Pre scientific work

Change of Earth orbit because the sun gradually releases more energy

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(and here translated to English)

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Abstract

The sun's energy output has been rising since its inception 4.6 billion years ago. This increase will be critical for life on Earth in the next half-billion years. Although there is scientific agreement on this increase in energy, there are still no concrete plans for protecting life on Earth.

The solution is to adjust Earth's orbit to the increasing energy output of the Sun so that the amount of energy received by the Sun remains the same.

This work shows that the scientific knowledge of mankind and the technical possibilities of humanity already available in the first attempts are sufficient to solve this problem.

Production of the system for shifting the orbit, energy supply and reaction mass supply lead to constraints, which clearly set the road to realization.

This problem-driven approach results in a list of key capabilities of humanity necessary for its implementation.

Foreword

What can humanity do, for what is humanity confident in doing? There is hardly a bigger difference than between these two questions. What mankind trusts itself can be seen in the numbers used in the Drake[1] equation for “L life of a technical civilization in years.” Only 304 to 100 million years are assumed.

At the moment there is an overwhelming pessimism, which considers humankind as a pest and estimates them even for less than 304 years of survival.

Expressing this pessimism, this self-contempt, this self-flagellation ranges from “Nature does not need man” to “Healthy planets have no humans”. There are frightening parallels to the medieval flagellantism, which has praised itself as a cure for the plague.

Which topic would be best suited for the argumentation “Nature needs man” and “Healthy planets need humans”? A topic where, without highly technical human civilization, only an inhospitable, hot and lifeless Earth orbits around the sun, whereas a civilization preserves life on Earth?

There is no better subject than this, that humanity, because of its technical and scientific abilities, can not only achieve much more, but has to, and a highly technical human civilization is very useful for life on earth.

1: Wikipedia Drake equation: estimate the number of civilizations

Table of contents

Introduction

Can mankind sustain life on Earth and itself for the next 6 billion years, the time when our sun will still be in the main sequence of stars?

A few hundred years ago, humanity considered the universe, which at that time was considered to be tiny, a well-organized clockwork. The very idea that the Earth is not the center but revolves around the sun triggered unbelievable reactions.

In 1920, Arthur Eddington's[1] first theories were that nuclear fusion could be the energy source of the sun. Today it is already possible to simulate the past and future of our sun very accurately. By 1981 at the latest with the assessment of the Chicxulub crater[2] in Yucatan as a meteorite crater, the idea had to end that the universe is a well-ordered clockwork. The universe is not a golden cage for humanity, where there is always someone providing optimal conditions, but a constant challenge for all the abilities of a civilization to survive in the long term.

New findings create new requirements. The realization of Dr. Semmelweis created the requirement of hygiene. The realization that CO_2 from fossil combustion is changing the climate creates a need to move from fossil fuel combustion to modern technology. This requirement is still very poorly and inadequate represented in politics today, although catastrophic changes can be expected within the lifespan of a human being.

The realization that the sun's energy output is increasing creates the need to move Earth's orbit. But in contrast to climate change through CO_2, the impact of ignorance is not noticeable within a human lifespan, but only after about 10 million lifetimes.

The challenge is not technology but ethics. Elon Musk shows with modest investments of a few billion US $, how quickly one can advance the transition to electric mobility. What would have been possible with a few trillion US $, the size of the US military budget over a decade?

Here we have to create the consciousness “We are a civilization, we will exist for many billions of years” and eradicate the idea “We are a horde of savages that destroys everything and therefore do not deserve to survive”.

1: Wikipedia Arthur Eddington

2: Wikipedia Chicxulub crater

1 State of solar research

In strong contrast to the climate change caused by greenhouse gases, science is in complete agreement on the energy gain of the sun. There are only minimal differences between individual research projects.

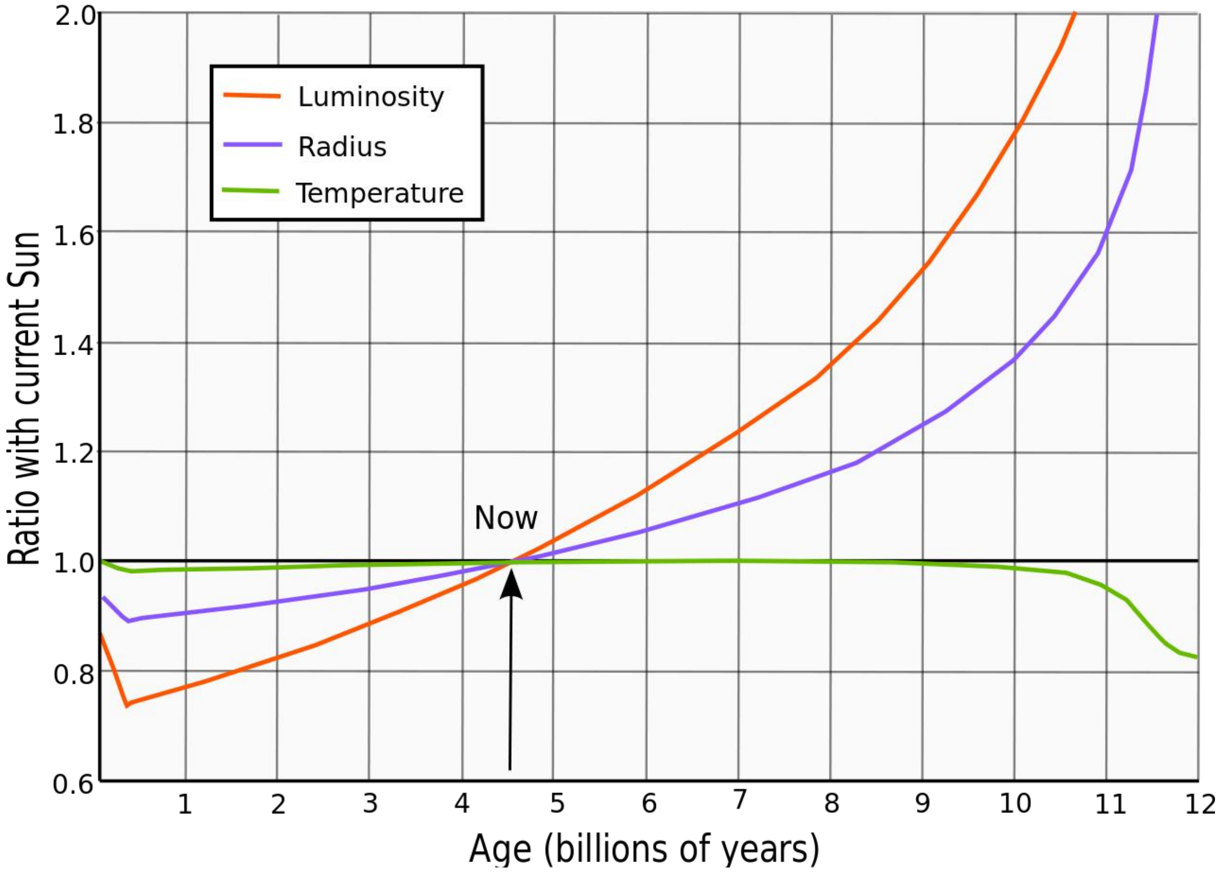

Table 1: The development of the sun in luminosity, radius and surface temperature
Picture: https://commons.wikimedia.org/wiki/File:Solar_evolution_(English).svg

Source: Own work, based on figure 1, Ribas, Ignasi (February 2010). "Solar and Stellar Variability: Impact on Earth and Planets, Proceedings of the International Astronomical Union, IAU Symposium"

Author: RJHall

The work of which the picture is from: https://www.cambridge.org/core/journals/proceedings-of-the-international-astronomical-union/issue/solar-and-stellar-variability-impact-on-earth-and-planets/9900CD803F8BC4E9C349B02A2A4A07EB

Quotation for the content of the picture: Ribas Ignasi (February 2010). "Solar and Stellar Variability: Impact on Earth and Planets, Proceedings of the International Astronomical Union, IAU Symposium" page 4.

The value here at 10 billion years is 78 % energy increase. We now compare this value with another study:

Table 1. Main physical properties of characteristic solar models.

Phase	Age (Gyr)	L ($L_\odot$)	T_{eff} (K)	R ($R_\odot$)	M_{Sun} ($M_\odot$)
ZAMS	0.00	0.70	5596	0.89	1.000
Present	4.58	1.00	5774	1.00	1.000
MS:hottest	7.13	1.26	5820	1.11	1.000
MS:final	10.00	1.84	5751	1.37	1.000
RGB:tip	12.17	2730.	2602	256.	0.668
ZA-He	12.17	53.7	4667	11.2	0.668
AGB:tip	12.30	2090.	3200	149.	0.546
AGB:tip-TP	12.30	4170.	3467	179.	0.544

Note: 1.00 au $= 215\,R_\odot$.

Tabelle 2: Development of the sun after Schröder, K. -P.; Connon Smith, R. (2008). "Distant future of the Sun and Earth revisited". Monthly Notices of the Royal Astronomical Society. 386: 155–163. arXiv:0801.4031 Freely accessible. Bibcode:2008MNRAS.386..155S. doi:10.1111/j.1365-2966.2008.13022.x. Page 156 Table 1.

1.1 High agreement between different research papers

Here stands at 10 billion years 84 % energy increase. Is not it fantastic how exactly our science is predicting 5.4 billion years into the future? 78 % or 84 % energy gain.

There are no lobby motives to influence the scientific findings, in contrast to climate change through greenhouse gases, where the fossil energy industry has considerable interest in delaying technological progress, to make money as long as possible with fossil technology.

What would the Earth look like with the sun's energy doubled, if it would still be in the same orbit as today? The Earth would get 4 % more energy than today's Venus. On the Venus[1] is a surface temperatures of up to 497 degrees.

That would be the fate of Earth without civilization until the end of the main sequence. When the sun turns into a red giant, it would be much warmer.

1.2 Rest of the work after Schröder 2008

Because the values of the forecasts are very similar, it makes no sense to write this work for different forecasts. For the rest of the work, therefore, the table according to the study by Schröder 2008 is used.

1: Wikipedia Venus

2 Data about the orbit change

Once it's clear we need to get out of here, it's time to work on the data for the orbital changes. When you move away from a light source, the intensity decreases with the square of the distance. Doubling the energy output therefore requires a 41 % larger orbit.

For each energy output of the sun, a required radius for the orbit can be assigned.

2.1 Properties of an orbit

In an orbit, two masses orbit each other at a distance where gravity and centrifugal force cancel each other out. Mass, radius of the orbit and velocity in orbit are related in a circular orbit in the following context:

$$v_o \approx \sqrt{\frac{GM}{r}}$$

v_o	Velocity orbital
G	Gravitational constant $6{,}67408 \cdot 10^{-11}$
M	Mass
r	radius

https://en.wikipedia.org/wiki/Orbital_speed

2.2 Change of orbit

The effort to change an orbit is the difference of the orbit velocities between the two orbits.

One accelerates, i.e. exerts a force in the direction of the trajectory in orbit and thereby slows down and reaches a higher orbit.

One brakes, i.e. exerts a force against the direction of the trajectory in orbit and thereby becomes faster and reaches a lower orbit.

> «The spiral trajectory appears to be a trivial solution, but there are some subtleties. Notice that the velocity increment Δv is actually equal to the decrease in orbital velocity. The rocket is pushing forward, but the velocity is decreasing. This is because in a r^{-2} force field, the kinetic energy is equal in magnitude but opposite in sign to the total energy»

Prof. Martinez-Sanchez https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-522-space-propulsion-spring-2015/lecture-notes/MIT16_522S15_Lecture6.pdf – page 3

2.3 Thrust to change the speed

In space you have to push something away to change your speed. You push something away and thereby change your own speed in the opposite direction. For this effect, the formula for the thrust is responsible:

$$\mathbf{T} = \mathbf{v}\frac{\mathrm{d}m}{\mathrm{d}t}$$

https://en.wikipedia.org/wiki/Thrust

T	Thrust
v	velocity
dm	Mass
dt	time

If a thrust of one Newton acts on a mass of one kg for one second, then the velocity of the mass will change by 1 m/sec. If we want to know all the power needed for orbital change, then we have to multiply the difference in orbital velocities with the mass of the Earth and the Moon. Fortunately, we can then divide by quite a few seconds to get the necessary thrust.

2.4 The necessary speed changes of the Earth

The table according to Schröder 2008 offers an intermediate point between today (Present) and the end of the main sequence (MS: final MS = main sequence) with the hottest point (MS: hottest), the time when the surface temperature of the sun is highest.

	Present	MS:hottest	MS:final	AGB:tip-TP
Age (Gyr = billion years)[1]	4.58	7.13	10.00	12.30
L (L ⊙ = luminosity)[1]	1.00	1.26	1.84	4,170.30
M Sun (M ⊙ = Mass of sun)[1]	1.00	1.00	1.00	0.544
Orbit (1.000 km)[2]	149,598	167,923	202,925	9,660,373
Orbit speed (m/sek)[3]	29,785	28,113	25,574	2,734
Time difference (Gyr)		2.55	2.87	2.30
Orbit speed difference (m/sec)		1,672	2,539	22,840
Difference per Gyr (m/sec)		656	885	9,930

Table 3: Required changes in the orbit and orbital velocity of the earth

1: Values according to the study Schröder 2008. ⊙ the present sun means 1.

2: Calculate an orbit with the same solar irradiance as today:

$$\sqrt{\begin{array}{l}\text{L ⊙}\\ \text{e.g.: 1.26}\\ \text{e.g.: 1.84}\end{array}} \bullet \begin{array}{l}\text{today's orbit radius}\\ \text{of the earth}\\ \text{149,598,023,000 m}\end{array} = \begin{array}{l}\text{Searched orbit radius}\\ \text{e.g.: 167,923,364,341}\\ \text{e.g.: 202,924,631,362}\end{array}$$

3: Calculate orbit speed. For the sake of simplification as a precisely circular orbit:

$$\sqrt{\frac{\boxed{\begin{array}{l}\text{Gravitational}\\ \text{constant}\\ 6{,}674080 \,.\, 10^{-11}\end{array}} \bullet \boxed{\begin{array}{l}\text{Mass of the sun}\\ \\ 1{,}988550 \,.\, 10^{30}\text{ kg}\end{array}}}{\boxed{\begin{array}{l}\text{Orbital radius of Earth}\\ \text{e.g.: } 149{,}598{,}023{,}000\text{ m}\\ \text{e.g.: } 167{,}923{,}364{,}341\text{ m}\\ \text{e.g.: } 202{,}924{,}631{,}362\text{ m}\end{array}}}} = \boxed{\begin{array}{l}\text{Orbit speed}\\ \\ \text{e.g.: } 29{,}785\text{ m/sec}\\ \text{e.g.: } 28{,}113\text{ m/sec}\\ \text{e.g.: } 25{,}574\text{ m/sec}\end{array}}$$

Without the gas giants Jupiter, Saturn, Uranus, and Neptune, it would be relatively easy even from the end of the main sequence to the red giant. The speed change would only have to be done about 15 times faster than at the beginning.

But so, what to do with Jupiter[1], which weighs 318 times as much as the Earth, how to get beyond today's Jupiter orbit? Thus, the problems to be solved for the period from the end of the main sequence to the red giant will increase by about 4 orders of magnitude.

2.5 Mass or speed, that's the question here

To achieve the required thrust, one can choose any combination of mass and velocity whose product is the required thrust. Great, we take as much speed as possible, so we need as little mass as possible. But to push away mass you have to give this mass kinetic energy.

100 Newtons of thrust can be achieved with 100 kg and 1 m/sec, 10 kg and 10 m/sec or 1 kg and 100 m/sec. Of course, this also works with 1 g and 100 km/sec and 1 mg and 100,000 km/sec. But before we continue to dream of reducing the mass to push away, called reaction mass, we have to look at the formula for kinetic energy:

2.6 Once linear, once square, that's here the problem

Here is the formula for the kinetic energy. As in the thrust formula, here too the mass is inside. As in the thrust formula, the speed is inside, but this time not linear, but square.

$$E_{\mathrm{k}} = \frac{1}{2} m v^2$$

https://en.wikipedia.org/wiki/Kinetic_energy

1: Wikipedia Jupiter

This is the catch on the idea to save reaction mass by a higher exit speed from the engine. You need a lot of energy for the reduction of the reaction mass. To reduce the necessary reaction mass to 1/10 means a 10 times higher energy requirement for the same thrust.

You can not save reaction mass and energy at the same time. You can always save only reaction mass or energy. But both have to be procured. Then there is the question, what is easier to obtain, more reaction mass or more energy?

2.7 Drag the Earth with the gravity of a mass

Because the Earth has an air envelope that reaches much higher heights than one would even dare to think in tall buildings, it is not possible to place the engines for the change of orbit on Earth.

A mass must be placed in the direction of the Earth's orbit, which uses its engines to resist the gravitational pull of the Earth, keeping it at a constant distance from Earth. For this we still need the formula for gravity:

$$F_{\mathrm{G}} = G\frac{m_1 m_2}{r^2}$$

https://en.wikipedia.org/wiki/Gravity

F_G	Force gravity
G	Gravitational constant $6.67408 \cdot 10^{-11}$
m_1	mass 1
m_2	mass 2
r	radius, distance between the masses

Now remains the question how far away from the Earth should this mass be positioned? In any case, farther away than the lunar orbit, definitely so far away that it forms an acute angle when you align the engine beams at 50,000 km above and 50,000 km below earth.

Without any further justification, I just assume 1 million km. May a fierce discussion break out about whether 700,000 km, 1,200,000 km or any other distance would be better.

2.8 Reaction mass, energy and pulling mass

How big must the pulling mass be 1 million km away from the Earth? What is the need for reaction mass and energy at different eject velocity and mass combinations?

Energy is net energy, the energy that is converted into thrust. Several factors are not taken into consideration:

1.) Ion-jet engines also need energy to ionize.

2.) The energy used to accelerate the reaction mass has an efficiency

3.) Aligning the engine beams at 50,000 km above and below the ground results in a force parallelogram, which only affects 99.88 % of the thrust.

These 3 factors should have an effect below 5 %. As this is only a matter of determining the order of magnitude, the net amount of energy is simply calculated here.

	Present to MS:hottest	MS:hottest to MS:final	present to MS:final
Total force (N)[1]	$1.011 \cdot 10^{28}$	$1.5351 \cdot 10^{28}$	
Necessary thrust (kN)[2]	125,630,455	169,501,399	
Reaction mass[3] (kg) at 100 km/sec	$1.011 \cdot 10^{23}$	$1.5351 \cdot 10^{23}$	$2.5461 \cdot 10^{23}$
Energy[4] (TW Terawatt)	6,282	8,475	
Reaction mass[3] (kg) at 1,000 km/sec	$1.011 \cdot 10^{22}$	$1.5351 \cdot 10^{22}$	$2.5461 \cdot 10^{22}$
Energy[4] (TW Terawatt)	62,815	84,751	
Reaction mass[3] (kg) at 10,000 km/sec	$1.011 \cdot 10^{21}$	$1.5451 \cdot 10^{21}$	$2.5461 \cdot 10^{21}$
Energy[4] (TW Terawatt)	628,152	847,507	
Gravity[5] from earth and moon in 1 Million km (mm/sec^2)			0.404
Mass (Gt Gigatons) to pull[6]	311	420	

Table 4: Energy and reaction mass requirements at different ejection speeds of ion beam engines

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1: The total required force is mass times speed difference between the orbits:

$$\left(\boxed{\begin{array}{l}\text{Mass of Earth}\\ 5.972370 \cdot 10^{24}\text{ kg}\end{array}} + \boxed{\begin{array}{l}\text{Mass of the Moon}\\ 7.342000 \cdot 10^{22}\text{ kg}\end{array}} \right) \cdot \boxed{\begin{array}{l}\text{Speed difference}\\ \text{of the orbits}\\ \text{e.g.: 656 m/sec}\\ \text{e.g.: 885 m/sec}\end{array}}$$

2: The thrust is the total force required divided by the seconds:

$$\frac{\boxed{\begin{array}{l}\text{Total force required for}\\ \text{orbital change}\\ \text{e.g.: } 1.0110 \cdot 10^{28}\text{ N}\\ \text{e.g.: } 1.5351 \cdot 10^{28}\text{ N}\end{array}}}{\boxed{\begin{array}{l}\text{Years for}\\ \text{the orbit change}\\ \text{e.g.: 2,550,000,000}\\ \text{e.g.: 2,860,000,000}\end{array}} \cdot \boxed{\begin{array}{l}\text{Seconds in}\\ \text{the average}\\ \text{Gregorian year}\\ \text{31,556,952}\end{array}}} = \boxed{\begin{array}{l}\text{Thrust}\\ \text{e.g.: 125,630,454,692 N}\\ \text{e.g.: 169,501,338,712 N}\end{array}}$$

3: The total force divided by the ejection speed gives the reaction mass.

4: Energy = Thrust · Ejection speed / 2.
The first calculation step is reaction mass = thrust / ejection speed.
The reaction mass must then be multiplied by the kinetic energy formula, where multiplying by ejection velocity squared occurs. Therefore, the equation can be shortened by the reaction mass to the above form.

5: Simplified here is taken the mass of earth and moon. This happens twice a month when the Moon is just 1 million km away from the pull fleet in orbit around Earth.

$$\boxed{\begin{array}{l}\text{Gravitational}\\ \text{constant}\\ 6.674080 \cdot 10^{-11}\end{array}} \cdot \frac{\left(\boxed{\begin{array}{l}\text{Mass of Earth}\\ 5.972370 \cdot 10^{24}\text{ kg}\end{array}} + \boxed{\begin{array}{l}\text{Mass of the Moon}\\ 7.342000 \cdot 10^{22}\text{ kg}\end{array}}\right)}{\boxed{\begin{array}{l}\text{Distance of the pull fleet from Earth}\\ 1{,}000{,}000{,}000\text{ m}\end{array}}^{\,2}}$$

6: Thrust / Gravity = required mass to transmit the force via gravity.

$$\frac{\boxed{\begin{array}{l}\text{Thrust}\\ \text{e.g.: } 125{,}630{,}454{,}692\text{ N}\\ \text{e.g.: } 169{,}501{,}338{,}712\text{ N}\end{array}}}{\boxed{\begin{array}{l}\text{Gravity, result from above}\\ 0.000404\text{ m/sec}^2\end{array}}} = \boxed{\begin{array}{l}\text{Mass that pulls Earth}\\ \text{e.g.: } 311.351 \cdot 10^{12}\text{ kg}\\ \text{e.g.: } 420.077 \cdot 10^{12}\text{ kg}\end{array}}$$

Since most can't imagine immediately something under $2.55 \cdot 10^{23}$ kg, our moon[1] has a mass of $7.342 \cdot 10^{22}$ kg. At only 100 km / sec output speed, the 3.47 times the mass of the Moon is needed as a reaction mass. If the ejection speed is increased to 10,000 km / sec, the reaction mass requirement drops to 3.47 % of the lunar mass, but in the first phase 628,152 TW are a lot of energy.

Since only ion-beam engines come into question for such high output speeds and ion-beam engines only need electricity, this energy is meant in the form of electricity.

Global electricity production[2] in 2017 was 25,551.3 TWh. Evenly distributed over the hours of the year, this is only 2.91 TW. Wow, 215,503 times more electricity will be needed. Do not panic, our civilization does not have to perish under a increasing sun, and surprisingly, solutions are already available today.

The first stage of the Saturn V[3] moon rocket had 35 Meganewton thrust for 168 seconds. 125 to 170 Giganewton thrust have to be achieved here for billions of years.

1: Wikipedia Moon

2: Wikipedia List of countries by electricity production

3: Wikipedia Saturn V

2.9 Summary on orbital change

A brief summary of the findings to date: We are placing a mass of 311 billion tons at a distance of one million km from the Earth. This mass braces itself with 125 billion Newton thrust against the gravity of the Earth, the engine beams go 50 thousand km above and below the Earth. Over time, reaction mass, equivalent to 3.47 % of the lunar mass, is being chased through the engines, requiring 628,152 TW of electricity in the first phase.

Thus, the task is divided into 3 problem areas with known sizes:

1.) Placing the pull fleet

2.) Power supply of the ion beam engines

3.) Reaction mass supply of the ion beam engines

Point 3 could be saved by the use of photon engines. Unfortunately, this would increase the energy requirement by 30 times. Therefore, 10,000 km/sec ejection speed for the ion-beam engine seems to be a good compromise between energy and reaction mass requirements.

3 The power supply of the ion beam engines

Deviating from the order of the three problem areas I take the power supply first. More than 200 thousand times more power demand than today's mankind produces is quite a heavy calculation result.

Fortunately, the solution is very obvious, only 150 km (from Salzbuurg) to Linz at Johannes Kepler University at Priv.-Doz. DI Dr. Martin Kaltenbrunner.

3.1 Breakthrough with very thin photovoltaic films

In 2012, this development even made it into the mass media: extremely thin photovoltaics with 10 W peak per gram.

> Abstract: Recent work is reviewed on organic solar cells thinner than a thread of spider silk, so flexible that they can be wrapped firmly around a human hair, lighter than autumn leaves and with an unprecedented specific weight of 10 W/g. Solar cell fabrication is based on planar process technologies only, commonly employed in semiconductor industry.

Martin Kaltenbrunner - M.S. White - Tsuyoshi Sekitani - Takao Someya:
Breakthroughs in Photonics 2012: Large-Area Ultrathin Photonics

3.2 Dramatic improvement in only 3 years

This thin-film photovoltaics was improved in 3 years to 12 % efficiency and 23 W peak per gram.

> Here, we report ultrathin (3 μm), highly flexible perovskite solar cells with stabilized 12 % efficiency and a power-per-weight as high as 23 W g^{-1}.

Martin Kaltenbrunner 1 * , Getachew Adam 2 , Eric Daniel Głowacki 2 , Michael Drack 1 , Reinhard Schwödiauer 1 , Lucia Leonat 2 , Dogukan Hazar Apaydin 2 , Heiko Groiss 3 , Markus Clark Scharber 2 , Matthew Schuette White 2 , Niyazi Serdar Sariciftci 2 and Siegfried Bauer 1: Flexible high power-per-weight perovskite solar cells with chromium oxide–metal contacts for improved stability in air

3.3 Assumption of photovoltaic for the rest of the work

The entire system is not just made of photovoltaic, but also of supporting structures and power lines. Most of the time, the mechanical stability requirement is very low, if the ship of the pull fleet holds with an acceleration of 0.4 mm / sec^2 its position in a million km distance against the gravity of the earth.

For the rest of the work, 5 watts per gram and 20% efficiency are assumed. The watt peak refers to 1,000 W/m^2 of irradiation and 25 degrees Celsius. However, the solar constant in space at Earth is 1,367 watts, but the cell becomes significantly warmer than 25 degrees Celsius, which reduces the yield. Instead, 20 % more power per Watt peak is assumed.

Following this assumption, one gram of photovoltaic, with all the structures producing 6 watts, will require 105 billion tonnes for 628,152 TW. That was however calculated with the net need. But even if all efficiencies and other consumers increase gross demand significantly, 120 billion tonnes of photovoltaic systems are significantly lighter than the 311 billion tonnes total mass of the pull fleet.

3.4 What about a less favorable state of photovoltaic technology?

What if the state of the art had only been 1/4 of the energy per gram of complete photovoltaic system? There are 2 solution strategies for this:

Instead of 311 billion tons in one million km distance then just place 1,244 billion tons in two million km distance. In a four-fold heavier pull fleet could then accommodate four times more weight of photovoltaic, which then brings the same power.

Or instead of 10,000 km/sec eject speed reduce it to 2,500 km/sec and use four times more reaction mass.

Coincidentally, the decision for 10,000 km/sec for the ion-beam engine and one million km for the pull fleet to Earth harmonizes well with the state of the art for photovoltaics.

3.5 Protection and recycling of photovoltaics

How much do charged particles from the sun contribute to the degradation of photovoltaics? Is it useful and possible to set up a magnetic field around individual ships of the pull fleet or around the entire pull fleet in order to distract charged particles like the magnetic field of the Earth?

How long does the photovoltaic foil last? How can this be directly recycled on the ships of the pull fleet?

A lot of questions, a lot of necessary research, a lot of new technology that needs to be developed.

4 Place the pull fleet

How do you get 311 billion tons into position a million km away? Certainly not in one piece. Since this mass must constantly brace itself against the gravity of the earth, a failure of the engines would lead to it falling down to Earth.

The energy of an impact of 311 billion-tons that falls from 1 million km is just an order of magnitude lower than the Yucatan meteorite impact that created Chicxulub crater 65 million years ago, leading to the extinction of the dinosaurs.

The pull fleet can consist of any number and mass of individual objects, which together weighs 311 billion tons.

After already having met 2 specifications with simple round numbers, 10,000 km/sec ejection speed of ion beam engines, 1 million km distance to Earth, I will assume without further justification that the pull fleet should consist of the necessary number of 10,000-ton spaceships. That would be 31.1 million ships, whose reaction mass tank is full. With a reaction mass of 4,000 tonnes and assuming that it is on average half full, it would be just under 40 million ships, which are simultaneously in the deployment area of the pull fleet and pull Earth.

4.1 The rocket equation

Because for this chapter of such importance, here is not only the formula, but also text from the Wikipedia article:

> «The Tsiolkovsky rocket equation, classical rocket equation, or ideal rocket equation (also known mistakenly as delta-v) is a mathematical equation that describes the motion of vehicles that follow the basic principle of a rocket: a device that can apply acceleration to itself using thrust by expelling part of its mass with high velocity and thereby move due to the conservation of momentum.
>
> The equation relates the delta-v (the maximum change of velocity of the rocket if no other external forces act) with the effective exhaust velocity and the initial and final mass of a rocket, or other reaction engine.»

$$\Delta V = v_e \ln \frac{m_0}{m_1}$$

V_e Velocity exhaust
m_0 Mass of the rocket with reaction mass
m_1 Mass of the rocket

https://en.wikipedia.org/wiki/Tsiolkovsky_rocket_equation

Using this formula for the ejection speed of fuel and the necessary speeds to Earth orbit or other targets in the solar system results in very frustrating results:

> «Real payload fractions from real rockets are rather disappointing. The Saturn V payload to Earth orbit was about 4 % of its total mass at liftoff. The Space Shuttle was only about 1 %. Both the Saturn V and Space Shuttle placed about 120 metric tons into Earth orbit. However, the reusable part of the Space Shuttle was 100 metric tons, so its deliverable payload was reduced to about 20 tons.»

Flight Engineer Don Pettit 2012 The Tyranny of the Rocket Equation

2013 Don Pettit made a presentation on the subject, whose YouTube video i would highly recommend to understand the problem

Just to increase the ratio of m_0 and m_1 you throw away technology worth hundreds of millions of US$ every time you launch. The “tyranny of the rocket formula” made the extra weight to land this expensive technology impossible. So far, it was only possible to reuse parts of two different space systems: NASA Space Shuttle and SpaceX Falcon 9 and Falcon Heavy.

Only in a few years will the SpaceX BFR Big Falcon Rocket be the first complete and fast reusable spacecraft. This is made possible by new materials that were previously unavailable.

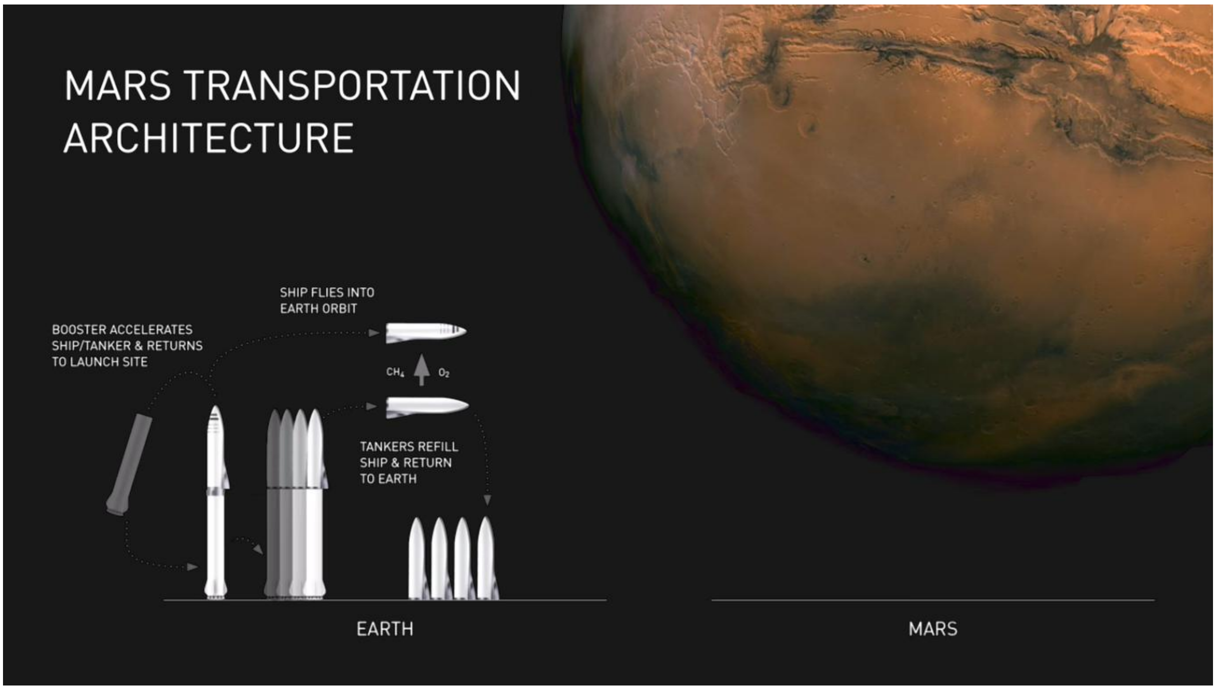
It should be noted here, which luck we have with the size of the Earth. Smaller planets almost completely lose their atmosphere over time, such as Mars. A planet with double the diameter, the same density, and therefore an eightfold mass, would have extremely difficult conditions for space travel at 15.8 km/sec for an orbit.

4.2 The starting method of the BFR - Big Falcon Rocket

SpaceX managed to land the first stage of a Falcon 9 rocket for the first time on December 22, 2015[1]. The reusability of the first stage led to a significant cost advantage, which led to a market-dominant position of SpaceX.

On September 29, 2017, Elon Musk gave a lecture at the International Astronautical Congress in Adelaide, Australia. For a colonization of Mars space travel must be considerably cheaper.

1 Wikipedia Falcon 9 flight 20



Picture 1: Elon Musk SpaceX speech at the IAC in Adelaide 2017 – Video at 33:42
Multiple refueling of the BFR – Big Falcon Rocket in orbit.

The upper part BFS - Big Falcon Ship - arrives in orbit without fuel. The booster flies back to Earth, gets a tanker and starts back to the BFS and hands over 150 tons of fuel, methane and oxygen. Then again booster and tanker land. This procedure must be repeated several times.

Other systems have different payloads depending on whether the target is LEO (Low Earth orbit), GEO (Geostationary Orbit), Moon or Mars. By refueling in orbit, the BFR system has a constant payload to every point in the inner part of the solar system.

Based on the information provided, I estimate 23 kg of methane is needed to bring 1 kg to the deployment area of the pull fleet. The fuel methane and oxygen become water and carbon dioxide and fall back to Earth. Power to Methane[1] can be used to produce methane and oxygen from CO_2 and H_2O.

The system is good for bringing 150,000 tons of material to Mars for a first settlement with a thousand flights, or perhaps it will be used when the first prototypes of the pull fleet are mounted in orbit, but it is far too costly to bring 311 billion tons to the deployment area of the pull fleet, there are 6 orders of magnitude in between.

1: Wikipedia Power to Gas

4.3 Different starting methods and places in comparison

As even SpaceX's BFR system, which is currently under development, is unsuitable for the task, we will examine different starting methods. Not just starting methods, why start from Earth at all?

	Earth	Moon
Methane oxygen rocket	possible	possible
Methane per ton to target	23 t	0.4 t
What happens with reaction mass	falls back to Earth	lost in space
Start with an ion beam	much too few thrust	much too few thrust
Start with a linear motor	impossible	possible

Table 5: Starting methods from Earth or Moon in comparison

A methane oxygen rocket requires much less fuel to launch from the moon, but hydrogen and carbon are very rare on the moon.

Ion-jet engines are very good at delivering thrust with little reaction mass over a long period of time. But even the much weaker gravity of the Moon is far too high to start with an ion-beam engine.

Remains the linear motor[1]. Previously used on the Transrapid and on newer aircraft carriers[2] as a replacement for the steam catapult for launching aircraft. However, for take-off speeds of several km/sec, this is only possible outside the atmosphere, so it can not be used on Earth.

	Earth CH_4 O Rocket	Moon linear motor
Energy for 1 kg to target[3] (kJ)	1.289.037	3.645
Efficiency (Power to Methane[4] vs linear motor)	60 %	90 %
Energy for 1 kg with Efficiency (kJ)	2.148.395	4.050

Table 6: Start from Earth with a chemical rocket vs from the moon with linear motor

1: Wikipedia linear motor

2: Wikipedia Electromagnetic Aircraft Launch System

3: Based on the video from Elon Musk's talk 23 kg of methane at 55,625,000 J/kg
For the linear motor launch from the Moon: $2{,}700^2 / 2 = 3{,}645{,}000$ joules

4: Oxygen and methane burn to CO2 and H2O. It is believed that most of the exhaust gas falls back to earth and can be reused via power to gas. Source of Power to Gas Efficiency: Wikipedia Power to Gas

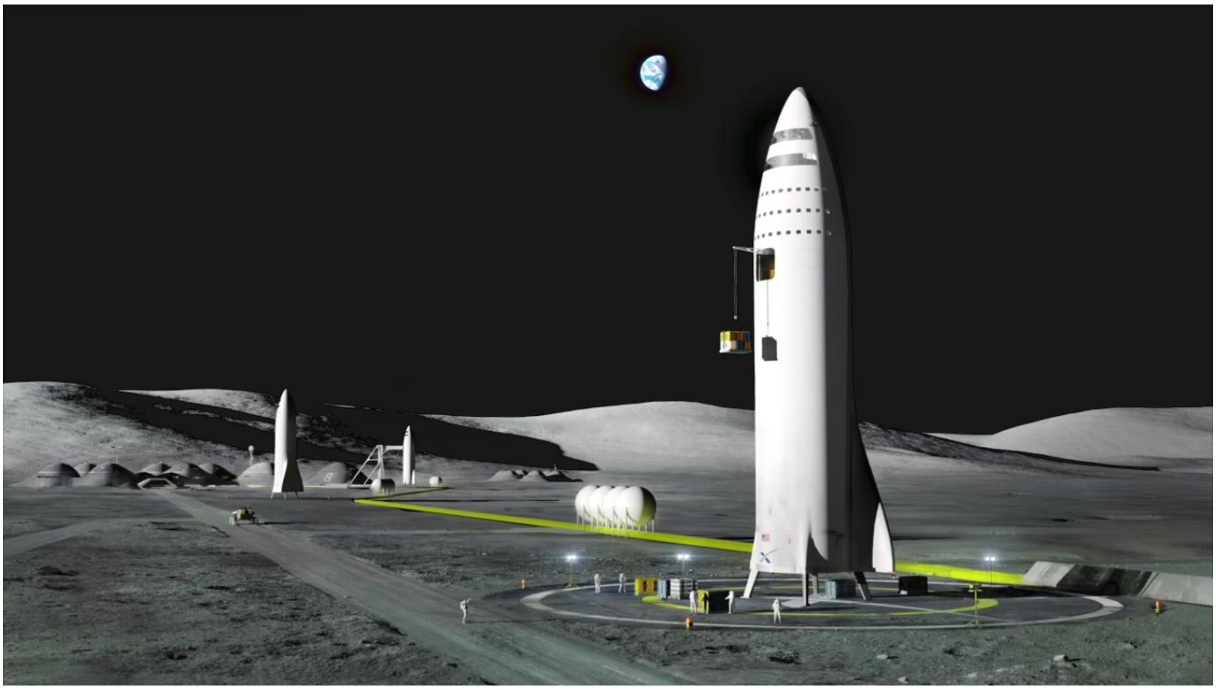
This very drastic difference is only partly due to the lower speed needed to get from the moon to the position of the pull fleet. The rest are the shortcomings of the repulsion drive, which you only use in the most extreme emergency, if you have no other option.

Let's do a thought experiment. Someone with 100 kg weight stands on a 1 kg skateboard. He pushes the skateboard away with 10 m/sec. After the thrust formula, this gives 10 N thrust. This speeds up the 100 kg man to 0.1 m/sec. The energy for pushing the skateboard away is 50 joules.

But if he pushed Earth away instead of the skateboard, he would have reached 1 m/sec with an energy input of 50 joules.

After this overwhelming advantage when launching spacecraft, we now have to investigate whether the moon does not offer further advantages as a production site for the pull fleet.

4.4 Industrial zone Moon



Picture 2: Elon Musk SpaceX Speech at the IAC in Adelaide 2017 – Video at 32:30
On the Moon, a BFR – Big Falcon Rocket is unloaded.

This picture, perhaps as early as 2030 reality, is a 1620 reminiscent of the Mayflower's[1] arrival on what is now the East Coast of the United States. Surprising how similar the data between Mayflower and BFS are: 180 t payload at the Mayflower, 150 at the BFS. 102 settlers and 30 men crew at the Mayflower, 80 to 120 at the BFS. Only 1/4 millennium later, the first transcontinental railroad[2] was opened from the east coast to the west coast.

1: Wikipedia Mayflower

2: Wikipedia First Transcontinental Railroad

	Earth	Moon
Rocket starts	very expensive	with linear motor
Energy costs	high	low
Ground	expensive	cheap
Environmental regulations	expensive and difficult	none necessary

Table 7: Production costs on Earth and Moon in comparison

On Earth you have to expect a 300 watt photovoltaic module and the weight of the elevation with 30 kg. Only 0.01 watts per gram. A light foil would be blown away by the wind. On the Moon, on the other hand, you can easily roll out the same thin foil as for the ships of the pull fleet. With a ring cable around the Moon, the night side can be supplied with electricity. This gives 2 to 3 orders of magnitude lower energy costs for mining and industry.

On Earth, there will soon be 10 billion people competing to use the surface for a variety of tasks.

On Earth there is weather in the atmosphere, water and tectonics. All of these things can lead to mining waste products going to the wrong place and poisoning biological life there. Nothing of this exists on the Moon.

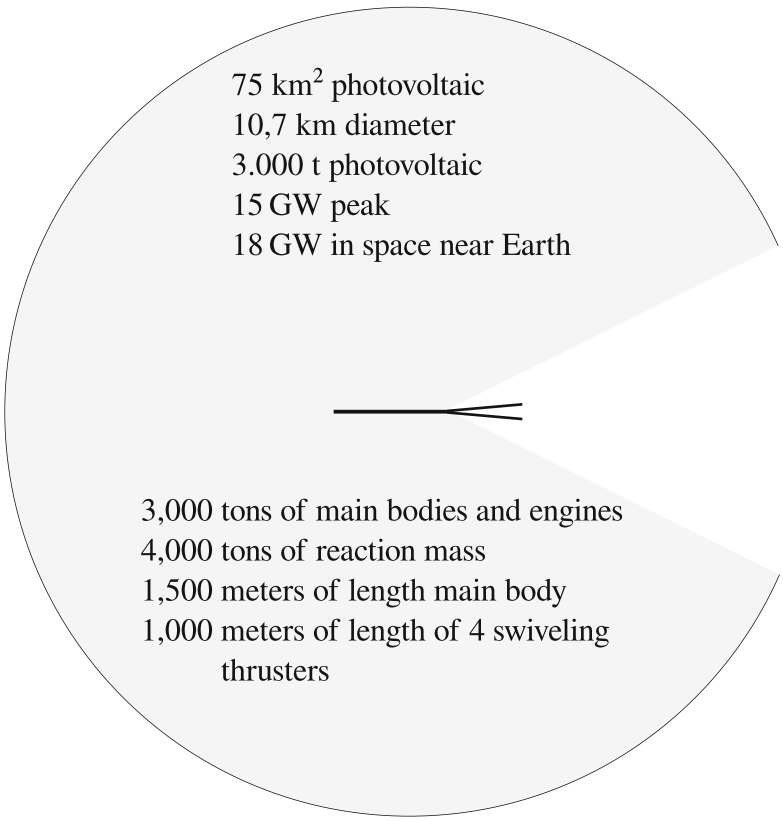
With the expected advances in industrial robots and fully automatic production, the Moon offers extreme locational advantages for the production and launch of the pull fleet.

4.5 Spaceships of the pull fleet

With the specifications of 10,000 t, 5 watts peak per gram of complete photovoltaic system, 20 % efficiency of photovoltaics, swivelling engines, so that the ion beam can always be directed past other objects, but the sum of the individual forces results in the desired thrust vector.

Each of the 4 engines is one kilometer long because it needs 4.5 GW to be transmitted to the propulsion jet. This also makes it clear why it is absolutely necessary to avoid hitting something with the drive jet: The energy corresponds to the explosion of 1,075 kg TNT[1] per second.

For the start from the Moon, the photovoltaic system is folded forwards and backwards and the spaceship is mounted on a take-off train. After starting, the photovoltaic is deployed. From then on, the spacecraft is exposed only to minimal forces.

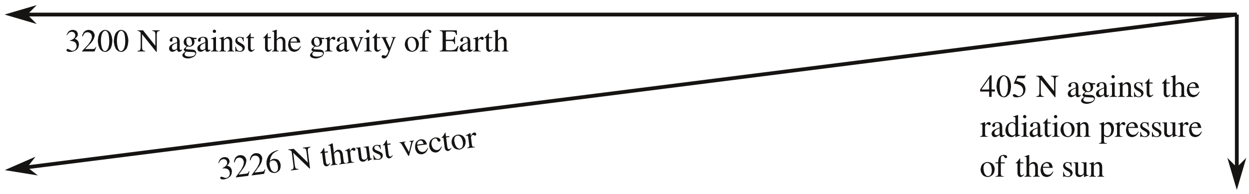


For 75 km^2 of photovoltaics, you have to consider things that otherwise do not matter:

The radiation pressure[2] of the sun.

With little reflection this could be 5.4 µPa. Acting on 75 million m^2, these are 405 Newton's of unwanted drift that needs to be compensated.

Picture 3: A ship of the pull fleet



Picture 4: Parallelogram Gravity and radiation pressure

1: Wikipedia TNT equivalent: 1 g contains 4.184 Joule

2: Wikipedia Radiation pressure

The energy of the 75 km^2 photovoltaic must always be consumed immediately. The engines therefore run in the deployment area of the pull fleet constantly with 18 GW. The respectively required thrust is achieved by a different ejection speed and different amount of reaction mass.

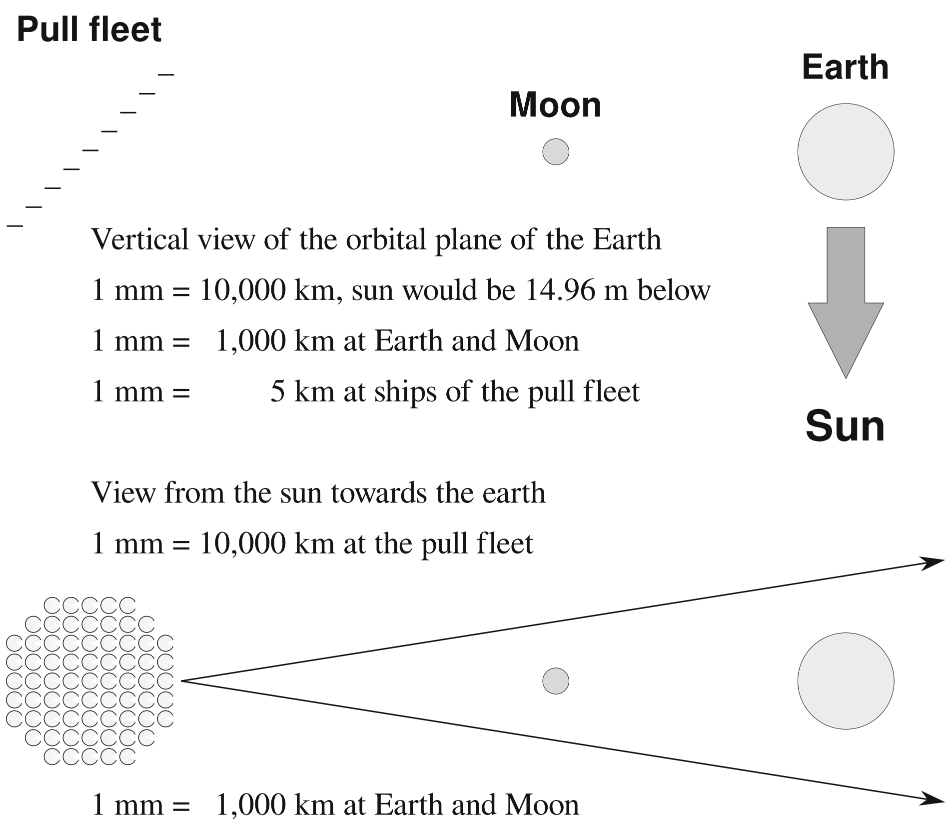
Hold position at 1 million km distance from Earth with 4,000 tons of reaction mass on board.	4,055	Newton thrust
	8,875	km/sec ejection speed
	0.457	g reaction mass / sec
	0.404	mm / sec^2 acceleration
Hold position at 1 million km distance from Earth with 500 tons of reaction mass on board.	2,654	Newton thrust
	13,565	km/sec ejection speed
	0.196	g reaction mass / sec
	0.404	mm / sec^2 acceleration

Table 8: Keep position at 1 million km distance from Earth

It's a simple equation. The thrust formula must give the desired thrust, the kinetic energy formula must give the available energy, after deducting the energy required for the ionization of the reaction mass.

4.6 Deployment area of the pull fleet

The spaceships must be positioned so that each receives full sunshine and the direction for the engine beams is free.



Picture 5: Deployment area of the pull fleet

Because of the need for all ships to have full sunshine, this setup results in distances of 900,000 to 1,100,000 km. In order to optimize the reaction mass requirement, ships with full reaction mass reserves are placed 1.1 million km away. With the gradual consumption of the reaction mass, the position is changed to ever closer positions to Earth, down to 900,000 km, where the departure for refueling is imminent.

Hold position[1] at 1.1 million km distance from Earth with 4,000 tons of reaction mass on board. Direct after the start from the Moon.	3,359 10,715 0.314 0.333	Newton thrust km/sec ejection speed g reaction mass / sec mm / sec^2 acceleration
Hold position at 1,1 million km distance from Earth with 3,500 tons of reaction mass on board. After returning from refueling.	3,194 11,270 0.283 0.333	Newton thrust km/sec ejection speed g reaction mass / sec mm / sec^2 acceleration
Hold position at 1 million km distance from Earth with 2,000 tons of reaction mass on board.	3,253 11,065 0.294 0.404	Newton thrust km/sec ejection speed g reaction mass / sec mm / sec^2 acceleration
Hold position at 0.9 million km distance from Earth with 500 tons of reaction mass on board. Before departure for refueling.	3,263 11,030 0.296 0.498	Newton thrust km/sec ejection speed g reaction mass / sec mm / sec^2 acceleration

Table 9: Engine parameters at different positions of the pull fleet

With the change of position in the pull fleet depending on the level of the reaction mass a very uniform consumption of reaction mass is achieved. With 3,000 tons, between return from refueling and to departure for refueling, the position can be held for 326 years.

1: Acting gravity see section 2.8 footnote 5
Required thrust see section 2.8 footnote 6
The ejection speed is given by the following equation:

Given is thrust, $18 \cdot 10^9$ joules of energy, the ionization energy of hydrogen, the ejection speed is sought:

Ejection speed · reaction mass = thrust

Ejection speed^2 · reaction mass / 2 + reaction mass · hydrogen ionization per kg = $18 \cdot 10^9$

4.7 Key figures on the industrial zone Moon

The Moon industrial zone will develop around the equator. Production target for the project to bring Earth into a higher orbit is 5,000 ships each with 10,000 tons per year. This is not about details, but a first estimate of the magnitude. Let's assume 50 kWh of electricity per kg from mining to leaving the Moon via the linear motor start system. 5,000 ships · 10,000 tons · 50 kWh per kg are only 2,500 TWh, 285 GW with even consumption. That is only four times the power requirement of Germany. All you need is a 380 m wide photovoltaic foil around the equator[1].

If half of the consumption is on the dark side of the moon and another 10 % near the day / night limit, where photovoltaic power is already significantly lower, then 171 GW will have to be redistributed around the moon.

The largest HVDC line[2] is currently the 2,210 km long from Hami to Zhengzhou[3] with 800 kV and 8 GW. Around the Moon, it's only five times as long, and nearly 22 times more power is needed. A major component of the lunar surface is Al_2O_3 alumina, since aluminum is almost as good a conductor as copper is therefore the logical material for the line.

A 500 mm aluminum line around the half moon has only 0.74 ohm resistance[4]. Operated with 5 MV and 40 kA you get there already 200 GW over it.

4.8 The first linear motor starting system on the Moon

In the first expansion phase, the linear motor rail is to bring a pull ship with 1 G acceleration to 2.7 km/sec, from the moon directly to the deployment area of the pull fleet. The ship is mounted on a take-off train to transfer the forces evenly over the entire length of the ship. At 1,679 m/sec, gravity and centrifugal force cancel each other out; at 2.7 km/sec, the centrifugal force is already 2.6 m/sec^2 greater than gravity.

After the ship and take-off train have separated, the take-off train is braked and drives back to the space station. With a 500 km long system, a start is possible every 25 minutes, but the track shows only a small part of the month in the ideal direction. That is why with a launch rail no 5,000 starts per year are possible.

In the last second before the separation of ship and take-off train, 405 GW are needed for 10,000 tons of ship and 5,000 tons take-off train. Local power storage is therefore necessary to cover this peak power. The total starting up to the return of the take-off train with a reasonable efficiency calculated are only 12 GWh.

1: Theoretically, a photovoltaic aligned parallel to the surface on the equator of a rotating celestial body has a yield of 1 / π compared to directly aligned with the sun.
Because of more reflection losses at shallow angles, only 29 % are assumed here.

2: Wikipedia High-voltage direct current

3: Wikipedia UHVDC Hami Zhengzhou

4: Calculated by Chemandy.com Round Wire Resistance Calculator

4.9 Equator linear motor takeoff and landing system

For the next phase, the requirements are much higher. It should be able to achieve much higher launch speeds and the system should also serve for landing. The centrifugal force limits the maximum achievable speed:

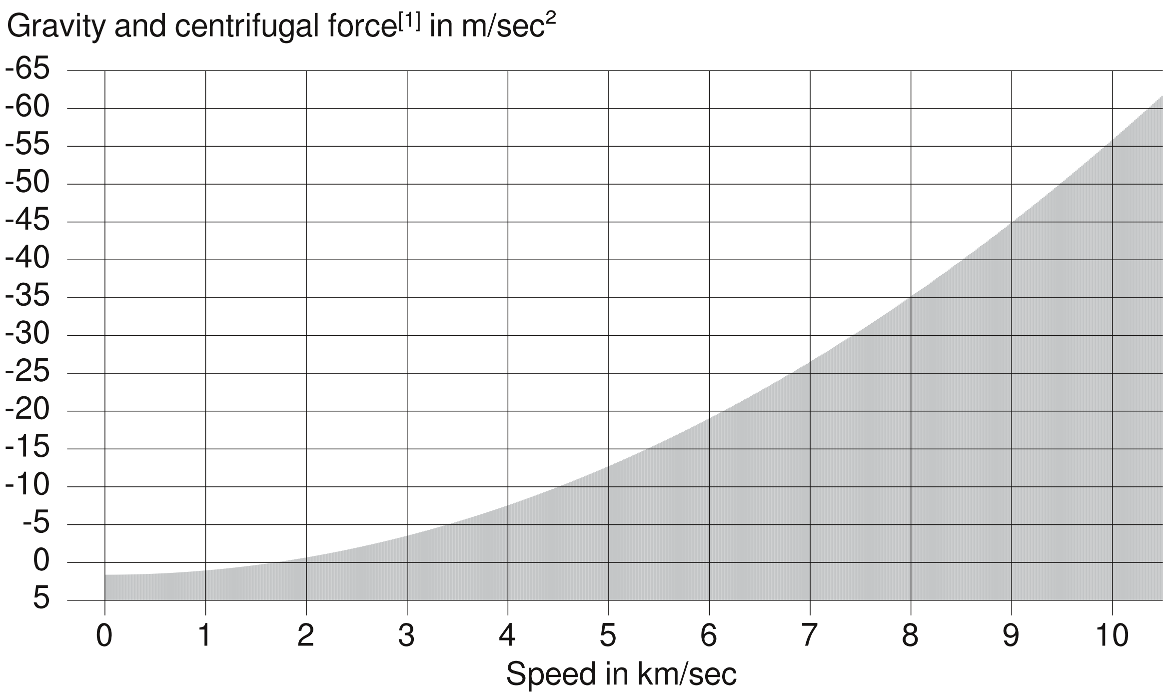


Table 10: Gravity and centrifugal force on the linear motor rail around the moon

The take-off train continues after the separation from the spaceship the round around the moon to the space station. Starts can be made in any direction in the plane of the lunar orbit.

It is also possible for multiple take-off trains to travel simultaneously on the linear motor rail when the number of take-offs and landings requires it.

For a landing, a rendezvous point is determined where spacecraft and train are traveling parallel at the same speed. The train then grabs the spaceship and begins to brake. Because of the much higher requirements, a complete new construction is necessary.

1: Gravity and centrifugal force at the Moon linear motor rail

$$\boxed{\begin{array}{l}\text{Gravity on the lunar}\\ \text{surface}\\ 1.62\ \text{m/sec}^2\end{array}} - \frac{\boxed{\begin{array}{l}\text{Speed}\\ \text{e.g.: 2,700 m/sec}\\ \text{e.g.: 8,000 m/sec}\end{array}}^{\,2}}{\boxed{\begin{array}{l}\text{Radius Moon}\\ \text{1,737,100 m}\end{array}}} = \boxed{\begin{array}{l}\text{Influential force}\\ \text{e.g.: -2.77 m/sec}^2\\ \text{e.g.: -35.32 m/sec}^2\end{array}}$$

5 The reaction mass supply of the ion beam engines

It is about $2.55 \cdot 10^{21}$ kg. That's 3.47 % of the Moon's mass, or 2.71 times the mass of the dwarf planet Ceres, the largest object in the asteroid belt. Ceres has 964 km in diameter. Almost 3 Ceres have to be accelerated to 10,000 km/sec for the maneuver by the ion-beam engines, just to make that figure clear.

5.1 Basic decision reaction mass

Before you can accelerate reaction mass with an electric field, the reaction mass must first be brought into a state to respond to this electric field. This is done by ionization.

	Atommasse	Ion 1 kJ/mol	Ion 1 kJ/kg	Max thrust at m/sec
Hydrogen[1]	1.008	1,312.0	1,301,587	51,021
Helium[1]	4.003	2,372.3	592,690	34,429
Oxygen[1]	15.999	1,313.9	82,124	12,816
Silicon[1]	28.085	786.5	28,004	7,484
Xenon[1]	131.293	1,170.4	8,914	4,222

Table 11: Ionization energy of different elements

The maximum thrust is achieved when the available energy is used 50 % for ionization and 50 % for the acceleration of the reaction mass. For hydrogen, the ionization energy is so high that this equilibrium is reached just over 51 km/sec. The table clearly shows why xenon is so popular in ion beam engines at the moment, needs very little energy for ionization.

At higher ejection speeds, the energy fraction for ionization becomes completely meaningless. With the high reaction mass requirement, only material can be selected which is present in very large quantities.

On the Moon, Ceres and other objects in the asteroid belt, the moons of Jupiter and Saturn, oxygen and silicon are present. Considering the entire mass of the solar system, however, oxygen and silicon are very rare materials. Hydrogen and helium are much more common, these are the main components of the sun and the large gas planets.

This $2.55 \cdot 10^{21}$ kg reaction mass is just the need to the end of the main sequence. Then our sun gradually becomes a red giant, the ideal Earth orbit beyond Jupiter, Saturn, Uranus and Neptune. Maybe the only solution is to move these planets to an even higher orbit? Maybe this maneuver has to be done at just 1,000 km/sec ejection speed, so that the power requirement is only 1,000 and not 10,000 times higher. Maybe then we do not need $2.55 \cdot 10^{21}$ kg, but $2 \cdot 10^{26}$ kg of reaction mass.

This is significantly more than all solid planets, dwarf planets and solar system moons taken together, but less than 1 % of the mass of gas giants.

The fundamental decision to use by far the most common materials in the solar system is a technical challenge to obtain.

1: Wikipedia Ionization energies of the elements

5.2 Air breathing ion beam engines

Again, there are already technical approaches. It's not like that, there's the atmosphere, there's space. Much more the air density with increasing height decreases continuously.

In a 260 km high orbit, the ESA satellite GOCE consumed around 10 kg of xenon per year to hold the altitude. The power for the engine supplied photovoltaic, so was already a much longer period of use of the satellite, as with a chemical drive, possible.

On March 5, 2018, ESA[1] published its first laboratory tests on the first ion beam engine, which will use the few air molecules at 200 km altitude.

5.3 Harvest reaction mass in orbit around the large gas planets

This first test is all about having a satellite catch as much air as is necessary to keep the altitude up against air resistance with the ion-beam engine.

Harvesting reaction mass in the orbit from Jupiter is much more difficult with 3 factors:

1.) It's not just about keeping up, but also filling up around 4,000 tons of reaction mass tank.

2.) The orbit speed is 5 times higher at Jupiter

3.) Jupiter is more than 5 times farther from the Sun

It is not intended to store electricity in ships of the pull fleet. Even in Jupiter orbit, the 75 km^2 of photovoltaics still provide 800 MW. Even with an optimistic 500 Wh/kg battery, 500 MWh would require 1,000 t of rechargeable batteries. If the ship sinks too far on the night side of Jupiter, it is lost.

So here's a trick to work with: Let's investigate the possibility that the pull ship will hang a long tube into a deeper orbit, on which a device for collecting reaction mass will hang. The bag hangs at a height where the residual atmosphere is 100 times denser than at the pull ship.

Scale height[2] is the term used to calculate how many km difference in altitude 100 times more density is to be expected. A 100 times higher density is to be expected downwards at scale height · ln (100).

What must the hose endure? An orbit is where centrifugal force and gravity exactly cancel each other out. Below, gravity is higher and speed slower because the sack has the same orbital time around the planet, but the orbit is shorter.

The orbit radius is assumed to be 15 scale heights over the radius of the planet.

1: ESA space engineering & technology - world first firing of air-breathing electric thruster

2: Wikipedia Scale height

	Jupiter	Saturn	Uranus	Neptune
Scale height (m)	27,000	59,500	27,700	19,700
Orbit pull ship[1] (m/sec)	41,977	24,904	14,935	16,517
Length of the hose[2] (m)	124,340	274,008	127,563	90,722
Pull at the bag[3] (mm/sec^2)	127	137	127	119

Table 12: Forces on a hose that is 15 scale heights long

Results over 1 m/sec^2 would have been regarded as critical for the idea, reason to examine the distribution of forces on the entire hose and the available materials exactly. Of these critical values, all four gas planets are far away. The values are surprisingly close together.

1: orbit radius = radius of the planet + 15 * scale height

Radius of the planet

e.g.: 71,492,000 m (Jupiter)
e.g.: 60,268,000 m (Saturn)
e.g.: 25,559,000 m (Uranus)
e.g.: 24,764,000 m (Neptune)

+ 15 ·

Scale height

e.g.: 27,000 m (Jupiter)
e.g.: 59,500 m (Saturn)
e.g.: 27,700 m (Uranus)
e.g.: 19,700 m (Neptune)

With the orbit radius, the orbit speed can now be calculated:

$$\sqrt{\frac{\text{Gravitational constant} \cdot \text{Mass of the planet}}{\text{Orbit radius from the calculation above}}} = \text{Orbit speed ship in m/sec}$$

Gravitational constant

$6.674080 \cdot 10^{-11}$

Mass of the planet

e.g.: $1.898200 \cdot 10^{27}$ kg
e.g.: $5.683400 \cdot 10^{26}$ kg
e.g.: $8.681000 \cdot 10^{25}$ kg
e.g.: $1.024300 \cdot 10^{26}$ kg

Orbit radius from the calculation above

e.g.: 71,897,000 m
e.g.: 61,160,500 m
e.g.: 25,974,500 m
e.g.: 25,059,500 m

Orbit speed ship in m/sec

e.g.: 41,976.99
e.g.: 24,903.72
e.g.: 14,935.06
e.g.: 16,516.69

2: Length of the hose = scale height · ln (100)
Because in several subsequent calculations needed, we calculate the flight radius of the bag here.

Orbit radius ship		Scale height		Flight radius bag
e.g.: 71,897,000 m	- ln (100) •	e.g.: 27,000 m	=	e.g.: 71,772,660 m
e.g.: 61,160,500 m		e.g.: 59,500 m		e.g.: 60,886,492 m
e.g.: 25,974,500 m		e.g.: 27,700 m		e.g.: 25,846,937 m
e.g.: 25,059,500 m		e.g.: 19,700 m		e.g.: 24,968,778 m

3: Pull on the bag. This must be calculated to determine if such a long hose is feasible at all. The angular velocity in orbit is the same, but the orbit radius is reduced by the length of the pipe.

$$\frac{\text{Flight radius bag}}{\text{Orbit radius ship}} \bullet \text{Orbit speed ship} = \text{Flight speed bag}$$

Flight radius bag	Orbit radius ship	Orbit speed ship	Flight speed bag
e.g.: 71,772,660 m	e.g.: 71.897.000 m	e.g.: 41,976.99 m/sec	e.g.: 41,904.40 m/sec
e.g.: 60,886,492 m	e.g.: 61.160.500 m	e.g.: 24,903.72 m/sec	e.g.: 24,792.15 m/sec
e.g.: 25,846,937 m	e.g.: 25.974.500 m	e.g.: 14,935.06 m/sec	e.g.: 14,861.71 m/sec
e.g.: 24,968,778 m	e.g.: 25.059.500 m	e.g.: 16,516.69 m/sec	e.g.: 16,456.90 m/sec

Next step: The acting force is gravity less centrifugal force.

$$\text{Gravitational constant} \bullet \frac{\text{Mass of the planet}}{\text{Fight radius bag}^2} - \frac{\text{Flight speed bag}^2}{\text{Flight radius bag}}$$

Gravitational constant: $6,674080 \cdot 10^{-11}$

Mass of the planet	Fight radius bag	Flight speed bag	Flight radius bag
e.g.: $1.898200 \cdot 10^{27}$ kg	e.g.: 71,772,660 m	e.g.: 41,904.40 m/sec	e.g.: 71,772,660 m
e.g.: $5.683400 \cdot 10^{26}$ kg	e.g.: 60,886,492 m	e.g.: 24,792.15 m/sec	e.g.: 60,886,492 m
e.g.: $8.681000 \cdot 10^{25}$ kg	e.g.: 25,846,937 m	e.g.: 14,861.71 m/sec	e.g.: 25,846,937 m
e.g.: $1.024300 \cdot 10^{26}$ kg	e.g.: 24,968,778 m	e.g.: 16,456.90 m/sec	e.g.: 24,968,778 m

Result see table.

After the idea has stood up the first check, how much reaction mass can be harvested per second at all, how long does it take to refill the almost empty reaction mass tank with maybe 100 t rest to 4,000 t?

The limiting factor is the available thrust of the engine, which must be used to compensate for the forces on the ship, hose and bag. First of all, it is estimated that 70% of the impacting matter can be captured and processed. Part of the material that has just been harvested must be used as reaction mass right in the engine. What remains comes into the reaction mass tank.

	Jupiter	Saturn	Uranus	Neptune
Distance to sun (Gm)	779	1,434	2,742	4,495
Orbit around sun (m/sec)	13,056	9,622	6,957	5,434
Photovoltaic output[1] (MW)	797	235	64	24
Ejection speed[2] (km/sec)	102.2	69.4	64.6	67.4
Reaction mass usage[3] (g/sec)	35.6	19.3	5.8	2.0
Thrust[4] (N)	3,639	1,340	377	138
Fill the tank[5] (g/sec)	51.4	44.4	15.7	5.0
Time for 3,900 t (years)	2.405	2.782	7.860	24.826

Table 13: Reaction mass harvesting at the gas giants

This table did not take into account:

Saturn: Axis tilt and effect of shading by the ring.

Uranus: has a very extreme axial inclination.

Neptune: Axis tilt.

This first overview gave very surprising results, because Saturn's significantly lower photovoltaic power was almost compensated by the lower speed difference between orbit and equatorial rotation.

1: The radiation decreases with the square of the distance to the sun.
A cool photovoltaic has a better efficiency. For this 20 % addition.

2: The available energy is given, to optimize the harvest result, only the ejection speed can be varied.

Step 1: How many joules are needed for 1 kg of reaction mass at discharge speed N, assuming a 1 : 1 mixture of hydrogen and helium:

$$\frac{\boxed{\begin{array}{l}\text{Ionization energy}\\ \text{for 1 kg hydrogen}\\ \text{1,301,587,302 J}\end{array}} + \boxed{\begin{array}{l}\text{Ionization energy}\\ \text{for 1 kg helium}\\ \text{592,689,752 J}\end{array}}}{2} + \frac{\boxed{\begin{array}{l}\text{Ejection speed}\\ \text{e.g.: 70,000 m/sec}\\ \text{e.g.: 102,200 m/sec}\\ \text{e.g.: 150,000 m/sec}\end{array}}^{2}}{2}$$

3: Step 2: How much reaction mass can be processed per second. The average of the photovoltaic power during an orbit is assumed to be 29 % of the maximum.
Of these, 95 % are converted into drive power.

Average energy for propulsion

219,700,847 J

―――――――――――― =

Result from the above calculation, effort per kg of reaction mass

e.g.: 3,397,138,527 J
e.g.: 6,169,558,527 J
e.g.: 12,197,138,527 J

Reaction mass per sec

e.g.: 0.064672 kg
e.g.: 0.035610 kg
e.g.: 0.018012 kg

4: Thrust = Reaction mass per second · Ejection speed

Reaction mass per sec	·	Ejection speed	=	Thrust
e.g.: 0.064672 kg		e.g.: 70,000 m/sec		e.g.: 4,527 N
e.g.: 0.035610 kg		e.g.: 102,200 m/sec		e.g.: 3,639 N
e.g.: 0.018012 kg		e.g.: 150,000 m/sec		e.g.: 2,702 N

5: With the thrust, the braking effect of matter hitting on ship, hose and bag must be compensated.

Thrust / impact speed = compensable mass.

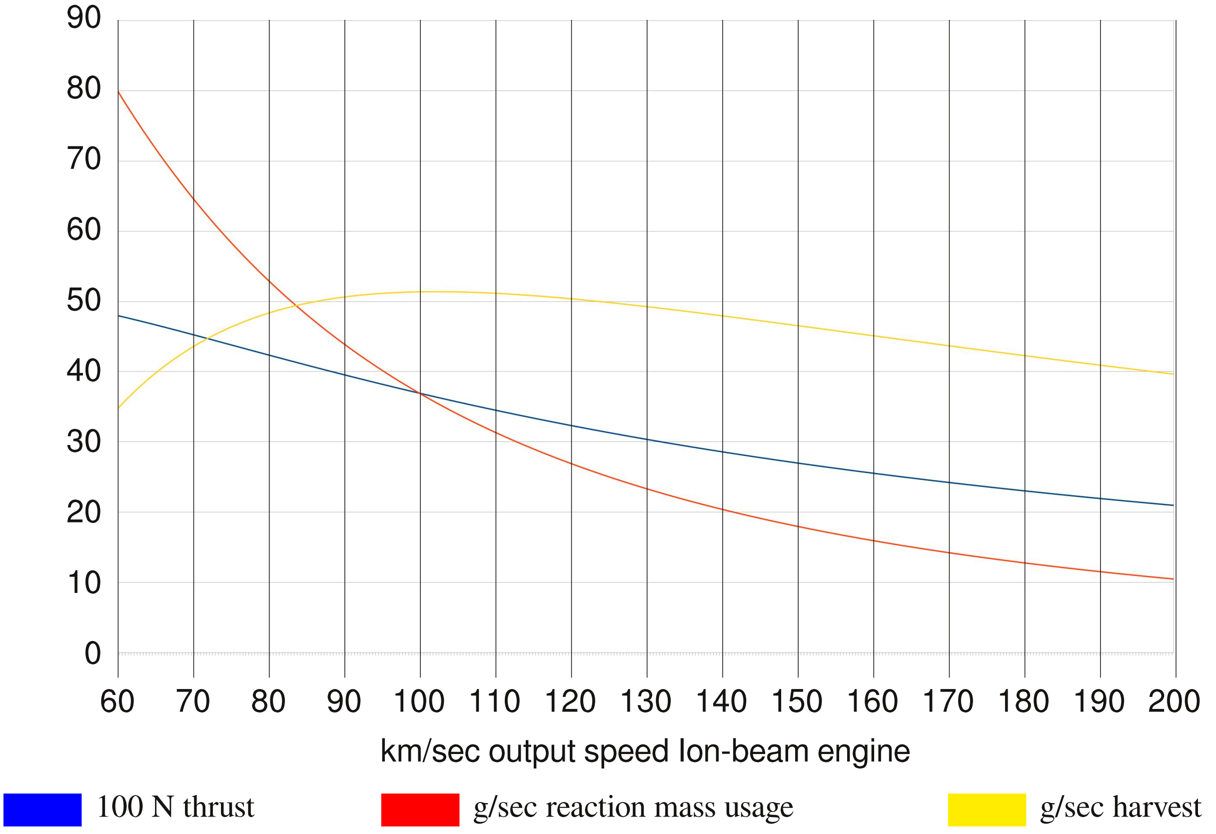
The impact speed is:

Speed of bag - Rotation speed at the equator

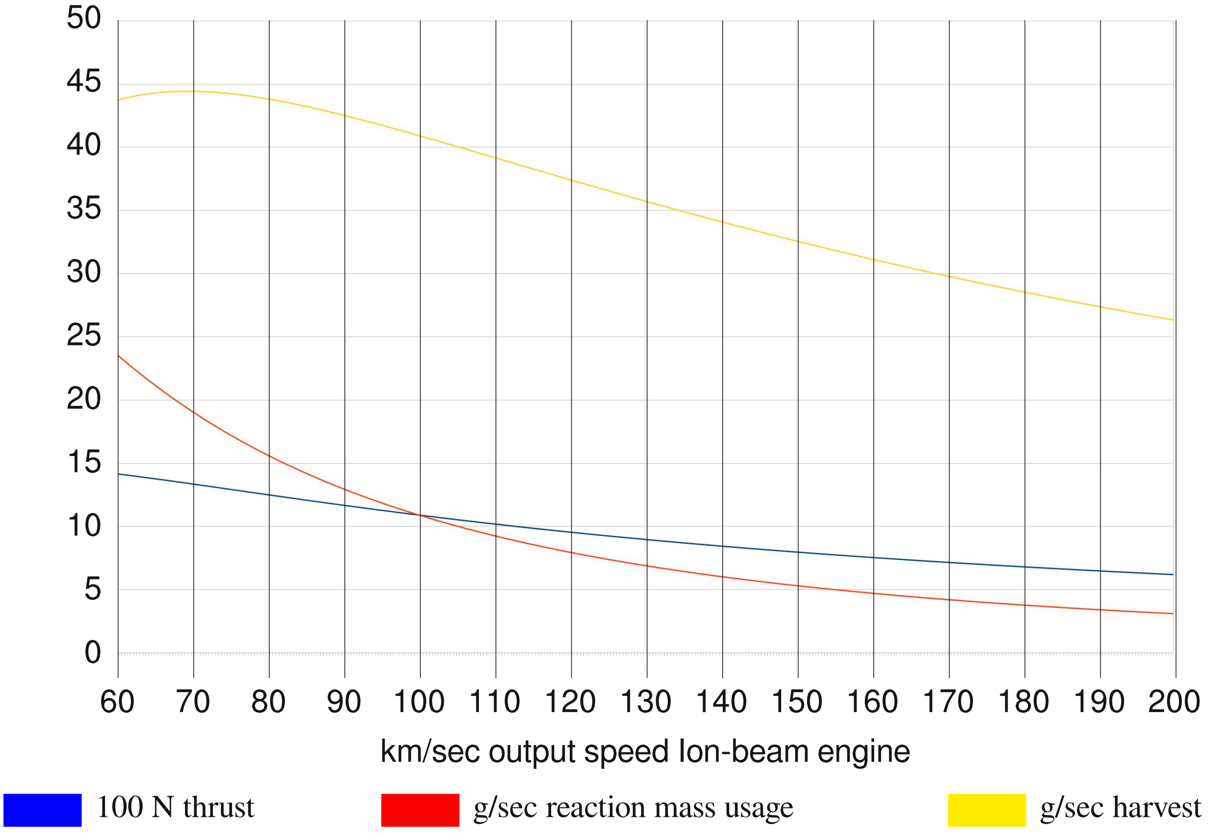
The rotation speed at the equator is 12.6 km/sec at Jupiter,
which is more than the escape velocity from Earth.

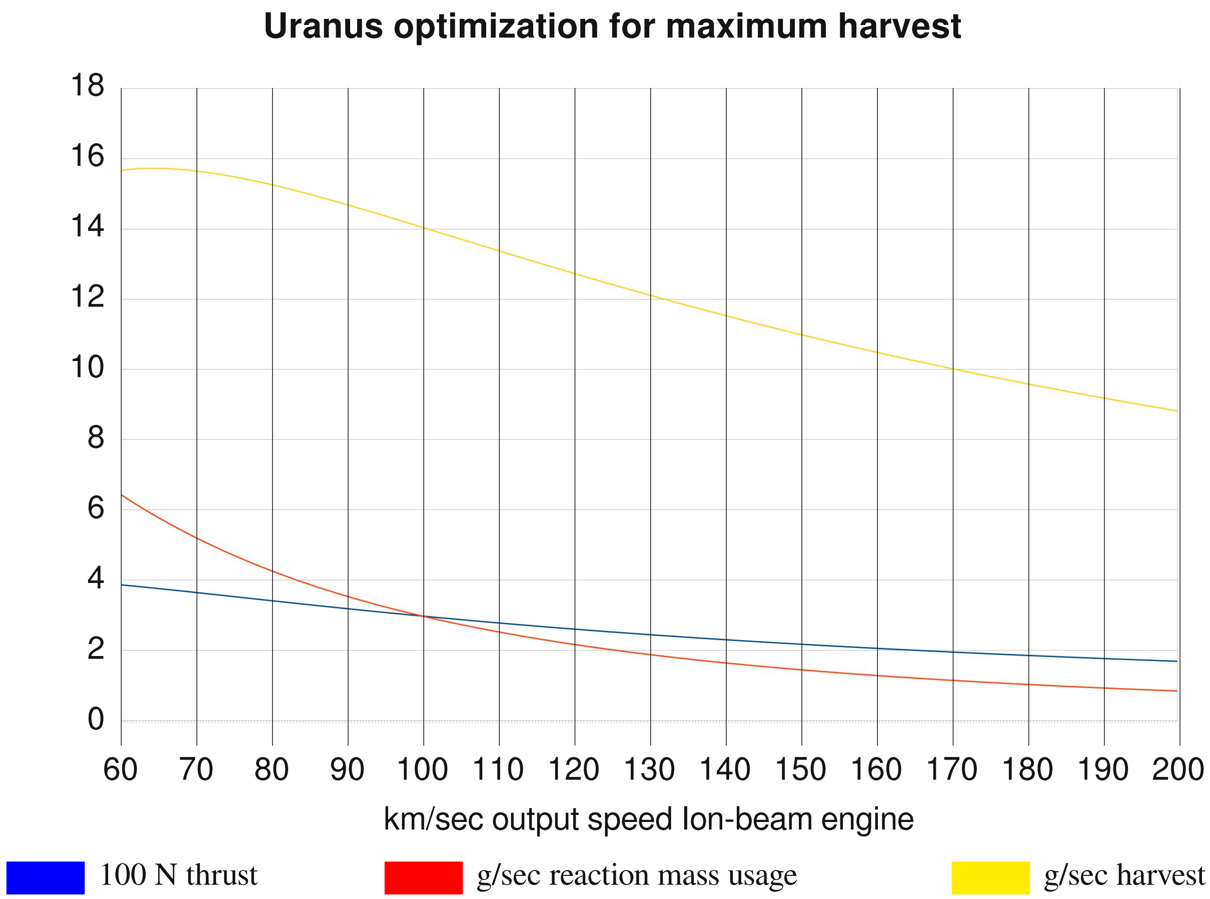
It is believed that 70% of the hitting mass can be used. Part of the catched mass has to be used as a reaction mass. The rest is available to fill the reaction mass tank.

Jupiter optimization for maximum harvest



Saturn optimization for maximum harvest




Uranus optimization for maximum harvest
18
16
14
12
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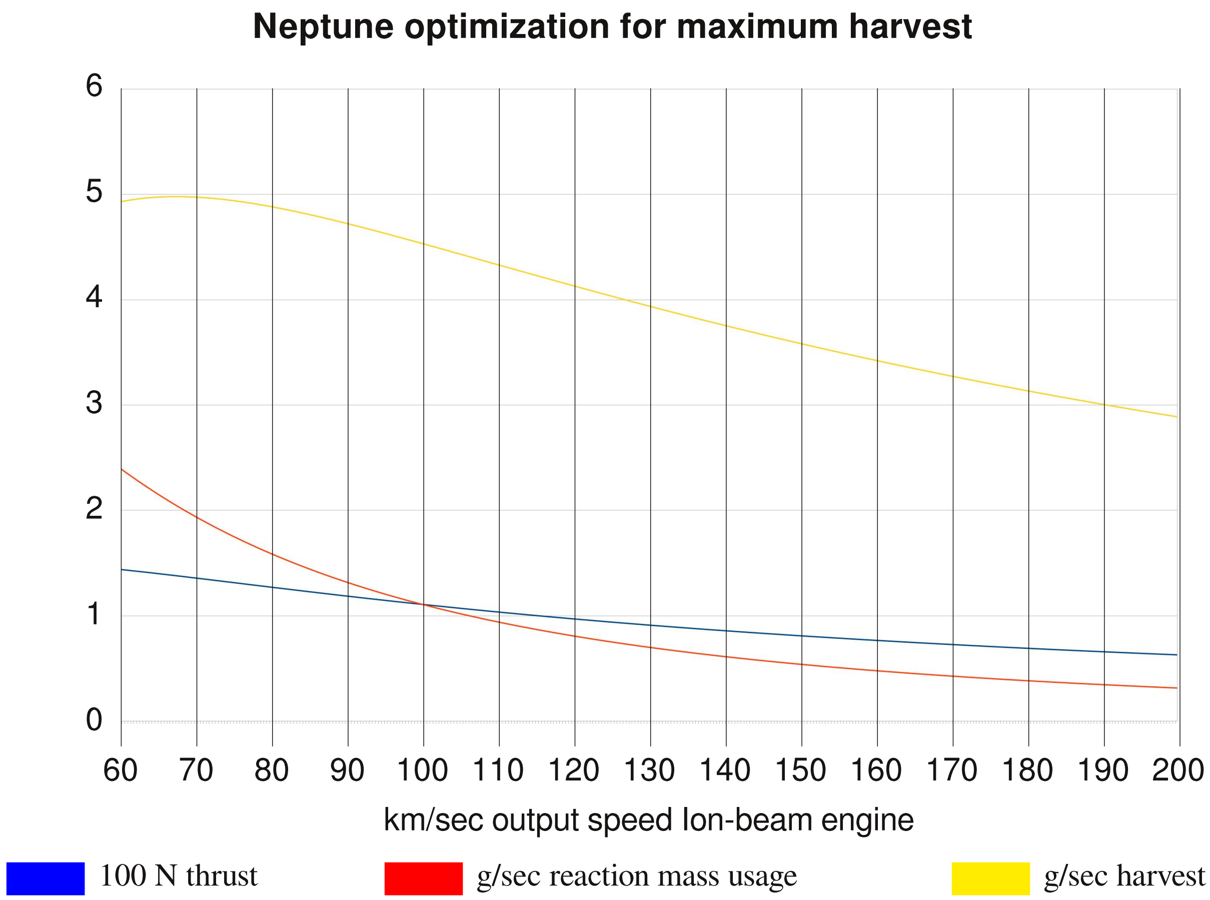
60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
km/sec output speed Ion-beam engine
100 N thrust
g/sec reaction mass usage
g/sec harvest


Neptune optimization for maximum harvest
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60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
km/sec output speed Ion-beam engine
100 N thrust
g/sec reaction mass usage
g/sec harvest

5.4 Traffic congestion in Jupiter orbit

It was already clear that refueling takes a little bit longer than if a firefighting plane just takes 10 tons of water out from a river, but the calculation shows several years for this process.

Jupiter is big, but even if you place a spaceship in orbit every 100 km, you only have 4,500 pieces of space there. With the very long dwell time to collect the reaction mass, this is probably by 2 orders of magnitude too few.

Intersecting orbits seem as impossible as parallel orbits that can only be sustained using the engines. Redistributing half of the traffic to Saturn and Uranus also brings far too little traffic relief.

The entire pull fleet will not be built in a year, not even in 1,000 years. A realistic schedule would be 10,000 years. First, it's about testing and perfecting the technique. Only when you are very sure about a useful life of well over 10,000 years, mass production will begin.

In the first phase, the ships of the pull fleet will still gather reaction mass in a low orbit around Jupiter. But as soon as the mass production starts, a better solution for the reaction mass pickup on Jupiter is needed.

5.5 New traffic model for Jupiter necessary

With traffic congestion of 2 orders of magnitude, radically new approaches have to be found. The pull fleet is about 40 million ships simultaneously busy pulling the Earth. Several million ships are still on the way to get reaction mass and fly back to the area of operation. If this process takes 24 years, there are 3 million ships, but this process takes only 16 years, there are only 2 million ships.

The entire refueling process can be divided into 5 sections:

1.) From the pull fleet near Earth to Jupiter
2.) Reduce orbit height
3.) Collect reaction mass
4.) Increase orbit height
5.) Return flight from Jupiter to the pull fleet near Earth

Going down into a low orbit to collect reaction mass is a much greater speed change than from Earth to Jupiter. This change in speed is also under much less favorable conditions than from Earth to Jupiter. On the way to Jupiter, the energy output of photovoltaics is reduced from 18,000 MW to 797 MW because of the greater distance to the sun. When the orbit becomes lower, an ever larger part of the orbit is in the shadow of Jupiter. The photovoltaic can not be aligned to the sun, but must be parallel to the trajectory. The average power is reduced to about 29 %, only 231 MW.

It would be ideal if a pull ship could take over the reaction mass several million km away from Jupiter and then fly back immediately.

5.6 Ring planet Jupiter

Again, the constraints hit. We will soon have two planets with a ring in our solar system. Saturn with a natural and Jupiter with an artificial one.

First, we need a new type of ship, the ring segment ship. As the name implies, each of these ships forms a segment of a ring around Jupiter in a low orbit.

Because of the limitations of the linear motor start system on the moon to 10,000 tons, a ring segment ship is only 1 km long and has only 10 km to the left and right each photovoltaic. Together 20 km^2 of photovoltaic contribute 800 tons to the weight. Later, 90 km of photovoltaic will be added to each side, making the ring 200 km wide. After the launch from the moon on its way to Jupiter, the ring segment ship unites with two photovoltaic elements, each weighing 3,600 tons, each 90 km^2, which are also launched from the moon only a few seconds away. For this, the photovoltaic elements have course correction engines.

Single ring segment ships are equipped with additional facilities. The device long hose and large bag to collect the reaction mass or the device to create from the collected hydrogen a cylindrical 800 m long and 10 m diameter ice block with 2 Kelvin.

At the ends of the cylinder position correction engines are then attached. Their only task is to turn the cylinder so that the cylinder always points towards the Sun during the flight. These are supplied with 2,000 m^2 photovoltaic foil.

If an ice block is ready, it will be picked up by one of the take-off trains. There are several hundred take-off trains on the linear engine start and landing system on the ring. At the right point, the starting train accelerates the ice block by almost 17 km/sec to transfer it into an elliptical orbit, where the rendezvous with a pull ship or other ship type takes place 5 million km away on the other side of Jupiter.

Ring orbit height	71,897 km
Ring orbit speed	41,977 m/sec
Ice block ellipse[1] Perigee height	71,897 km
Ice block ellipse Perigee speed	58,940 m/sev
Ice block ellipse Apogee height	4,928,103 km
Ice block ellipse Apogee speed	860 m/sec
Transfer ring to ellipse Perigee	16,963 m/sec
Time start until takeover	1,103,299 sec
Escape speed at Apogee	7,170 m/sec
Transfer Apogee to escape speed	6,311 m/sec
Gravity of Jupiter im Apogee	5.216 mm/sec^2
Gravity of the Sun at Earth	5.930 mm/sec^2

Table 18: Trajectory data from the Ring of Jupiter to the takeover point

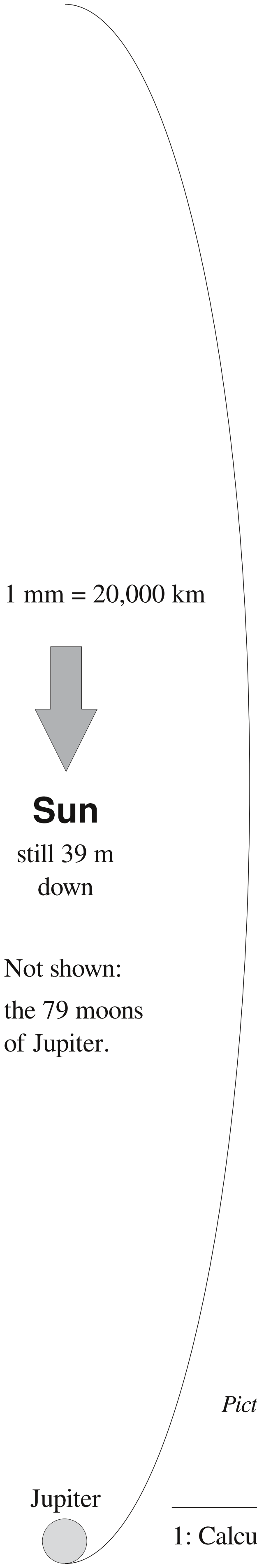
On average, a 4,000-tonne block of ice is launched every 4 minutes on the journey to the takeover point.

A million km from Earth, a pull ship can only fly away by increasing its thrust. Only 0.404 mm/sec^2 of gravity must be overcome.

At the takeover point at the apogee of the ellipse, however, are 5.216 mm/sec^2, more than three times as much as maximum thrust is available. A pull ship can here only reach in spirals a higher and higher orbit until it finally manages to get away from Jupiter.

The flight times are essentially determined not by the distance, but by the speed differences to be overcome. It's like a car driving serpentine for serpentine uphill because the direct route to the mountain top is too steep.

In order to save reaction mass, arrival and departure from the reaction mass takeover point should be done with 500 km/sec ejection speed. This takes about a year in the area of Jupiter.



Pictrure 6: The ellipse from the Ring of Jupiter to the takeover point

1: Calculation of the elliptical orbit with Omnialculator.com Dominik Czernia

5.7 Electricity in the shadow of Jupiter

A ring segment ship has 200 km^2 of photovoltaic, which delivers 2,126 MW when oriented towards the sun. Throughout the rotation an average of 617 MW remains. How do you get the electricity to the part of the ring that is being shadowed by Jupiter?

When it comes to electricity, there are small consumers such as the hundreds of take-off trains or the devices that separate the harvested reaction mass for hydrogen and helium and produce the ice blocks from the hydrogen. The bulk consumers are the ion beam engines.

Do the engines on the shaded side need to be powered? When about 129 t of Jupiter's residual atmosphere per second causes resistance, this develops 3.8 GN of deceleration. If this deceleration is compensated only on the sunny part of the ring, tensile forces of 2 GN are created. This clearly shows that the engines on the shaded side of the ring need to be powered.

	Moon	Earth 2100	Jupiter ring
Lenght of the ring (km)	10,915	40,006	452,000
Day/night period (hours)	709	24	3
Total electric power (GW)	285	30,000	300,000

Table 19: Transfer power from the day side to the night side

At the moon, it is a trifle, 500 mm aluminum conductors with 5 MV and 40 kA. In the case of the earth is the consideration, power storage or lines. But if you calculate that out of 300,000 GW about 200,000 GW have to be redistributed, then you get into very extreme combinations. About 1 GV with 200 kA. A GV can blow through several kilometers of air, which we can observe at every thunderstorm.

A 700 mm thick aluminium cable has 16 Ohm resistance at 226,000 km. Two of these ladders would be equal to 2,077 tons in each ring segment ship even without insulation.

How about batteries? Even before a ring segment gets into the shadow of Jupiter, the photovoltaic is so obliquely to the sun that significantly less power comes. So we expect 2 hours of storage per rotation, 1,416 MWh. The next generation lithium batteries should have 400 Wh/kg. These are 3,540 tons of batteries. The useful life of batteries is specified in charging cycles, the ring rotates in just under 3 hours around the Jupiter, makes 8 charging cycles per day. Even an extremely durable battery with 20,000 charging cycles would then be ready for recycling after only 7 years.

With flywheels? With 40 Wh/kg we would be at 35.540 tons additional weight per ring segment ship. At this point, we prefer to return to the aluminum ring conductor. Perhaps it will be possible to use such high voltages that the 700 mm lines are sufficient, perhaps 200 MV is the maximum and two rectangular 20 m high 100 mm wide ladder with 10,800 tons are mounted after the start in addition to a ring segment ship to transfer 200,000 GW with 200 MV and 1 MA. Why so flat and rectangular? Because of the larger area for the radiation of power loss.

5.8 Comes an ice block flown

How does a ice block from frozen hydrogen survive the nearly 13 days of flying from the Ring of Jupiter to the takeover point? The position correction engines turn the block in the first hours towards the sun. This reduces the sun-drenched area from 8,000 m^2 to 80 m^2.

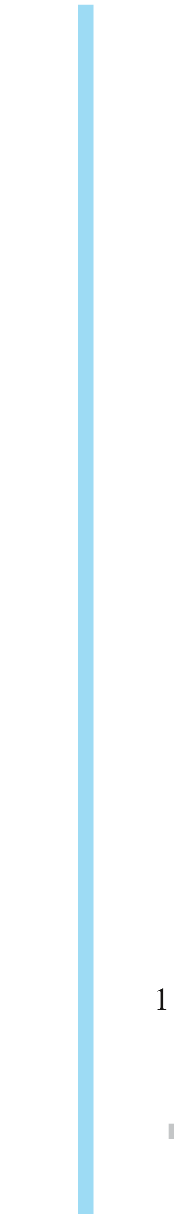
	Hydrogen	Helium
Melting point (K)	13.99	0.95
Heat of fusion (J/kg)	58,036	3,448
Boiling point (K)	20.71	4.22
Heat of vaporization (J/kg)	448,413	20,712
Heat capacity (J/(kg·K))	14,304	5,192
From 0,5 K to vaporization (J/kg)	789,244	43,472
Vaporization per m^2 and hour (kg)	0.23	4.18

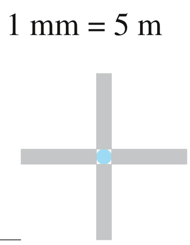
Table 20: How fast does hydrogen and helium evaporate

The evaporation is measured after the solar irradiation at Jupiter. The values are calculated with 100 % absorption because I did not find any information about the reflection of frozen hydrogen. On the way to the takeover point, less than 0.3 % of the ice block is likely to be lost.

Since helium is completely unsuitable for shipping as an ice block, hydrogen and helium are separated in the ring. Helium is used as the preferred reaction mass for the engines of the ring.

The 23.4 % mass fraction of helium in the Jupiter atmosphere is not quite sufficient to operate the engines, so some hydrogen is needed in addition.





Picture 7: Ice block with position correction engines

Side view rear view

At the rear are 4 pieces 10 m x 50 m large photovoltaic modules for the supply of the position correction engines. These supply 20 kW near the Jupiter.

5.9 Logistics of reaction mass supply

The ring is clearly oversized for shifting Earth alone. Sure is sure, from the necessary speed changes forth is a deep Jupiter orbit is a very difficult reachable point in our solar system.

	Ring segment	Entire ring
Ring segment ships[1]	1	452,000
Photovoltaic area (km^2)	200	98,400,000
Average photovoltaic output (MW)	617	303,418,433
Thrust with 107.6 km/sec ejection speed (N)	8,373	3,784,802,464
Reaction mass hydrogen helium (kg/sec)	0.078	35,175
Harvesting after all deductions (kg/sec)	0.091	41,121

Table 21: Performance data of individual ring segment ships and the Jupiter ring

Part of the material just harvested must be used to compensate for the braking effect. If a starting train accelerates a 4,000-tonne block of ice to the transfer point by almost 17 km/sec, then the opposite force acts on the ring. This must also be compensated. The optimum production is at 107.6 km/sec ejection speed of the engines. The engines point slightly diagonally downwards, so that the reaction mass hits Jupiter again.

1 mm = 5 m

Here is an estimate of the traffic around Jupiter. It is assumed that a pull ship needs one year to approach the takeover point and leave the area around Jupiter.

Spaceships from and to the takeover point	131,500
Ice blocks from the ring to the takeover point	4,600
Container from drop point to ring	1

Table 22: Traffic density in the area of Jupiter

Analogous to the procedure to transport the reaction mass for the spaceships as an ice block to the takeover point, there is also a method where transport ships bring a container on a trajectory, where it is intercepted by a take-off train on the ring. In a container the same size as an ice block, 10,000 sets of position correction drives could be inside, which are then attached to the ice blocks.

Picture 8: Container with course correction engines.

To supply the ring containers are used, which are brought by a transport ship in an elliptical orbit, which is exactly parallel to a take-off/landing train on the ring in the perigee.

The container is equipped with course correction engines, which are powered by 2 pieces of 800 m x 50 m photovoltaic. At Rendezvous ice block pull ship, the pull ship must make the course corrections. However, since a rail vehicle can not make course corrections, this must be done here by the container.

1: Same calculation as for a ship of the pull fleet, only the params changed to 85 % instead of 95 % of the electricity and 65 % instead of 70 % utilization.

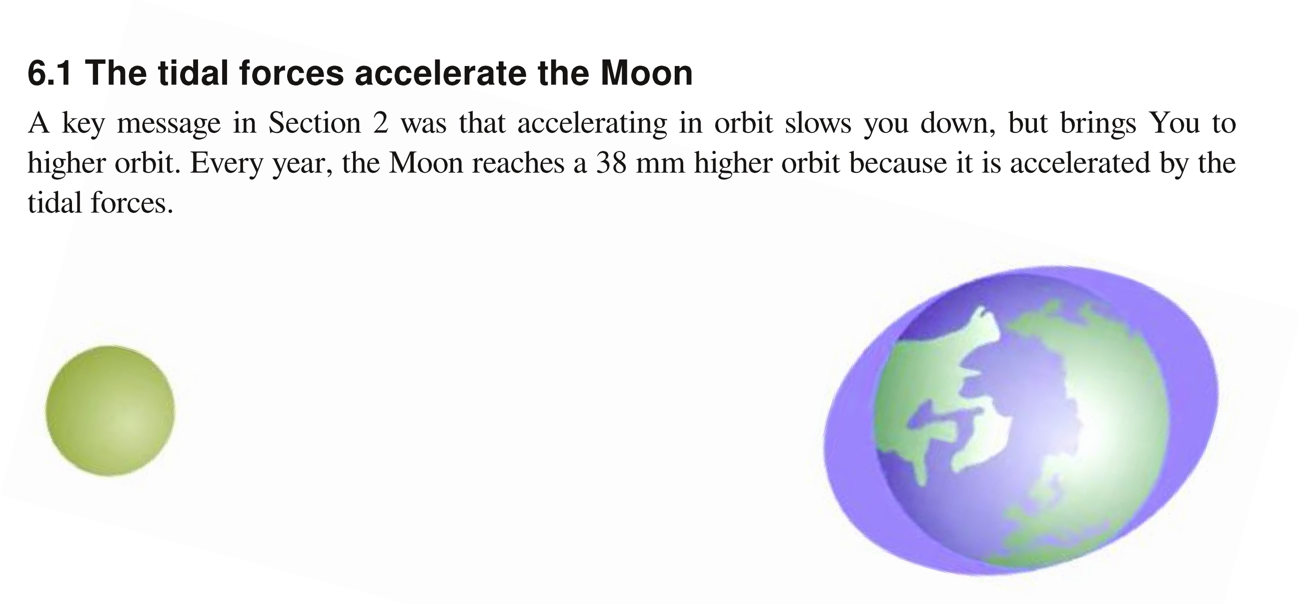
6 The Moon should stay where it is

Shall, but he does not. Even without any human influence, the Moon moves away 38 mm from Earth each year. The pull fleet adds another impact on the lunar orbit. For the Moon to stay where it is, several forces must be compensated.

Since the Moon has no atmosphere, the engines can be installed directly on the surface. At each point of the lunar orbit, the orbital forces have to be compensated immediately.

6.1 The tidal forces accelerate the Moon

A key message in Section 2 was that accelerating in orbit slows you down, but brings You to higher orbit. Every year, the Moon reaches a 38 mm higher orbit because it is accelerated by the tidal forces.



Picture 9: How the tidal forces accelerate the Moon.

Heavily overdrawn is here shown the faster rotation of the Earth anticipatory flood mountain. Anton Petrov "Why Is Moon Moving Away From Earth?"

In order to compensate for this acceleration of the Moon by the tidal effect of Earth[1], a thrust of 107 MN against the direction of the moon is necessary.

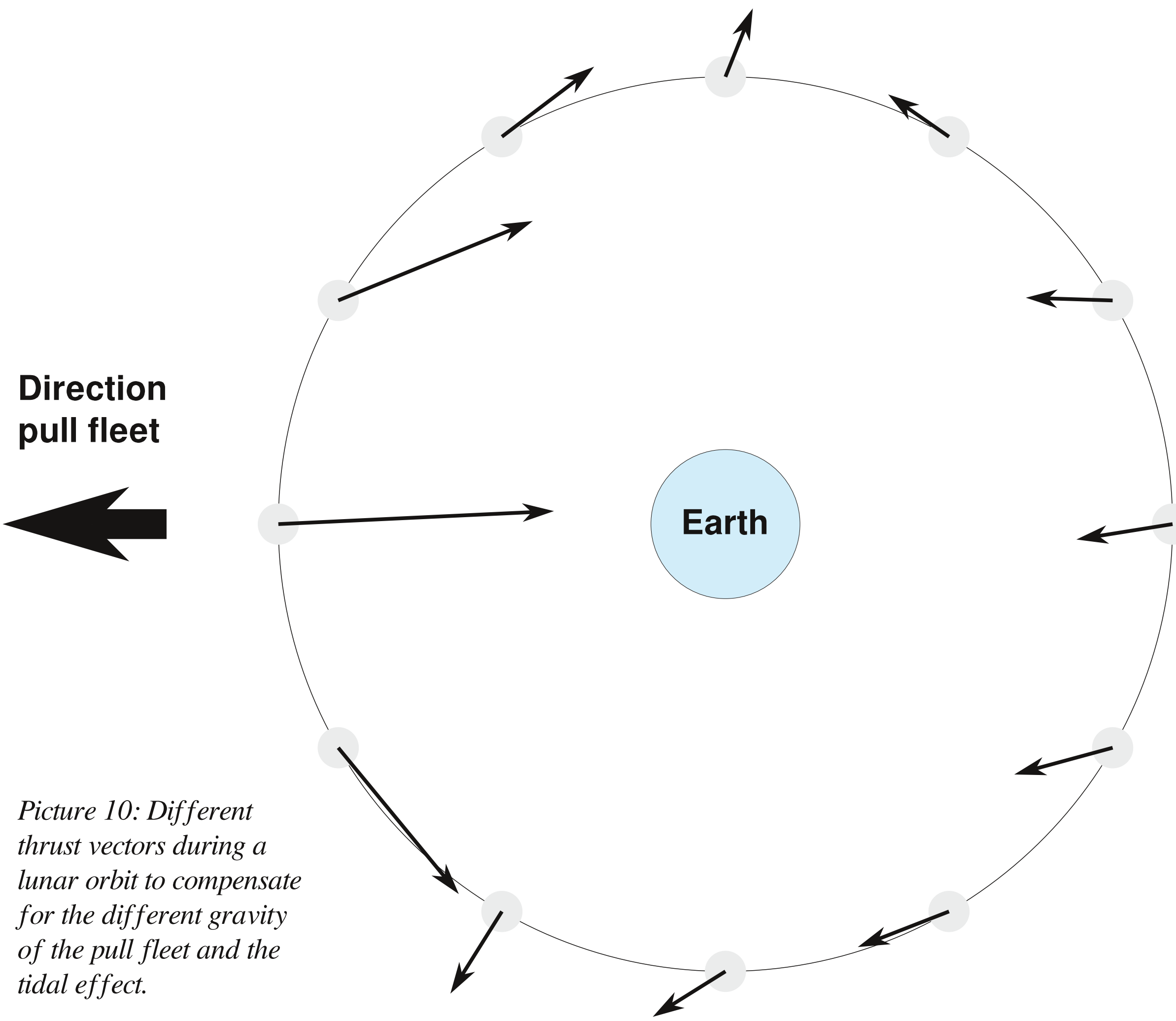
1: So that the speed difference is already visible in the first decimal places, we calculate the orbit speed for today and in one million years with a 38 km higher orbit. To simplify the calculation we use a circular orbit.

$$\sqrt{\frac{\text{Gravitational constant } 6.674080 \cdot 10^{-11} \;\bullet\; \text{Mass of Earth } 5.972370 \cdot 10^{24}\text{ kg}}{\text{Moon orbit today } 384{,}399{,}000\text{ m; in 1 million years } 384{,}437{,}000\text{ m}}} = \text{Orbit speed today } 1{,}018.305\text{ m/sec; in 1 million years } 1{,}018.255$$

$$\frac{\boxed{\begin{array}{l}\text{Mass of the Moon}\\ 7.342000 \cdot 10^{22}\text{ kg}\end{array}} \bullet \boxed{\begin{array}{l}\text{Speed difference}\\ \text{of the orbits}\\ 0.0503289\text{ m/sec}\end{array}}}{\mathbf{1{,}000{,}000} \bullet \boxed{\begin{array}{l}\text{Seconds in}\\ \text{the average}\\ \text{Gregorian year}\\ 31{,}556{,}952\end{array}}} = \boxed{\begin{array}{l}\text{Thrust to}\\ \text{compensate}\\ 117{,}094{,}479\text{ N}\end{array}}$$

6.2 Compensating unequal forces of the pull fleet

The deployment area of the pull fleet is always 1 million km in the direction of the flight of the earth around the sun. But since the moon orbits around the earth, the direction and distance to the pull fleet is different. In order to avoid a deformation of the lunar orbit, the differences must be compensated. To this must be added the thrust vector to compensate for the tidal forces. The demand for thrust ranges from 474 MN to 2,502 MN.



Picture 10: Different thrust vectors during a lunar orbit to compensate for the different gravity of the pull fleet and the tidal effect.

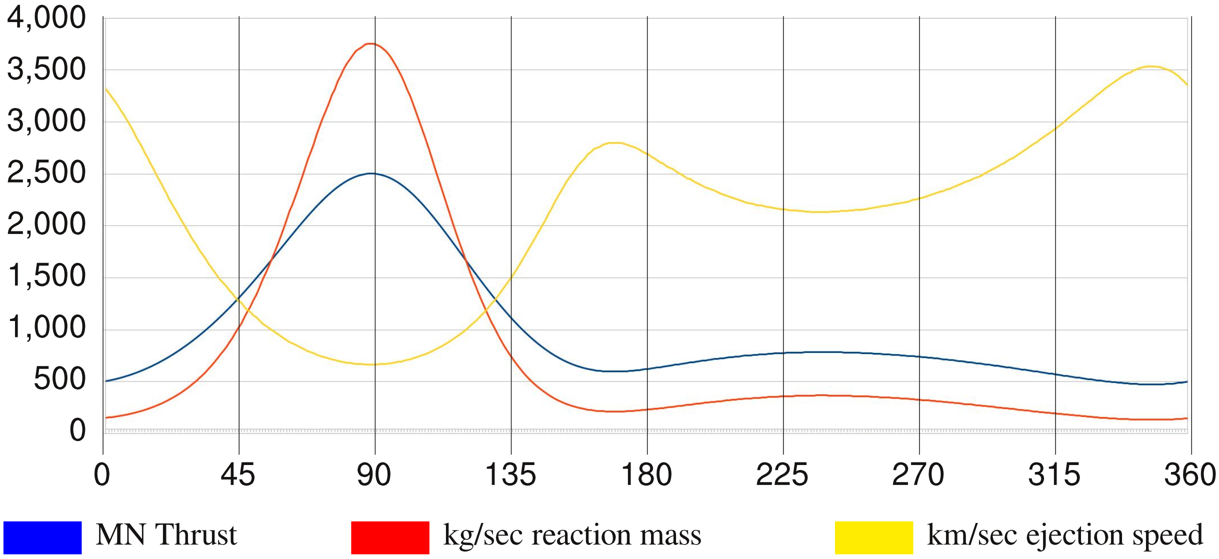


Table 23: Engine data for force compensation during a lunar orbit

Assuming that 840 TW of electricity is available, the maximum required thrust of 2,502 MN is only possible with 3,751 kg/sec of reaction mass because the available energy is only suitable for 667 km/sec ejection speed.

To calculate the reaction mass requirement, a whole lunar orbit was calculated[1].

1: For the calculations, a coordinate system in m is used, PA means path angle to get every position of the Moon during an orbit around Earth.

$$\overrightarrow{\text{Position pull fleet}} = \begin{pmatrix} 0\text{ m} \\ 0\text{ m} \end{pmatrix} \qquad \overrightarrow{\text{Position Earth}} = \begin{pmatrix} 1{,}000{,}000{,}000\text{ m} \\ 0\text{ m} \end{pmatrix}$$

$$\overrightarrow{\text{Position Moon}} = \begin{pmatrix} 1{,}000{,}000{,}000 + 384{,}399{,}000 \cdot \sin(\text{PA})\text{ m} \\ 384{,}399{,}000 \cdot \cos(\text{PA})\text{ m} \end{pmatrix}$$

$$\overrightarrow{\text{Gravity pull fleet on Earth}} = \begin{pmatrix} -2.077982 \cdot 10^{-14}\text{ m/sec}^2 \\ 0\text{ m/sec}^2 \end{pmatrix}$$

$$\overrightarrow{\text{Tidal effect on Moon}} = \begin{pmatrix} -\cos(\text{PA}) \cdot 1.594858 \cdot 10^{-15}\text{ m/sec}^2 \\ -\sin(\text{PA}) \cdot 1.594858 \cdot 10^{-15}\text{ m/sec}^2 \end{pmatrix}$$

$$\overrightarrow{\text{Compensation}} = (\overrightarrow{\text{Gravity pull fleet on Moon}} - \overrightarrow{\text{Gravity pull fleet on Earth}}) - \overrightarrow{\text{Tidal effect on Moon}}$$

To get from an acceleration in m/sec^2 to a thrust in Newton, one only has to multiply by the mass of the Moon:

$$\overrightarrow{\text{Thrust for Compensation}} = \overrightarrow{\text{Compensation}} \cdot \text{Mass from the Moon}$$

The average over the entire lunar orbit is fortunately only 838 kg/sec. At this usage, a transporter will land every 79 minutes using the Moon equator linear motor system and deliver 4,000 tonnes of reaction mass from Jupiter. Similarly, a transport ship must make its journey to the takeover point at Jupiter every 79 minutes. Some of these transporters will carry a container with 10,000 position correction engines which will be stuck on the ice blocks or bring other goods for the Jupiter ring.

6.3 Can be shortened in the compensation?

If you multiply and divide by the same number in an equation, you can shorten it. The pull fleet is always 1 million km towards Earth's trajectory, but as the Earth revolves around the Sun, this direction changes 360 degrees.

That raises the question, can one shorten in the compensation of forces or not? Since I do not trust myself to answer this question correctly and more important all well-founded, I leave it in the somewhat more difficult scenario without shotening.

6.4 Christo got the Moon

The maximum required 2,502 MN thrust is 2 % of the thrust of the entire pull fleet. In the pull fleet would be 800,000 ships with 60 million km^2 photovoltaic responsible for this thrust.

Either we are now dealing with fantastic wireless energy transfer facilities over millions of kilometers in the petawatt area or we are packing large parts of the moon into photovoltaics.

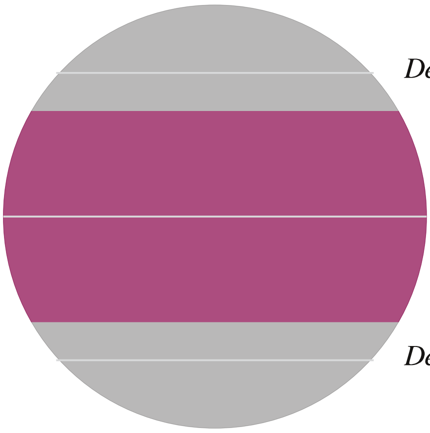
Picture 11: Earth and Moon photographed from Lagrange Point[1] 1.

Photo NASA 2015: From a Million Miles Away, NASA Camera Shows Moon Crossing Face of Earth

1: Wikipedia Lagrangian point

The Moon only looks bright from the night side of the earth. In direct comparison with the Earth, the Moon is very dark. Here the visible side facing away from the Earth is brighter than the side we see from the Earth (Picture last page).

Therefore, the photovoltaic surface will hardly change the appearance, which is perceptible from the Earth to the naked eye.



Picture 12: Division of the lunar surface

One idea for this would be to mount the photovoltaic on 20 m high columns in a grid with 100 m distance. This keeps the surface underneath usable. According to the standard assumption for this work, 1 ha of photovoltaic have only 2,000 kg of mass. Only makes 3,240 N pressure on the Moon.

The engines must be swiveling, under 1.62 m/sec^2 gravity at the lunar surface is therefore a considerably shorter length than the pull fleet possible. Therefore only 100 m with 450 MW per piece. 840 TW thus require 1.87 million engines. At pro ha an engine, this is only 18,700 km ^{2}.

6.5 We need a second Moon to stabilize the Earth's rotation

Remains the problem that the rotation of Earth[1] decreases. Also, by compensating the tidal effect from Earth to the Moon, the force still acts on the Earth and slows down the rotation.

Not every moon drifts away. The moon Phobos[2] is getting closer and closer to Mars. The difference is, Phobos orbits Mars faster than Mars rotates. Then comes the opposite effect with the tides, in which obviously not only water is involved.

Since there are probably no simple formulas and probably the computing power of super-computers is necessary for a simulation, I leave here only a suggested topic for a study:

«We need a second Moon. How the Earth's rotation can be kept constant by placing an artificial celestial body much lower than in geostationary orbit.»

1: Wikipedia Earth's rotation

2: Wikipedia Phobos loses per year 20 mm height

7 Collision protection

This work covers a period of over 6 billion years. The last catastrophic meteor impact was just 66 million years ago. What if today an astronomer discovers a similarly sized meteorite that will strike in 3 years? Today's humanity would be as helpless in this situation as the dinosaurs were 66 million years ago. This impact was not an isolated case.

There are even larger impact craters, there is a list of controversial structures[1], where science is not yet sure if it is really a impact crater, with up to 600 km in diameter.

Not acting at changing the Earth orbit will have consequences only in the distant future, but no possibility of fending off a larger meteorite, may have immediate consequences. The pull fleet's ability to influence the trajectory of a meteorite could therefore be an important argument in favor of the project.

7.1 Those in darkness drop from sight

The perceptibility of objects in our solar system, but far from the sun, decreases with the fourth power of the distance to the sun. The light coming from the sun decreases with the square of the distance. Then this light is reflected and decreases with the square of the distance to the Earth. An object 100 billion kilometers away is only 1/10,000 as clearly visible as an object 10 billion kilometers away.

> «The Oort cloud, named after the Dutch astronomer Jan Oort, sometimes called the Öpik–Oort cloud, is a hypothetical cloud of predominantly icy planetesimals proposed to surround the Sun at distances ranging from 2,000 to 200,000 AU »
>
> https://en.wikipedia.org/wiki/Oort_cloud
>
> «Planet Nine is a hypothetical planet in the outer region of the Solar System. Its gravitational effects could explain the unlikely clustering of orbits for a group of extreme trans-Neptunian objects (eTNOs)»
>
> https://en.wikipedia.org/wiki/Planet_Nine

The recalculation of the trajectory of Oumuamua[2] revealed that this object from outside our solar system had come close Earth up to 24 million km. It was only discovered in October 2017, after it had already increased distance to 33 million km.

If just a 100 km object were heading for Earth 10 billion kilometers away, we could not register it. The visibility would be much lower than that of Oumuamua.

Insurance calms, so we now examine the qualities of the pull fleet as collision protection insurance[3].

1: Wikipedia List of impact craters on Earth

2: Wikipedia Oumuamua

3: Wikipedia Asteroid impact avoidance

7.2 Methods of trajectory influencing

There are several theories for influencing the trajectory of meteorites. These can be divided into three groups:

1.) Remote effect from the earth through energy beams.

2.) A spaceship flies towards the object and makes path-influencing measures in passing. For example, explode some hydrogen bombs.

3.) A spaceship lands on the object and then begin the path-influencing measures. For example, install an engine or drill a deep hole into which a hydrogen bomb is sunk.

There are some known dangerous objects that repeatedly cross the Earth's orbit and eventually hit. However, the greater danger potential may be objects from the interstellar space, whose approach is discovered very late, where countermeasures must start immediately after the measurement of the trajectory. This eliminates all methods where the object first has to be flown towards in a time-consuming manner.

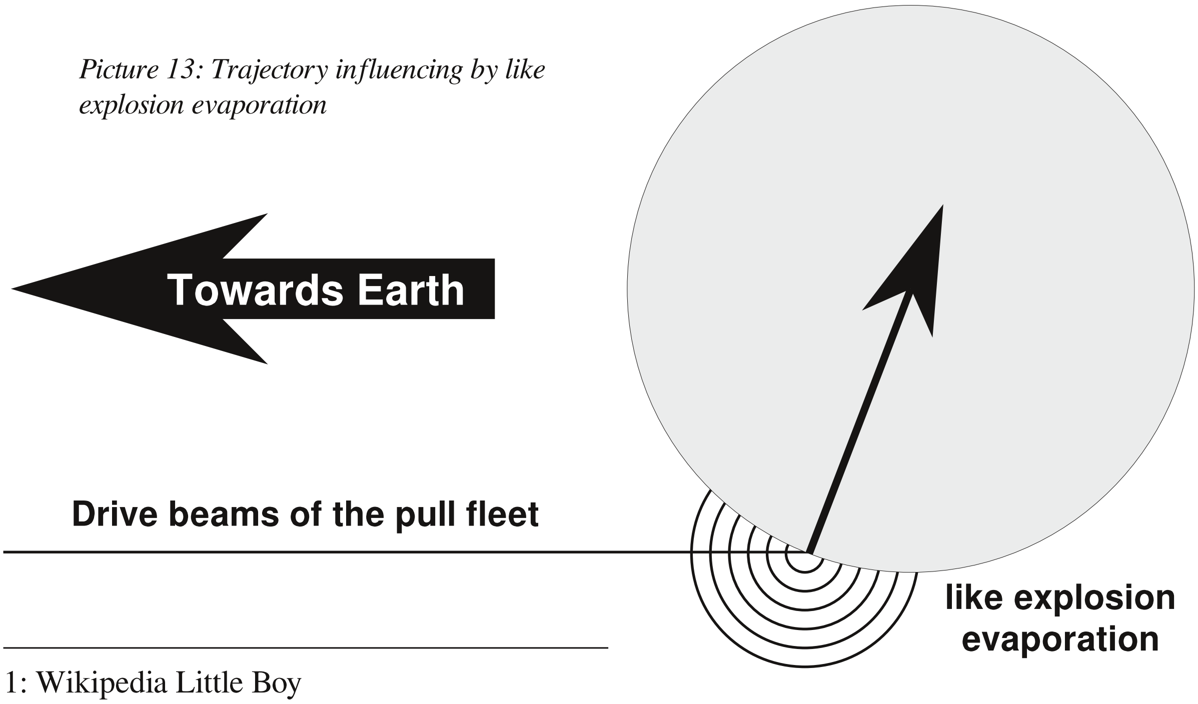
7.3 Drive beams for influencing the trajectory

Each engine of the pull fleet accelerates ions with 4.5 GW. 40 million ships, each with 4 engines, make 720 PW, as much as the explosion of 172 million tonnes of TNT per second. That's over 10 thousand Hiroshima[1] or 3 Tsar bombs[2] per second. At the target, an like explosion evaporation is supposed to change the trajectory of the object.

The essential thing is the effect, which arises perpendicular to the direction of flight of the object. It makes no difference whether the object hits Earth at 30,000 m/sec or 29,999 m/sec, but 1 m/sec perpendicular to the direction of flight causes within 80 days whether Earth is hit right in the middle or the object flying past Earth.

So that the thrust vector resulting from the like explosion evaporation comes as close as possible to the right angle to the direction of flight, the object must be hit close to the edge.

Picture 13: Trajectory influencing by like explosion evaporation



1: Wikipedia Little Boy

2: Wikipedia Tsar Bomba 57 Mt TNT

7.4 Estimation of the effect

Now must be estimated. The drive jets hit the surface, heat up the surface and the material, indeed which material actually evaporates.

The surface of our Moon consists to a large extent of SiO_2[1] and Al_3O_2[2]. If the approaching object has a similar composition, then a little bit of heating is of no use at all. As 1,000 degrees Kelvin makes not any effect, this material becomes not even liquid. As 2,000 degrees Kelvin are of no use, the SiO_2 finally becomes liquid.

SiO_2 has a boiling point of 3,220 Kelvin, Al_3O_2 3,250 Kelvin. It is also not enough if the surface begins to evaporate gently. Anything that is not accelerated beyond the escape speed will fall back and have no effect on the trajectory.

After a long puzzling over the estimation method, I have decided to a very simple estimation method: for how many kg of matter, the energy from the drive beam is enough to accelerate to 10 km/sec. Half of it is considered an effective boost. That's 10,000 joules per Newton thrust or 72 TN thrust for 720 PJ.

This is significantly more than the thrust of the pull fleet, because here the surface of the object used as reaction mass is brought to only 10 km/sec by like explosion evaporation.

If of the 72 TN thrusts 60 TN are perpendicular to the trajectory, the trajectory of an object with the mass of Ceres can be changed by 1 m/sec in 181 days.

7.5 As little scattering of the drive beams as possible

The effectiveness of the system increases with the square of the distance in which useful bundling of the drive beams can be achieved. At a distance ten times greater, a change in direction is ten times longer effective, and the object can be impacted ten times longer.

The 1 km long engines of the pull ships should already provide a good basis for a very close bundling. The question is, up to what distance you can hold a scattering circle of 100 km in diameter. Between 100 million and 10 billion km there is at least a difference of 1 : 10,000 in the capacity for influencing the track.

Unfortunately, we rely on 2 estimates for the remaining part of this section, which have dramatic effects on the calculation results. Between 30,000 Jule per Newton and bundling 1 : 1,000,000 and 3,000 Jule per Newton and bundling 1 : 100,000,000 lie five orders of magnitude in the capacity for collision protection.

On a scattering circle of 100 km in diameter comes 91 MW per m^2. But the object should be hit as close to the edge as possible, because of the oblique angle of incidence, the effective area is much larger, the power per m^2 less.

If then the power for an like explosion evaporation is no longer sufficient, there is another option:

1: Wikipedia Silicon dioxide

2: Wikipedia Aluminium oxide

7.6 Concentration in time

With a concentration in time, the energy density can be increased considerably. Let's say the object is a billion miles away. First, the engines are set to 10,000 km/sec, 100,000 seconds to the target. Then the engines are gradually adjusted to higher speeds, always so that the emitted matter arrives at the destination at the same time. 96,000 seconds later, the engines are set to 250,000 km/sec, just 4,000 seconds to the target.

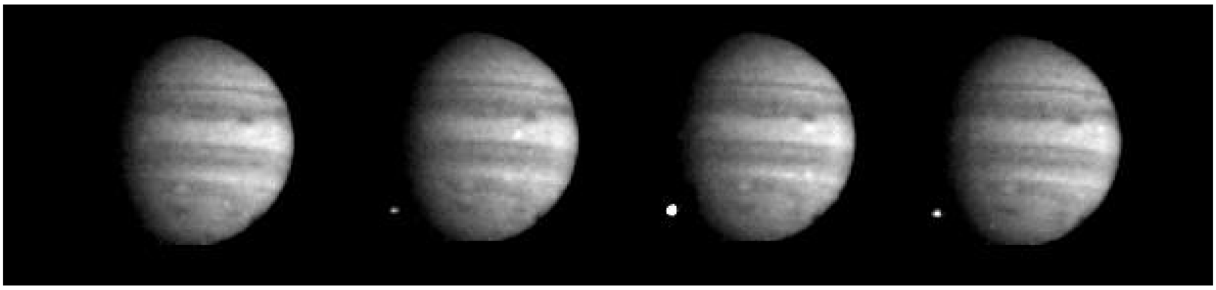
Under $6.9 \cdot 10^{22}$ joules, only a few can imagine something well, it is as much as in an area with 100 km in diameter every 6 m^2 a Hiroshima bomb.

With this trick, at very large objects, influencing the trajectory can begin much earlier, where continuous irradiation would be too weak for a like explosion vaporization.

7.7 Defense must also protect Jupiter

Jupiter, with its 318 times mass, in the truest sense of the word draws such misfortunes much more strongly than Earth. As a target he offers 126 times the surface of the earth. Impacts can throw the atmosphere up and cause the ring to crash.

For small objects it is sufficient to use a part of the engines of the ring. These can be supplemented by ships of the pull fleet, which do not fly back to Earth after the acquisition of new reaction mass, but participate in the trajectory control of an object.



Picture 14: Impact of Shoemaker-Levy 9 on Jupiter. «These four images of Jupiter and the luminous night-side impact of fragment W of Comet Shoemaker-Levy 9 were taken by the Galileo spacecraft on July 22, 1994.

The spacecraft was 238 million kilometers from Jupiter at the time, and 621 million kilometers from Earth. The spacecraft was about 40 degrees from Earth's line of sight to Jupiter, permitting this direct view. The images were taken at intervals of 2 1/3 seconds, using the green filter (visible light).» Jet Propulsion Laboratory

This picture made the spacecraft Galileo from the impact of one of the fragments of Shoemaker-Levy 9. The luminous appearance of the impact is about 8,000 km in diameter. An impact like this could cause the ring for collecting reaction mass to crash.

7.8 Current collision warnings with other galaxies

Originally, this section was planned as “Collision with Andromeda”, but then came in early January 2019 surprisingly nor the collision warning with the large Magellanic cloud to:

> «Here, we show that the LMC is on a collision course with the MW with which it will merge in 2.4+1.2−0.8 Gyr (68 per cent confidence level).»

Monthly Notices of the Royal Astronomical Society, Volume 483, Issue 2, 21 February 2019, Pages 2185–2196 Marius Cautun Alis J Deason Carlos S Frenk Stuart McAlpine

> «The Milky Way is destined to get a major makeover during the encounter, which is predicted to happen four billion years from now. It is likely the sun will be flung into a new region of our galaxy, but our Earth and solar system are in no danger of being destroyed.»

With Andromeda many objects, which are not bound to a solar system, come to us with 300 km/sec. The possibilities for influencing the path decrease with the square of the speed. Suns from Andromeda can fly close to the Milky Way 's suns, this can be also 100 billion km, so more objects can be detached from these solar systems and fly around somewhere.

In the big periods, the saying “That's as unlikely as a Lotto 6” wins a whole new meaning: If only one type is cast each week, then the probability calculus[1] states that in 6 billion years, over 35,000 lottery 6 at 6 out of 45 are expected.

Now we investigate the capacity of the pull fleet in influencing trajectories. The assumptions are: In the like explosions evaporation 10,000 Jule for 1 Newton thrust is needed, 80% of the thrust are effective perpendicular to the direction of flight, the bundling of the drive beams is 1: 10,000,000. The trajectory influencing starts when the drive beams of the fleet have a scatter of 1/3 of the diameter of the object.

As a first example we take the largest suspected historic accident on earth:

> «The origin of the Moon is usually explained by a Mars-sized body striking the Earth, making a debris ring that eventually collected into a single natural satellite, the Moon, but there are a number of variations on this giant-impact hypothesis»
>
> https://en.wikipedia.org/wiki/Origin_of_the_Moon

This was not an isolated case, also Uranus had a serious collision:

> «We verify the results from the single previous study of lower resolution simulations that an impactor with a mass of at least 2 M ⊕ can produce sufficiently rapid rotation in the post-impact Uranus for a range of angular momenta.»
>
> J. A. Kegerreis: The Astrophysical Journal, Volume 861, Number 1

1: Source Google “Probability 6 out of 45”

	An object like Theia, as big as Mars	An object as big as Ceres from Andromeda	An object as big as Vesta from Andromeda
Mass (kg)	$6.417 \cdot 10^{23}$	$9.393 \cdot 10^{20}$	$2.598 \cdot 10^{20}$
Diameter (km)	6,779	946	525
Speed (km/sec)	30	300	300
Ships of the pull fleet	40,000,000	53,000,000	53,000,000
Thrust (GN)	72,000	95,400	95,400
Start trajectoty changing (Gm)	22,597	3,153	1,751
Time to Earth (Days)	8,718	122	68
Achieved trajectory change (km)	25,462	4,489	5,006

Table 24: Three objects at the limits of possibilities

This is a rough estimate because bundling in particular has a very large impact on the outcome. The achievable trajectory deviation increases with the square of the bundling, because then the start of the trajectory control can begin at twice the distance.

Picture 15: Better bundling of engine beams improves the range. The path control starts when the scatter of the engine beams has 1/3 of the diameter of the object. Twice as good a bundling makes this possible at twice the distance.

7.9 Insurance calms, your planet collision protection insurance

Already with the first prototypes of pull ships a capacity in the meteorite defense is reached, which surpasses all previous studies. During the construction of the pull fleet, a capacity is quickly reached that could ward off anything that has hit Earth in the last billion years.

The fully developed pull fleet could even prevent the collision with an object with the mass of Theia. In the currently most probable theory of the formation of the Moon, such a collision is assumed.

8 Timetable

When can this be started? When can the entire system be used? Here is the attempt for a realistic timetable:

2030 First permanently crewed research station on the moon

2060 A prototype for a pull fleet ship is put together in Earth orbit. The goal is to gain data on the service life and the service effort of the components

2100 The tests will be extended to 20 ships. These are being built together in orbit.

2200 The first prototype is lost at the reaction mass refueling at Jupiter.

2250 Of 10 ships of the 2nd test series survive 5 the reaction mass refueling at Jupiter.

2280 A 500 km linear motor rail will be put into operation on the moon. The production of ships on the moon is in progress. After the evaluation of the experiences with the 20 test ships and numerous improvements one assumes an average of 1,000 years duration of use.

2400 The annual production on the moon is 1,000 ships. The predicted average duration of use should already be 2,000 years.

2420 The linear motor system is expanded to a closed ring around the equator of the moon. First landings of transport ships with the ring system.

2500 The first prototype of a ring segment ship starts for Jupiter

2600 The data of 100,000 ships makes it possible to perfect all components. 10,000 years of use should now be achievable.

2700 The production of the Moon industrial zone is now 5,000 ships per year.

2800 For the first time ever, the 30,000 1km long Ring Segment ships are transporting a 4,000-ton ice block with a linear motor rail into an elliptical orbit around Jupiter. At the highest point of the orbits, the block of ice is taken over by a pull ship as reaction mass.

3100 The ring around Jupiter is closed with 452,000 ring segment ships.

6000 Compensating influences on the lunar orbit begins.

14000 For the first time, 311 billion tonnes of the pull fleet's total mass will be reached in the deployment area.

15000 The production has fallen to 1,000 pieces per year. There are 5,000 landings and launches on the moon each year for overhaul.

16000 The construction of an artificial moon to stabilize the Earth's rotation begin.

90000 Only 100 pieces of production and 1,000 landings and launches per year for a complete overhaul.

8.1 Budget

What can a project cost, where the benefits will be considerable in the future? The benefit in the present is just the meteorite protection and a symbol of a unified humanity, the documentation of the claim to be a long-lived real civilization.

The buzzword for the budget target could be a EUR, a ton, a year. This would amount to € 311 billion a year, just half the US military budget, but not to 327 million US citizens, but to perhaps 10 billion people.

This budget target can only be achieved with extremely low production costs, for which further technological advances of humanity and the industrial zone Moon are necessary.

9 Required Key Skills of Humanity

In the course of the work, 6 key skills have emerged that are indispensable to achieving the goal of being a long-lived civilization.

9.1 Extremely light and durable photovoltaic

Any improvement in photovoltaics towards less weight and higher efficiency facilitates the operation. Higher ejection speed of the ion beam engines, longer residence time for pulling the Earth, fewer supply flights to fill up the reaction mass supplies, shorter flight times.

Logistically, it is not possible for the pull fleet's ships to fly to service every few years. It must therefore be possible to recycle photovoltaics on board and use them again and again.

9.2 Extremely high performance of ion beam engines

The 10,000-tonne pull vessel will have 3,000 tons of main body and engines. Even though 1,800 tons should be left for the engines, every kg of engine has to be able to handle 10 kW.

9.3 Mass production of spaceships in the industrial zone Moon

The budget target 1 EUR, 1 ton, 1 year is out of reach on earth. Much higher costs will not be politically enforceable.

9.4 Lunar equator linear motor start and landing system

Ion engines have far too little thrust for take-off or landing on the moon. For the amount of necessary takeoffs and landings, chemical engines can not be fueled. The linear motor system is essential for the task.

9.5 Take reaction mass from the gas giants

Gather in the orbit of Jupiter, Saturn, Uranus or Neptune reaction mass for the engines. For a sufficient amount, a ring around the Jupiter is necessary to extract reaction mass and to transport this via a linear motor start and landing system to a pick-up point.

9.6 Extremely durable self-recycling technology

One EUR, one ton, one year can only be budgeted for with a very long-lasting technology, which is constantly being renewed on board the pull ships.

Conclusion

During my first research before submitting the topic, I noticed a great lack of studies on it. About every 6,000 years, an object with 10^{19} kg weight passes close to earth[1], the Moon may be lost and not a word about how this object could be motivated to fly on this trajectory.

At all of this outstanding scientific achievements of mankind, why is there not anything really useful about on this theme?

I hypothesize, that there are mental barriers to imagine that our civilization could still be here in six billion years.

I have documented each formula used, there is nothing that you could not calculate with one of the usual in classroom pocket-calculator. Which supercomputers were used to create predictions for the Sun over the next some billion years? How many physicists have contributed to making such highly complex simulations possible? So much effort for the prognosis and in extreme contrast to this, so little for the question “How do we survive the predicted conditions?”

I used to be fascinated how archeologists and paleontologists reconstruct entire stories from finds. Now I sat in front of several spreadsheets and the future of humanity evolved in front of me: step by step, each with compelling logical decisions.

Moon Industrial Zone, Equator Linear Motor Launch and landing system for spaceships around the Moon, gather reaction mass in orbit around Jupiter. In March 2018, when I searched for this possibility for material, YouTube suddenly brought a video suggestion: “Air Breathing Ion Thrusters & Low Orbit Satellites”[2]. Just as I was looking for material on this topic, there had been in a laboratory first tests for initial approaches to this technique.

This repeated itself in February 2019, when I wrote the chapter on collision protection, the video suggestion “Scientists Figure Out Why Uranus[3] Spins on One Side” brought new material. A system that actively supports the search for knowledge.

With all the scientific and technical articles I've found while creating this work, I'm sure humanity has the technical scientific potential to do it, all we have to do is overcome the mental barriers of acting together as humanity and to create long-term goals.

I hope to be able to experience the big spectacle when the first prototype of a pull ship is built together in Earth orbit.

1: D.G. Korycansky: Astronomical engineering: a strategy for modifying planetary orbits

2: Scott Manley: Air Breathing Ion Thrusters & Low Orbit Satellites

3: Anton Petrov: Scientists Figure Out Why Uranus Spins on One Side

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