.

> After all they´d need to be observed close up, as you appear to realize.

Of course − but you don't need to observe all of them close up. Then you need to process those you finally select.

But a swarm of small probes can speed things up, and increase your chances of actually getting things done in time.

> The problem with Earth observatories is that at the distance we are talking about, the pixels have become pretty large.

I have some options on land in Chile in the atacama region − its one of the sunniest places on Earth and it will be a fantastic solar panel site to feed HVDC electricty to a wire running the entire length of Chile. Chile is sort of like 4 Californias stacked end to end.. right on the Pacific. A perfect place for the baby boomers to retire − provided there is enough power and infrastructure to support them. A beachside house for everyone.

Atacama desert also has an astronomical observatory.

http://www.news.cornell.edu/stories/May06/Atacama.Giovanelli.html

An advanced terrestrial telescope system is easily placed there − built around large numbers of commercially available telescopes − operated with AI/automatically − using a variety of optical techniques to create an optical vlbi as well as adaptive optics − a new approach I've developed to remove the atmosphere effects −

http://en.wikipedia.org/wiki/Tip−tilt_mirrorhttp://en.wikipedia.org/wiki/Uhdtv http://en.wikipedia.org/wiki/Adaptive_optics

Those methods of cancelling out athmosphere effects, like you rightly point out are new. The observatories that are using them indeed are all new or much renovated. Many of them can even be controlled through the internet by someone with access. I have spent years chatting with astronomers,,,so this isn´t an entirelly unfamiliar territory.

These methods remember have limitations. They work best if you look through the athmosphere the shortest distance out of it and it´s better to have less of it abow your observatory than more but that´s true of all observatories. Still, the more of the athmosphere you are looking through the less effective the adaptive obtics are in cancelling out the disturbance. That has created the contraint that the observatories have been limited the angles of view.

> > So even the best of them will only give a very rough idea what to expect.

> You are talking out of your gut − not out of a sound knowledge base. Are you familiar with the Rayleigh limit in optics? It tells you what sort of resolving power you get for a given apeture at a given distance.
>
> http://en.wikipedia.org/wiki/Optical_telescope#Angular_resolution
>
> Ar = 1.22 lambda / D
>
> Optical telescopes can be joined by optical fibers, synchronized by laser pulses and using holographic techniques,to create synthetic apetures that are very large, even while the elements are mass produced. So a modest array of telescopes in the Atacama desert can do quite a lot to observe asteroids.

But those will not have adabtive optics. Mind you it doesn´t matter how many scopes you gather together in that fashion. There is still a limitation in how much resolution you can get. What a large group of scope can enable you is to gather a lot of light, which mean you can observe either of the to; very faint objects or very distant ones.

But the asteroid are so small at the distance, there is no way even with huge constellations of observatories, to observe theyr surfaces in except the most rough manner. Like I said, the pixels are to large in the relation to the size of the objects being observed.

What you need to do is to bring the mirrors in closer like can be done with spaceprobes. Then you don´t need a very large mirror, only a very well made one. A superhighgrade camera.

> Microwaves have far longer wavelengths, but operated at far larger distances − vlbi − very long baseline interferometry − can achieve remarkable results in the microwave region
>
> http://www.news.cornell.edu/releases/Aug99/AsteroidPix.bpf.html

LOL, and Arecibo is well large. You were proposing constructing a number of observatories. The asteroid in question was only at the distance of 5,3 million miles. It was therefore very much closer to the Earth than the asteroids in the asteroid belt.

"The astronomical unit (AU or au or a.u. or sometimes ua) is a unit of length approximately equal to the distance from the Earth to the Sun. The currently accepted value of the AU is 149,597,870,691 ± 30 metres (nearly 150 million kilometres or 93 million miles)."

Near Earth asteroids are those that orbit within the distance of a single astronomical unit from Earth. Naturally those in groups can be imaged from surface based observatories. But that´s quite another thing when we are talking about those the orbit witin the asteroid belt propers,,,the pixels are to small or to large, whichever way you prefer to think it.

> A $30 million per year terrestrial program can achieve the goals I have for it in 3 years according to the universities that I have spoken with − continued funding of the equipment at a far lower level − will allow it to continue finding new asteroids and mapping them to the same degree.

Universities naturally want your money. But mapping them, will probably mean mapping theyr orbits, in theyr speak, not theyr surfaces...as tha´s clearly not possible at the distance involved except in very, very roughest outlines and then only with the very largest.

> Of course sending sensible energy to an asteroid and observing the effect on the ground − is a far larger program. Yet, assuming power satellites on orbit feeding energy to terrestrial systems on Earth − it is easy to see what sort of optical upgrades are required to make spots on asteroidal surfaces that can produce jets.

Oh, so you were actually thinking about blasting them with lasers from over here. Yeah, indeed that would call for some incredible focusing of the laser in order so that the beem will not become far, far to wide at that distance.

Wow...really. That will be gigantically expensive. You are talking about a huge focusing system. Ultra precision well beyond anything possible today. Orbital mind you. Will have to be shielded against micrometeroids, one hit could ruin the whole thing. Think in terms of hundreds of billion.

Admittedly the alternative is also super expensive, i.e. a trained cadre of astronauts. Deep space vessels. But those you will have to use aniway.

> > The problem with rubble piles is that they can´t be shifted, lest they come apart.

> Why not? Explain your reasoning. Consider that you're in zero gravity. So, shifting a loose load under those conditions − especially one that is gravitationally bound already − is not the same as doing the same thing on Earth under one gravity. So, lets start right there.

Eeer...we are talking about a very small levels of gravity. Meaning that if say you happened to be standing on the surface, hypothetically, then simply jumping would launch you into orbit.

The gravity is to small to compact them together. So they are very loselly bound. That astronomers know as a fact, as many of them even the metallic ones have smaller density than water...which can only be explained if there are large empty space within due to them being so looselly bound together that theyr material isn´t actually compaced at all.

Yeah really, they would come apart. You can trust that.

> For example, you could get a dense metallic asteroid orbiting nearby, attach a thruster to it, and use the metallic asteroid as propellant and a gravity 'tug' − to pull both back to Earth − at reasonable gees in reasonable times.

Even the metallic asteroids will not be used to acceleration. I´m talking about those that are solid through. They will have been stable in theyr environment for billions of years. You absolutelly don´t want to begin to shift them with high acceleration. In such a case even they might come apart.

Remember these are rocks that are in space. Never have seen any athmosphere. Theyr qualities are not identical to rocks you can observe here on Earth.

> Then, consider that taking the asteroids apart is a step in the process using them to build stuff. Since the rubble piles are already broken apart, it seems that part of the work is already done.

Will be very tricky to shift them any. But, a factory ship might be able to use an one if the ship would first travel to each of them. Then either of the two tugs could move the product gradually over to Earth or solar sail could be attached to each cargo item independently and then that could cruise ever so gradually over to Earth. Solar sails as is known can either of the two cruise on solar energy alone or they can be speeded up with lasers.

An alternative type of operation, but quite possible.

>> You´d need some sort of a factory ship on the spot, is my expectation.

> I said you'd need to dispatch crews to the asteroids you selected to process them for return. Since it takes about 7 years on a hohmann transfer orbit to bring back an asteroid, and a year or a year and a half at each end to accelerate them − you'll have time to do quite a bit of work en−route.

But an alternative is for the refined ore to cruise on a solar sail of its own towars Earth. A very economic operation it would appear. Hohmanns transfer can be made with low thrust.

>> You appear not to consider solar sails as propulsion method,

> I considered it and rejected it because the thrusts are too low to meet my requirement that it take less than 18 months to impart the required delta vee to the targets.
>
> http://www.nasa.gov/centers/glenn/testfacilities/Sailing_on_Sunbeams....

But, you really want to accelerate asteroids gently. So solar sails really would be ideal. Anyhow, we have time enough. The asteroids aren ´t going anywhere.

> Low power equals low thrust equals long mission times. This may be acceptable for missions like planetary defense where you locate an asteroid that will collide with Earth in 206 years and then dispatch a solar sail to take 100 years to modify its orbit − and its orbit is earth crossing so its spends time closer to the sun than Earth.

They can be speeded up with your beemed power, in which case theyr thrust will depend on the power of your laser. In addition, as the target will be far larger than your intended one, i.e. the backend of whatever unit you intend to do the accelerating, the problem of focusing the beem will be more managable presumably.

> It is unacceptable for something you want to get done to feed all the people of Earth before 2040 operating at distances where light levels are only a small fraction of what they are at Earth. It als is unacceptable if you want to earn a profit in your lifetime.

There is no reason to decide to feed all the people of Earth by that time in that fashion. We have lived over here quite comfortably for a long time.

I reckon that if food produced in space in the fashion you suggest becomes economic, then it will be imported to Earth. That way, large tracts of land currently used for food production could be given back to nature,,,yet the population would essentially stay put.

> Ceres is a good representative asteroid. Its the biggest and the first one discovered. It has a semimajor axis of 2.76AU − that means that the sunlight on Ceres is only 13.1% of that on Earth. So, you'll need 7.6 times the sail area at Ceres as you need on Earth to get the same level of thrust − or get 1/8th the thrust as you do on earth − and what takes a day to do on Earth with a solar sail − will take a week on Ceres. since power level equates to thrust − thrust is very low.
>
> Thrust and specific impulse and power are related. Solar sails use photons, the specific impulse is infinite since no propellant is used − but the power needed to produce a Newton of thrust is tremendous. Using laser energy generated in Earth orbit from sunlight, and beaming that reliably to a thruster in the asteroid belt, to move material around − can operate at a wide range of specific impulses. Either as a laser light sail − with infinite specific impulse or energizing a portion of the asteroidal mass. What specific impulse do we need? The answer is, the one that has the least cost and time associated with it. And that is, the one where the specific impulse has the exhaust speed equal delta vee. For a hohmann transfer orbit from Ceres this is around 800 sec Isp.

I would like to keep Ceres undisturbed. The fact is that moving it would disturb the rest of the asteroid belt in a hard to predict fashion. After all Ceres is a large percentage of the overall mass of the asteroid belt. Believe me, you really dont whish to move Ceres or the other five largest asteroids. Gravity is a bitch sometimes.

Anyhow, Ceres might sometime become rather useful for a whole other purpose, i.e. moving the Earth itself. But if a large enough object moves in an orbital resonance between the Earth and Jubiter, the orbit of Earth can be gradually widened.

An option humanity might really like to keep open for the later future.

> > but they
> > have the merit of not needing fuel

> Thats true but they need a tremendous amount of energy. Given that energy −particularly solar energy− is in short supply while billions of metric tons of materials are freely available to use as propellant − one clearly would like to reduce energy use to a minimum. Since there are other constraints of a for profit system − such as getting things done in less than a decade − thrust levels needed cannot be achieved by any practical solar sail system. The mass of the sail gets unweildy when trying to move things quickly at that distance.

But with Solar sail in comination with beemed energy, you´d not need to waste any mass.

> > and would also benefit from your
> > lasers you assume will be plased in the viscinity of the Sun.

> Compute the power level needed to bring the 21,000 metric tons of material from the asteroid belt each day using an optimized laser rocket blasting 36,000 metric tons of propellant − which was less than 20 GW. and compute the power needed to do the same thing − with laser light sails.
>
> http://en.wikipedia.org/wiki/Poynting_vectorhttp://science.howstuffworks.com/solarsail.htm/printable
>
> Force = 2* Power / speed of light
>
> Now 21,000 metric tons per day is 243 kg per second. The delta vee total at both ends of the journey is 8,000 m/sec − I have limited the

> acceleration time to 36 months overall − 94.67 million seconds.
>
> Velocity = acceleration x time
>
> so, acceleration = velocity / time
> = 8,000 m/s / 94,672,800 s
> = 8.45e−5 m/s2
>
> Force = mass x acceleration
>
> Now the acceleration period is 3 years − and in 3 years at a 21,000 metric tons per day rate a total of
>
> mass = 243 kg/sec x 94,672,800 sec = 23,005,490,400 kg
>
> Force = 23.00e+9 kg * 8.45e−5 m/s2 = 1,943,964 Newtons
>
> Force = 2 x Power / speed of light
>
> Rewriting this to solve for power level needed
>
> Power = Force * speed of light / 2
> = 1.944e+6 * 3e+8 / 2 = 2.916e+14 = 291.6 TRILLION watts
>
> This reduces the mass flow needed to be supplied by the asteroid belt to zero. However, it increases the power level of the system by a factor of about 15,000 !!!! Using solar power at the asteroid belt means collector area is increased by a factor of 115,000x from what I proposed originally. Since the station masses 500 metric tons and covers 75.5 sq km. Converting to solar sails means we need 7.5 million metric tons of sails if powered from earth and 57.5 million metric tons of sails/collectors if powered from the asteroid belt.
>
> The sails can be reprocessed into useful stuff when they arrive, but the cost of making the sails is wasted − then there's the logistical problem of having sails the areas needed. No, the lower cost system is the one I have proposed with very few technical risks..

Now, the thing is you only need these asteroids at this scale levels if it´s there is a reason to move all foodproduction into space. If the reason is only to supply rawmaterials for industry, then the most economic method possible would be used. Solar sails, they can be accelerated with a laser, but they also can move without such a boost. In addition, it might be more sence to operate factory ships that would cruise about the asteroid belt. In that case the sails would only be moving the refined ore packages.

I don´t think it´s necessary to move all foodproduction into space. At the present time the Earth is making sufficient amount of food for all, even though it´s somewhat unequally distributed meaning food is scarce for some. It would make sence to produce food in space for those who come to live there.

Earth would continue to supply its own food.

> > The thing with asteroids, would be gentle movements. Sounds very doubtful that even the solid ones would be able to handle rapit rates of movement, so gentle acceleration perhaps like 0,001g or even 0,0001g which would make solar sails ideal.

> You haven't done the calculations. I can accept no less than 84.5 micro gees. This can be done with quite reasonable thrusts (approximately 200,000 kgf) − rubble piles can easily be moved at these levels using gravity tugs. So attaching to an appropriately sized dense metallic asteroid and navigating appropriately around a rubble pile, brings both back. Building a pipe from the rubble pile and pumping volatiles into the rocket engine − energized by laser light from a powersat in Earth orbit − provides adequate propellant to maintain the thrust for the needed period.
>
> Using laser sails at the same power setting reduces the mass flow rate to a trickle.

At the present time it´s not known wether asteroids can be safely moved at that rate. That´s a rather big undertainty don´t you think. I assume that the rate of movement will have to be gentle.

That´s a reasonable assumption I think.

> > In addition, as you think
> > rubble piles can be strapped together in some fashion.

> I didn't say that.

> > ..a delicate
> > operation for certain, I think you´d prefer towing to pulling. In fact towing may be preferable to pulling.

> If done gravitationally yes.

Yeah right, then you will have to be moving a quite massive oject for them to cling to. Problem there are none available that can be safely moved. At the very least none massive enough.

Gravity is a bitch sometimes.

> > In addition it´s necessary to consider the effects on the other asteroids.

> That's right.

Which means you have to leave the more massive asteroid alone. That means you´ll lack the eer massive object you intend to let that rubble cling to.

> > The path chosen has to be very carefully worked out, as after all you really don´t whish to make other asteroids careen out of theyr orbits.

> Correct

That will go out of the window if you attempt to shift any of the 5 largest asteroids. They will have to be a big no. They can though probably be safely mined by a mining ship which would move to them.

> > That means it´s very unlikely that some sort of a direct trajectory towards the Earth will prove practical.

> You are talking about terminal maneuvers during the 18 month period the asteroid is undergoing powered thrust. The 7 years it spends in transit this will unlikely be a problem. There are issues related to the stream of asteroids produced however, and that can actually assist things.

That time probably will at the very least be 14 years, probably longer than that.

> > More probably it
> > will be necessary to take several orbits around the Sun, before an asteroid can be finally moved out of the belt proper.

> Please show me your analysis on this? Certainly, if you have vastly

> lower gee forces than I am contemplating you will take centuries to move things. So, yes you will go round and round and round the sun as you spiral end. Assuming nothing breaks in all that time.
>
> Ceres orbital period is 4.599 years. My limit on acceleration says we have to complete the delta vee at the asteroid belt in less than a year − the delta vee at the asteroid belt is the smaller one − so, that means you're clear of the belt in less than 1/5th a turn. You have about two years to slow into Earth orbit. Here you're chasing the Earth a couple of times around the sun before sliding into your spot in polar orbit above Earth.

Now, Ceres will clearly be a big 'NO,' unless you whish to observe the orbits of a significant percentage of the other asteroids change as you move it. Undoubtedly interesting to watch, but you might not be popular with the rest of humanity afterwards.

It will depend on which asteroid, naturally, but with more than million of them about, I expect that it will take several Solar orbits to nudge the average small average size asteroid free if the intend is to cause the minimum disturbance to other asteroids.

Think about it, even though the volume of the Solar system is vast, and the volume of the asteroid belt huge, most are orbiting more or less along the plane of the rest of the Solar System. You will inevitably be crossing a real lot of orbits of the other asteroids. You will have to move it, nudge it, each time, when there is a good distance so gravity effects will be minimal. Sounds reasonable it will tale several orbits, even when assuming that you will be using the technologies you are assuming and moreover assuming that they really will work the way you assume they´ll work.

So my expectation is that you will be making a series of nudges till you are free of the other orbits. So moving clear will take unknown number of years, depending on the number of orbits necessary to cross.

> > I think it would be reasonable to reckon with 5 − 10 years of gentle moving and nudging untill Earth orbit.

> You haven't done any analysis of the critical factors and are wrongly assuming I haven't analyzed the noncritical factors you cite. That's why you are making so many mistakes.
>
> A hohmann transfer orbit from Ceres to Earth is about 7 years. I have put a 10 year limit on the transfer − this gets us the 84.5 micro gee limit. You have proposed using solar sails, any practical solar sail operated at the asteroid belt will take centuries not decades to complete a transfer.

Assuming there are no other orbits in between that must not be
disturbed. However, that´s not the reality. Remember over million
asteroids.

And we can´t move the largest asteroids.

> It may even be that 15 − 20
> years would even be necessary for the more fragile or distant ones.

You are talking out of your hat. You haven't done the numbers so you
are just waving your hands.

True, but it´s clear you are talking about a time consuming affair if
you really intend not to send asteroids careening this and that way.

The surface gravity of even a small rubble pile is greater than 84.5
microgees.

The surface gravity of Ceres is 28,000 microgees.

Ceres must not be moved.

The force exerted by an 800 sec Isp laser powered thruster operated at
a GW scale is 200,000 kgf −
The force exerted by an infinite Isp laser light sail operated at the
same power level is 4 kgf −

> Now, your ideas sound very nice,

Yours do not − they are dead wrong.

> but your figures sound to good to be
> true.

Where? The figures you cite are either out of date or wrong.

> Einar

> I would suggest you spend a little more thought on your responses in the future.

Now, I haven´t said that your ideas are impossible. Only that the timeframe you suggest is.

Einar

.