Navigation Plan: Earth to Moon

How will you stay on course?

Team name: The Argonauts

Spacecraft name: Argo

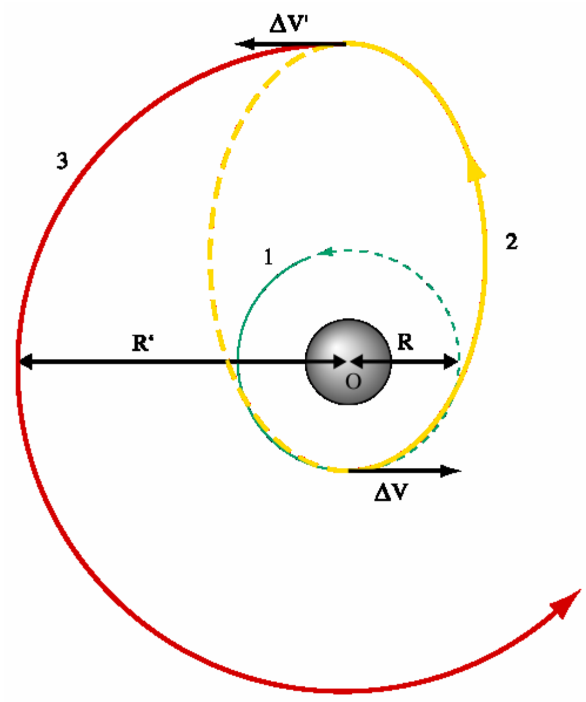
Launch time and date: No earlier than May 21, 2009, 21:32 UTC

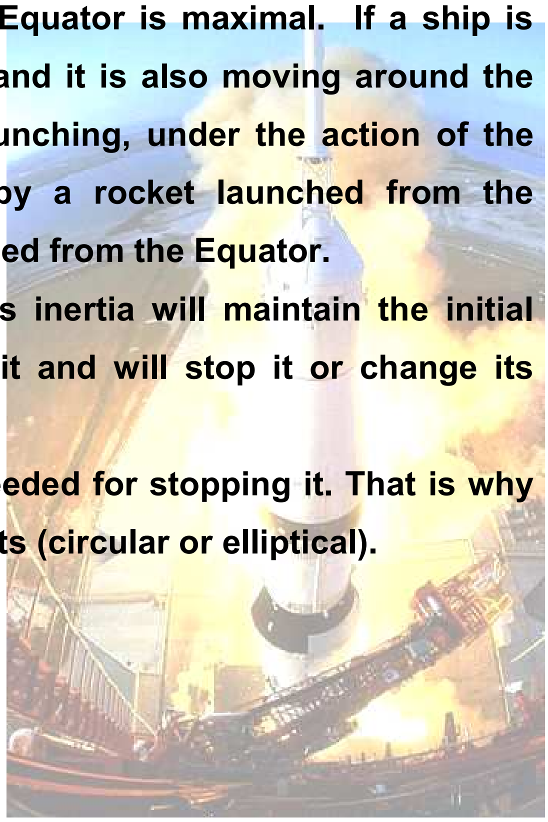
Duration of journey 7 days

Expected impact date: 28th May 2009

Description of route and orbital paths

We have chosen a Hohmann type trajectory for taking the satellite on orbit around the moon. Hohmann transfer orbit is an orbital maneuver using two engine impulses which move a spacecraft between two coplanar circular orbits. The satellite will be launched firstly on a circular orbit around the Earth (low orbit), then we will increase the satellite's speed, by firing the spacecraft's engine, for sending it on an elliptical, tangent on the first orbit. The point of tangency will be the aphelion of the elliptical orbit because at that point the satellite's speed is minimal. When the ship reaches the destination (in the perihelion of the elliptical orbit), the orbital speed of the craft must be decreased in order to direct the ship on a circular orbit around the Moon, so the engine will be fired to decelerate it to the required velocity. The spacecraft will allow Moon's gravity to capture it. Speed can be changed by increasing thrust to make a ship go faster, or retro-burning or aero-braking to slow it down.





The Earth's rotation speed is maximal at the Equator (approximately 1670 kph), that is why the kinetic energy of an object at the Equator is maximal. If a ship is launched from the equator it goes up into space, and it is also moving around the Earth at the same speed it was moving before launching, under the action of the Earth's gravitational force. The energy needed by a rocket launched from the Equator is minimal, that is why Argon will be launched from the Equator.

If an object is traveling in a straight line, its inertia will maintain the initial course and speed until a force will interact with it and will stop it or change its trajectory.

The more mass an object has, the more force is needed for stopping it. That is why we have chosen to send our satellite on curved orbits (circular or elliptical).

Navigation instruments

Our spacecraft has three main components:

a) The ACG (Artificial Crater Generator) a.k.a. Hercules

b) The LEV (Lunar Exploration Vehicle) a.k.a. Jason

c) The Satellite a.k.a. Boreas

Other tools:

- Spin stabilization
- Orientation and attitude measurements on AUVs and ROVs
- A rubber band-powered rover
- Ship motion monitoring
- A cardboard crane for maximum load-lifting ability
- Control moment gyros
- Solar sails
- Gravity-gradient stabilization

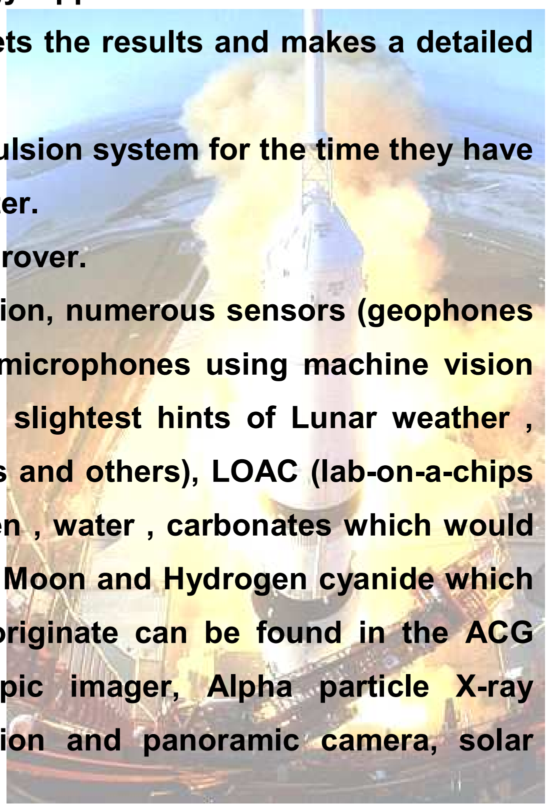
The exterior of the spacecraft: the spacecraft is made of the classic A 7075 aluminum alloy.

The satellite features machine vision technology applied for a sextant and other heavenly-body based navigation. The computer interprets the results and makes a detailed log of were it is and what course it should make.

Each section ACG-LEV-Satellite has its own propulsion system for the time they have to “split up”, a radio transmitter and a wireless transmitter.

The part that we call contains a moon exploration rover.

Jason will gather this data using his machine vision, numerous sensors (geophones and seismometers to register geologic lunar activity, microphones using machine vision technology, electric sensing devices for detecting the slightest hints of Lunar weather , altimeters , thermometers , numerous pressure sensors and others), LOAC (lab-on-a-chips to help determine what chemicals , especially hydrogen , water , carbonates which would prove that water existed at one point or another on the Moon and Hydrogen cyanide which is a organic compound from which all amino acids originate can be found in the ACG generated dust) , a rock abrasion tool, microscopic imager, Alpha particle X-ray spectrometer, rocker bogie mobility system, navigation and panoramic camera, solar arrays, calibration and high-gain antenna.



Methods of guidance, navigation, control, and tracking

Rules

1. **The Argo must do whatever is possible so as to keep all it's systems safe unless a mission objective implies the destruction , damage or abandonment of any system;**
2. **The Argo must undergo every mission stage and take out each of it's objectives;**
3. **The Argo must submit every order and report to analysis and if I doesn't contradict the previous 2 rules take out the order.**

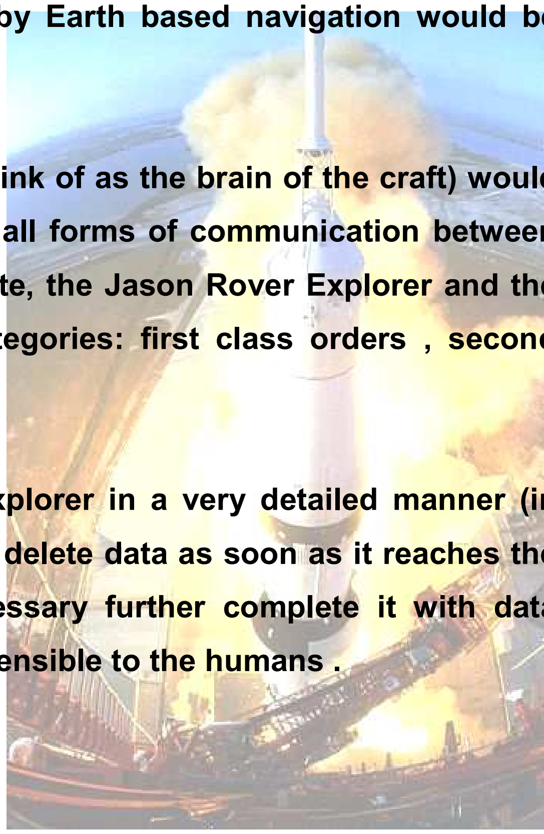
Navigation

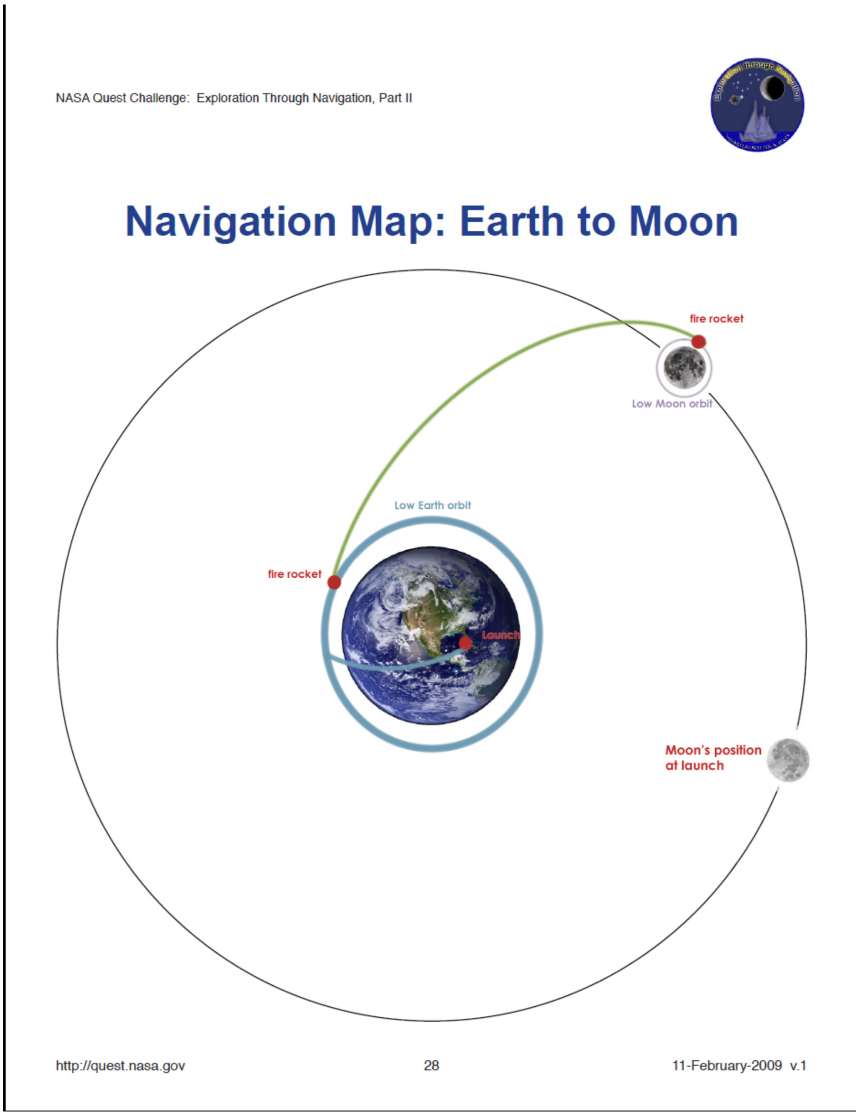
We've based the Argo control center on the satellite-part (which we call Boreas), the part which shall orbit the Moon while the Explorer investigates the impact crater made by the ACG (Artificial Crater Generator) and its surroundings.

Our reasoning is simple: there will always be a significant time delay if we were to control it from a center on the Earth, and if any of the systems components would have to react to any particular situation it would be far more effective if reports and orders could be issued at high speeds. Another safety-issue posed by Earth based navigation would be possible interferences.

The main Data Acquisition System (which we think of as the brain of the craft) would be mounted on the Argus satellite .We have ordered all forms of communication between the Argus Control Center on Earth, the Boreas Satellite, the Jason Rover Explorer and the Hercules ACG (Artificial Crater Generator).into 3 categories: first class orders , second class orders and report data.

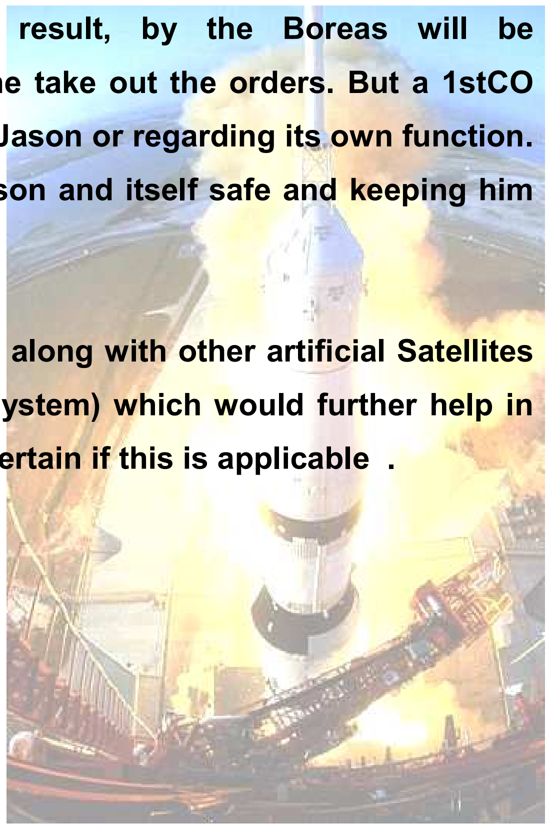
Report data is issued initially by the Jason Explorer in a very detailed manner (in order to conserve memory space on the rover we will delete data as soon as it reaches the Boreas), the Boreas will then organize (and if necessary further complete it with data acquired by it's systems) the data into report comprehensible to the humans .





Second Class orders (2ndCO) are orders (other than the main mission course or MMC impregnated in the Argo's system before it left Earth) which are given from the Earth to the Boreas. The Boreas must acknowledge and take them out one way or another.

First class orders (1stCO) are only issued by the Boreas satellite to the ACG and then to Jason. 1stCO's are usually 2ndCO orders from the Earth which, after being approved or, if necessary, improved or modified so as to provide a much more fruitful result, by the Boreas will be forwarded to Jason who will acknowledge them and the take out the orders. But a 1stCO can also be a routine procedure given by the Boreas to Jason or regarding its own function. A routine procedure usually has to do with keeping Jason and itself safe and keeping him on the MMC.



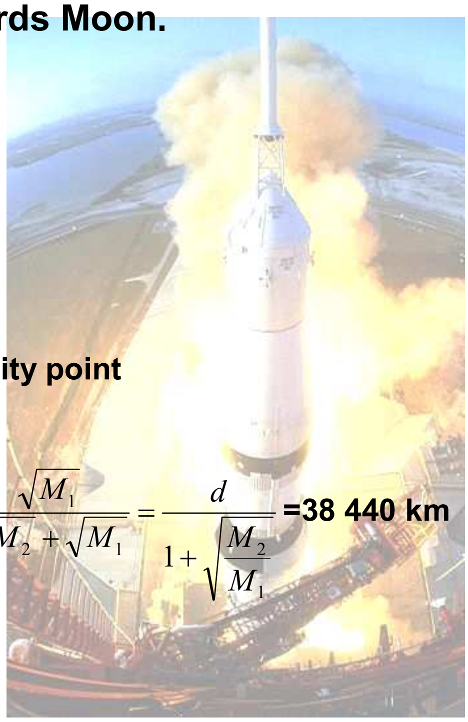
We also thought about using the Boreas Satellite along with other artificial Satellites of the Moon to help create a LPS (Lunar Positioning System) which would further help in guiding Jason on the Lunar Surface but we are not yet certain if this is applicable .

Main Mission Course or MMC

The MMC consists of primary rules which all the Argo's systems must obey, mission objectives and a central timetable which will contain the dates of important mission stages.

The imponderability point

We will have to accelerate the spacecraft until it reaches the imponderability point, and then it will gravitate towards Moon.



$$\Gamma_1 = k\frac{M_1}{x^2}$$

$$\Gamma_2 = k\frac{M_2}{(d-x)^2}$$

$$\Gamma_1 = \Gamma_2$$

x-the distance between the Earth and the imponderability point
d=the distance between Moon and Earth

$$\frac{M_1}{x^2} = \frac{M_2}{(d-x)^2} \Leftrightarrow \frac{M_1}{M_2} = \left(\frac{x}{(d-x)}\right)^2 \Leftrightarrow \sqrt{\frac{M_1}{M_2}} = \frac{x}{d-x} \Leftrightarrow x = d\frac{\sqrt{M_1}}{\sqrt{M_2}+\sqrt{M_1}} = \frac{d}{1+\sqrt{\frac{M_2}{M_1}}}$$ **=38 440 km**

The first cosmic velocity **is the lowest velocity with which a body must be launched parallel to the ground to describe a circular orbit with the same radius of the Earth.**

The gravitational force is balanced by the centrifugal force produced by the revolution of satellites around a planet.

$$F_g = F_c$$

$$k\frac{M*m}{(R+h)^2} = \frac{m*v^2}{R+h}$$

$$v = \sqrt{\frac{k*M}{R+h}}$$

For h<<R, we obtain:

$$v_0 = \sqrt{\frac{k*M}{R}}$$ **, the 1st cosmic velocity**

$$v_0 = 7.9 \text{ km/s}$$

$$v = v_0\sqrt{\frac{R}{R+h}}$$

h – The altitude at which the satellite is orbiting (low orbit around the Earth)

The escape velocity **is the minimum velocity required for a spacecraft or other object to escape from the gravitational pull of a planetary body.**

From the law of conservation energy:

$$k\frac{M*m}{R} - \frac{m*v^2}{2} = 0$$

$$v = \sqrt{\frac{2*k*M}{R}} = 11.2 \text{ km/s}$$

The third cosmic velocity **is the minimum velocity that has to be imparted to a body relative to the Earth's surface to drive it out of the solar system.**

$$\frac{m*v^2}{2} - \frac{k*m*M_0}{d} = 0$$

$$V = \sqrt{\frac{2*k*M_0}{d}} = 42,3 \text{ km/s}$$

M_0**, the Mass of the Sun**

$$\frac{m*v^2}{2} - \frac{m*v^2}{2} = \frac{m*v_{00}^2}{2}$$

$v^2 = v_2^2 + v_\infty^2$

$v_\infty = v - v_p$,

$v_p = 30$ km/s → rotation of Earth around its axis

↔ $v_3 = \sqrt{11{,}2^2 + (42{,}3 - 30)^2} = 16.6$ km/s

We must launch the racket from the Equator because a point located on the Equator has the greatest velocity of all the points of the Earth, thus it has the greatest energy (because of the Earth's shape).

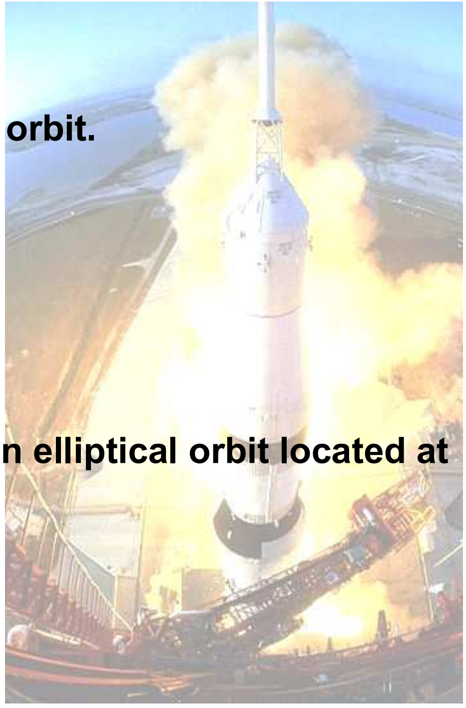
$E_0 = \frac{m*v^2}{2} = \frac{kM*m}{2R}$ → **the energy of the spacecraft on the Earth**

$E_1 = \frac{m*v^2}{2} - \frac{k*M*m}{Rp+H} = -\frac{k*M*m}{2(R_p+H)}$ → **the energy on the low orbit**

$V = \sqrt{\frac{k*M}{R+H}}$ → **the velocity on the low orbit**

R= the radius of the Earth

Transfer Orbit



We must transfer the spacecraft on an elliptical orbit.

$E = -\frac{k*M*m}{2a}$ → **the total energy on an ellipse**

$E = \frac{m*v^2}{2} - \frac{k*M*m}{R} = -\frac{k*M*m}{2a}$

$V = \sqrt{k*M(\frac{2}{r} - \frac{1}{a})}$ → **the velocity of an object on an elliptical orbit located at the distance r from the focal point**

a= major semi-axis of the orbit

Correction in velocity

We will make the transfer at the perigee point because this transfer is the most economical one.

$$v_p = \sqrt{k * M\left(\frac{2}{R} - \frac{2}{R+R_L+d}\right)}$$

R_L → the Moon radius
d → the Earth → Moon distance

$$a = \frac{R+R_L+d}{2}$$

$$\Delta v = v_p - v = v_p = \sqrt{k * M\left(\frac{2}{R} - \frac{2}{R+R_L+d}\right)} - \sqrt{\frac{k*M}{R}}$$

$$\Delta V = \sqrt{\frac{k*M}{R}}\left(\sqrt{\frac{2(d+R_L)}{d+R_L+R}} - 1\right) = 36{,}5 \text{ m/s}$$

Δv→ the value with which we must increase the velocity of the spacecraft in order to put it on the elliptical orbit

$$v_2 = \sqrt{k * M\left(\frac{2}{R_L} - \frac{2}{R+R_L+d}\right)}$$ **→ velocity at the apogee**

→ the velocity of an object orbiting Moon

$$v_L = \sqrt{\frac{k * M}{R_L}}$$

→ the value with which we must modify the velocity of the spacecraft to put it on the low orbit around the Moon

$$\Delta V' = \sqrt{\frac{k*M}{R_L}}\left(1 - \sqrt{\frac{2(R+d)}{R+R_L+d}}\right)$$

Observation: To change the spacecraft's aim point on the Moon we must fire the thrusters in a direction parallel to the direction we need to shift the aim point.

If we want to increase the velocity of the spacecraft, we must throw the fuel in the opposite direction the spacecraft is moving and if we want to decrease the velocity of it, we must fire the burst in the same direction the spacecraft is moving.

Duration of journey

k(M+ m) T^2**= 4**$\pi^2 a^3$

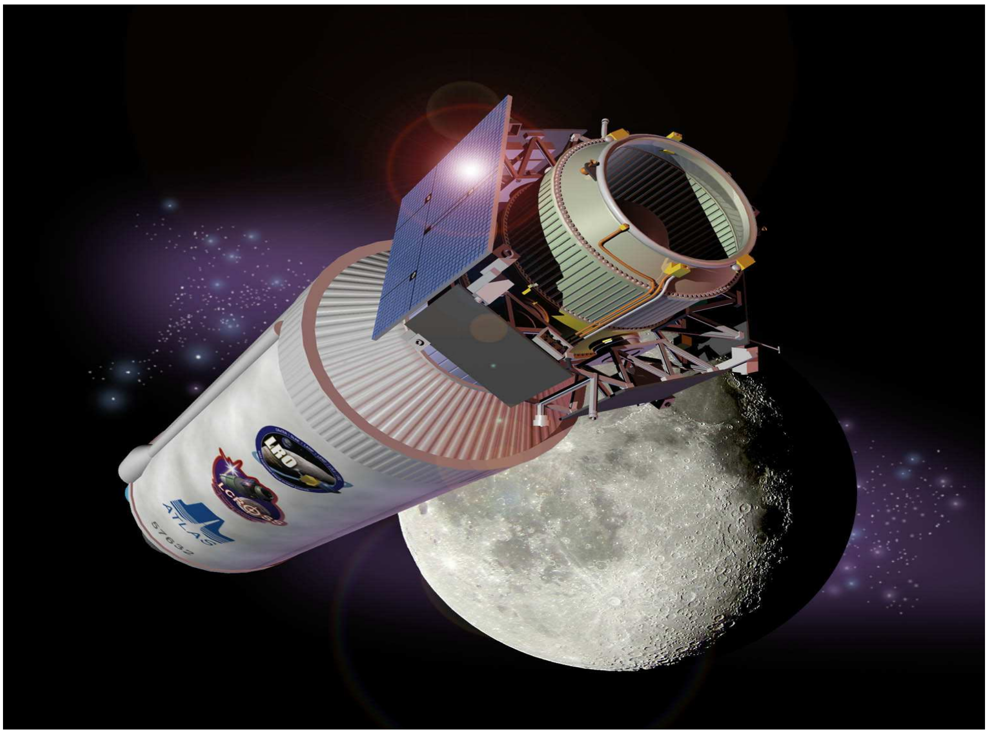
M = the mass of Earth
m = the mass of the satellite

a= $\frac{R+R_L+d}{2}$

m<<M → M+ m = M

T= $\frac{2\pi}{\sqrt{k(M+m)}} * \frac{R+R_L+d}{2}\sqrt{\frac{R_P+R_L+D}{2}}$

T=$\frac{\pi(R+R_L+d)}{\sqrt{2*k*M}}\sqrt{R+R_L+d}$

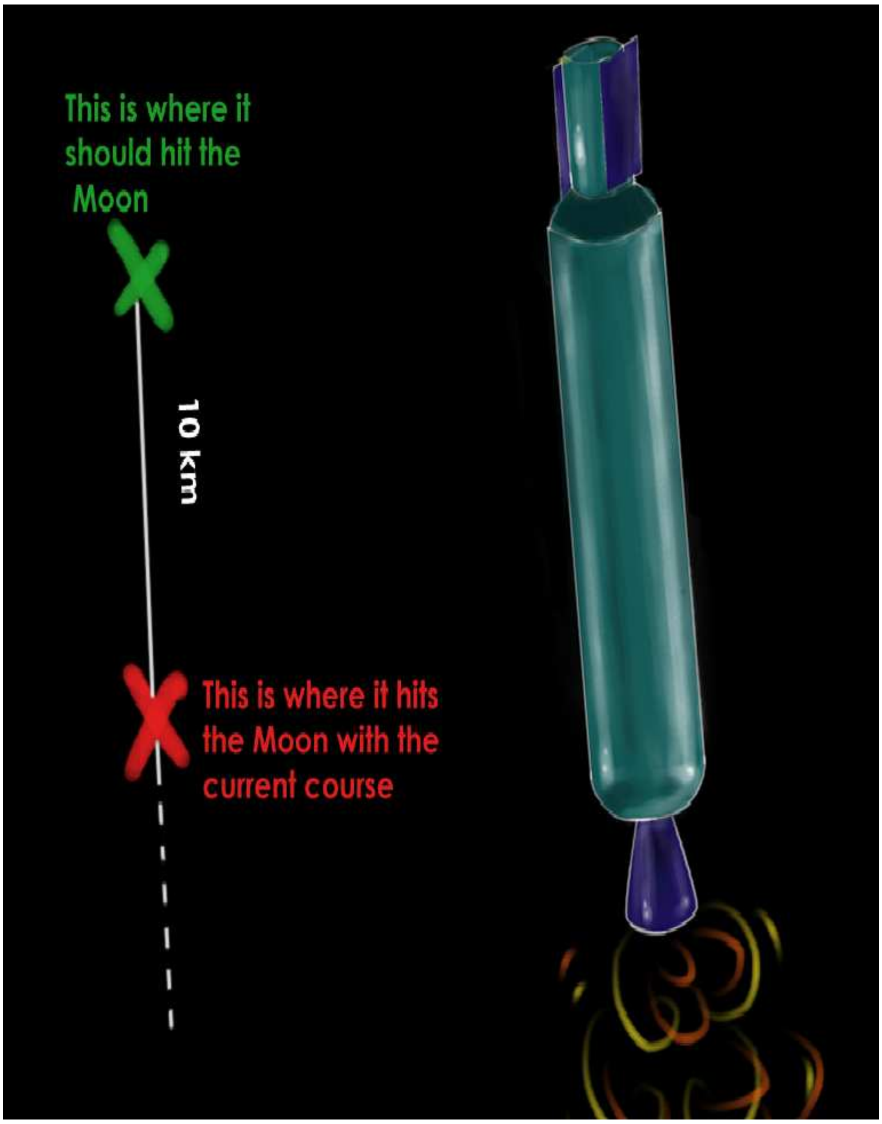


⇒ **Duration of journey : t= $\frac{T}{2}$= 7.08 days**

Redirecting the spacecraft

We have just received new tracking data that says the spacecraft is off course and will miss its impact point by 10 kilometers! That is to say, the spacecraft will fall 10 kilometers short of the target crater. We have 8 hours to correct this. We have 8 hours to correct this, so let's get it started.

Required correction: 10 km = 10,000 m
Time for correction: 8 h = 28,800 s
Velocity change Δv: 10 km / 8h = 0.35 m/s
Total spacecraft weight: 7,275 lb = 32,360.81 N
Total rocket thrust: 10 lbs of force = 44.5 N



Solve:

OBS: **In the outer space, there is no friction. The increase or decrease in spacecraft's velocity caused by the fired thrusters will make the racket to continue to move along a new path and at a new velocity until they are acted upon by another force. In conclusion, this correction in velocity is enough to get the spacecraft back on course and save the mission. This problem will be solved using mathematical expression:**

- **Force (F) equals change in velocity (acceleration, a) times mass (m):**

$$\vec{F} = m \cdot \vec{a}$$

- **Velocity (v) equals acceleration (a) times time (t) :**

$$v = a \cdot t$$

Also we will use that weight (w) equals mass (m) times gravity (g):

$$w = m \cdot g$$

At this point we can calculate the mass of the spacecraft:

$$m = \frac{w}{g}$$

The spacecraft acceleration will be:

$$a = \frac{F}{m}$$

$$a = \frac{F \cdot g}{w} \quad \textbf{(1)}$$

Furthermore we will use the velocity change mathematical expression:

$$v = a \cdot t$$

$$\Rightarrow \; t = \frac{v}{a} \quad \textbf{(2)}$$

From the equations (1) and (2) we find that:

$$t = \frac{v \cdot w}{F \cdot g}$$

Now, we will make the numerical solve of the problem:

v = 0.35 m/s
w = 32,360.8 N
F = 44.5 N
g = 9.8 m/s^2

=> $t = \frac{0.35 \cdot 32{,}360.8}{44.5 \cdot 9.8}$ **s**

t = 25.97 s

As a conclusion we found out that the thrusters should be fired for 25.97 seconds in order to correct the course error.

CAPE CANAVERAL, WE HAVE A TAKE OFF!