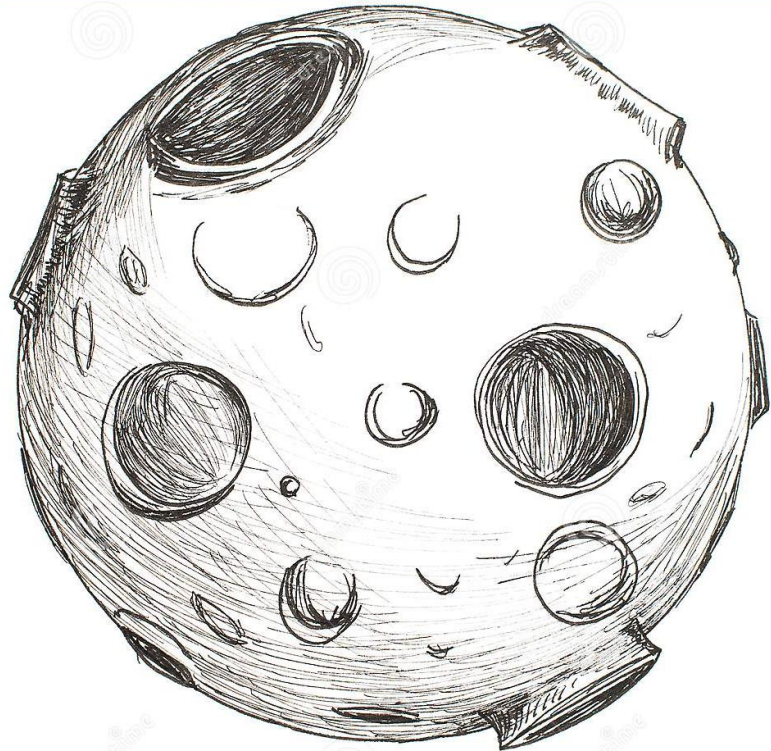


# Do Meseca i nazad 50 godina kasnije

Dušan Marčeta



# Ozarje

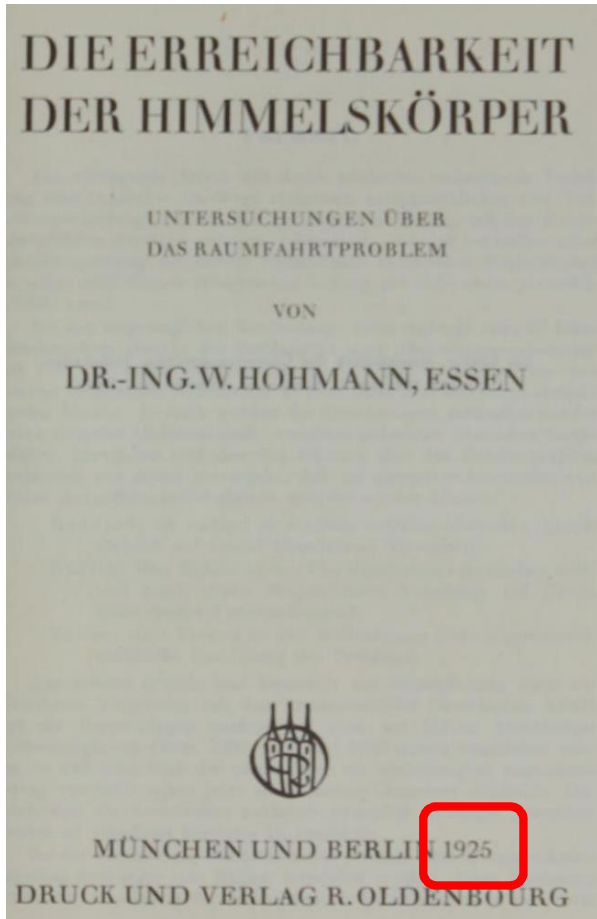


**zemlje, svitnica, azurina, belodina, jugovina, Evina jabuka, zembelica, švalerina, farosjaj...**

# Kojim putem do Meseca?



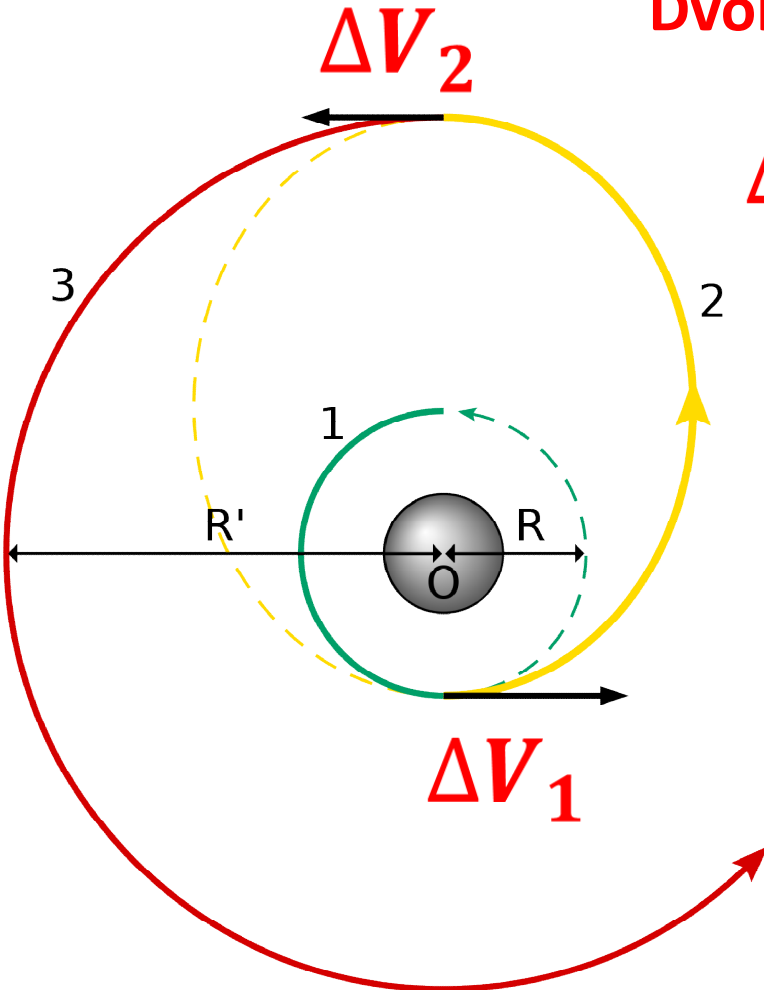
# Homanov transfer



**Walter Hohman**  
**1880 - 1945**

# Homanov transfer

Dvoimpulsni transfer



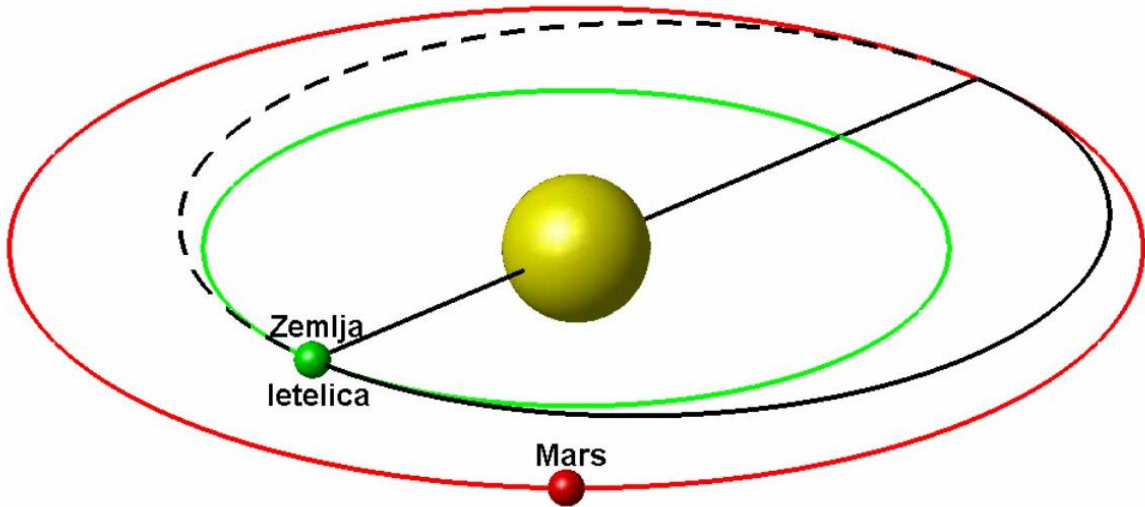
$$\Delta V = \Delta V_1 + \Delta V_2$$



$$\propto e^{\Delta V}$$

Lawden, 1952, J. Brit.  
interplanet. Soc.

# Homanov transfer

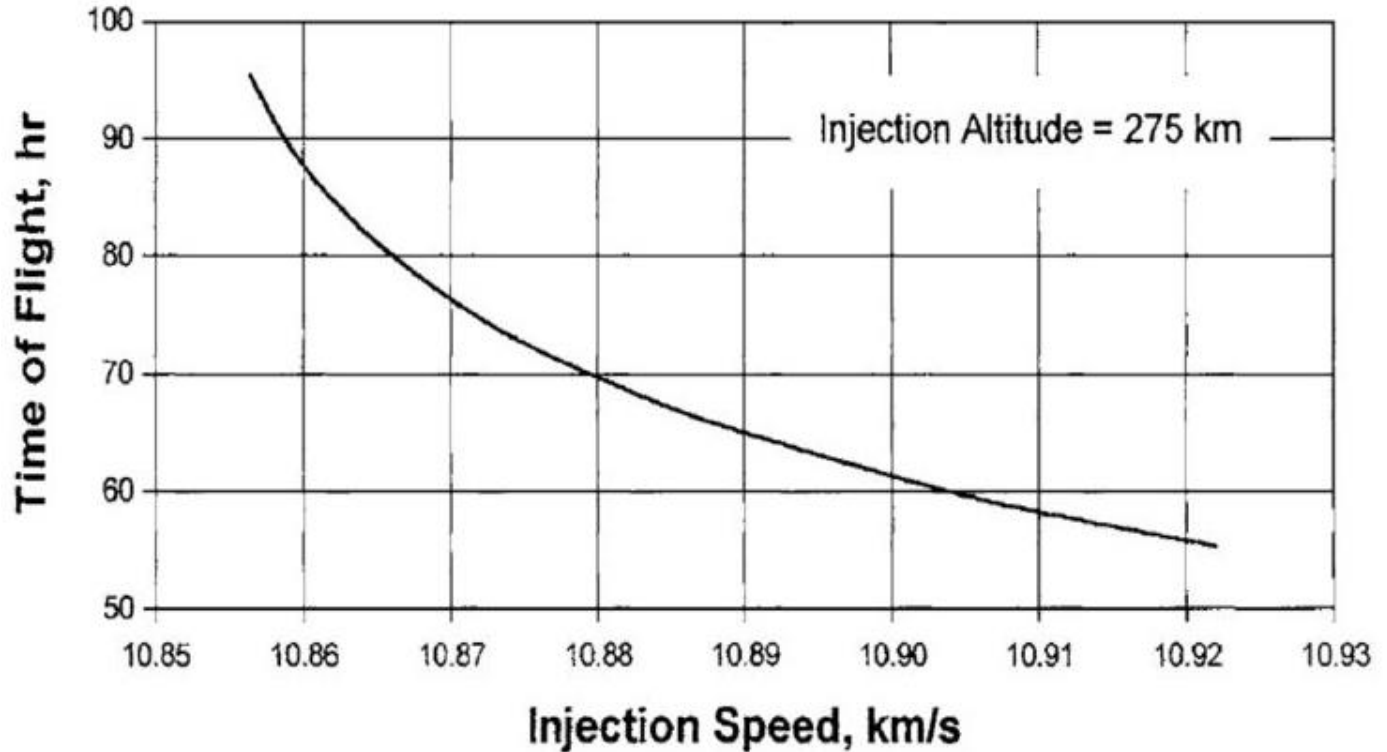


# Homanov transfer

Moduo transfera

$$\frac{\Delta V}{V_{kr1}} = \left( 1 - \frac{1}{r_2/r_1} \right) \sqrt{\frac{2 r_2/r_1}{1 + r_2/r_1}} + \frac{1}{\sqrt{r_2/r_1}} - 1$$

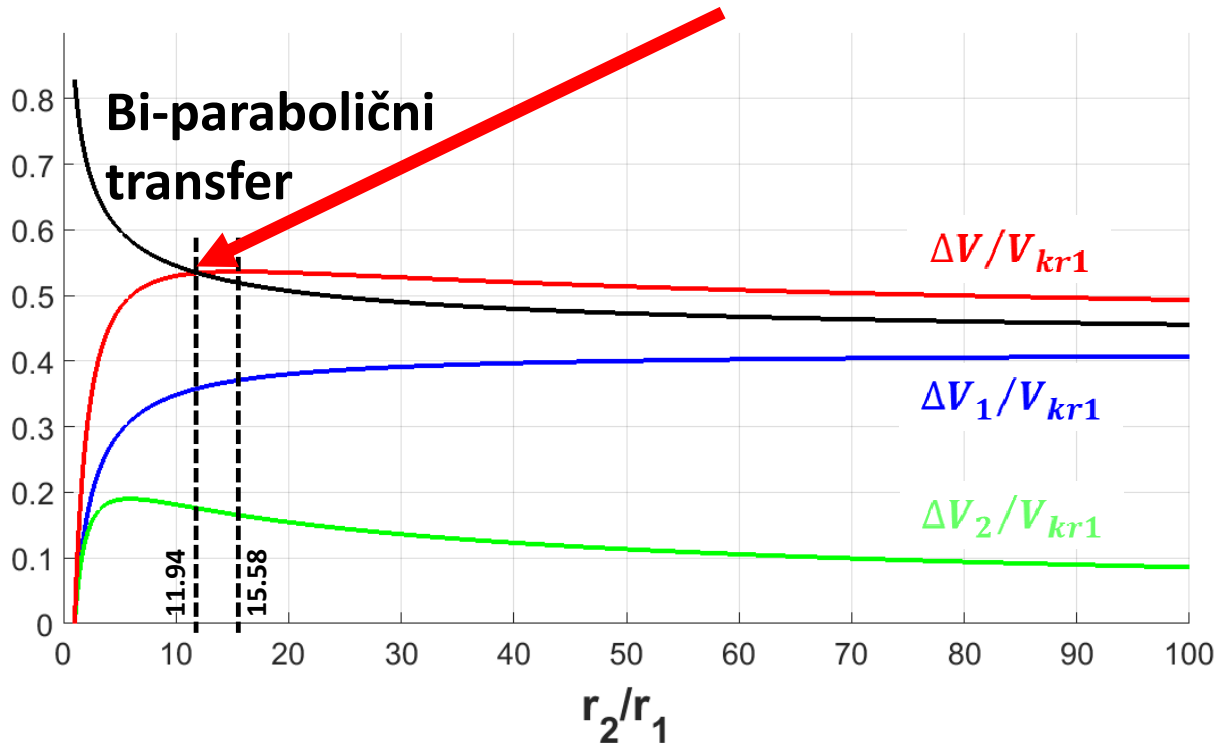
# Trans-Lunar Injection





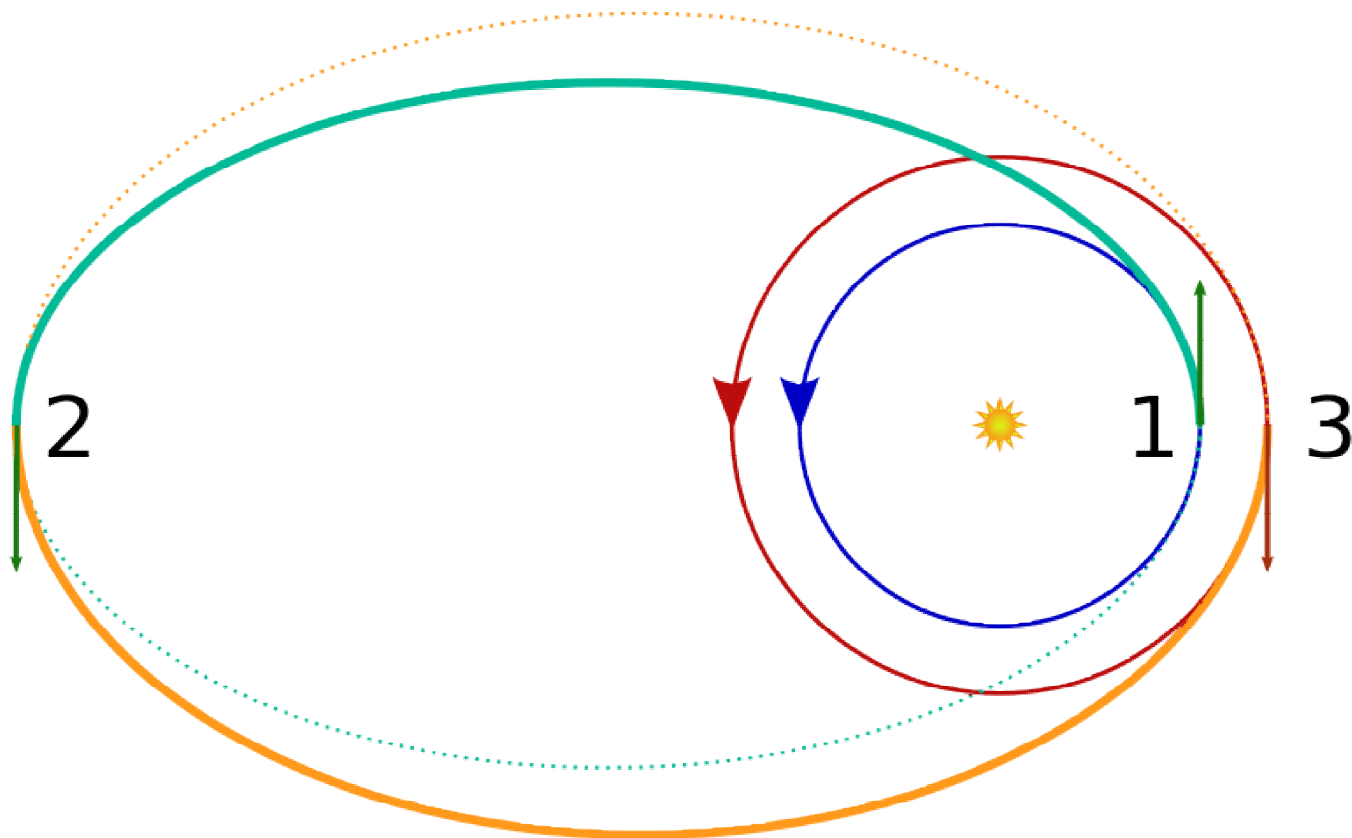
# Homanov transfer

Jeftinije je sa početne orbite otići u beskonačnost, pa se iz nje vratiti na krajnju orbitu, nego izvršiti direktan Homanov transfer sa početne na krajnju orbitu.



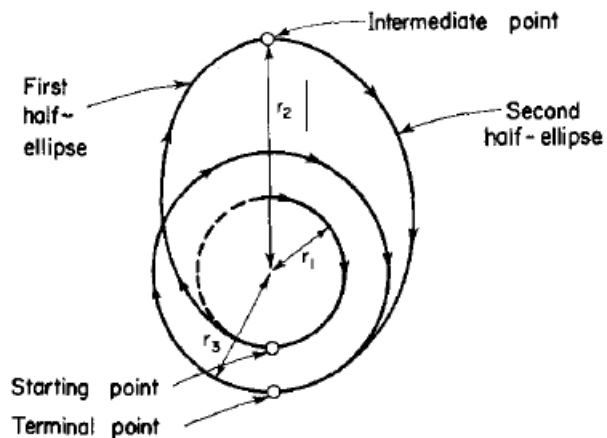
# Bi-eliptični transfer

Preko preče, naokolo jeftinije

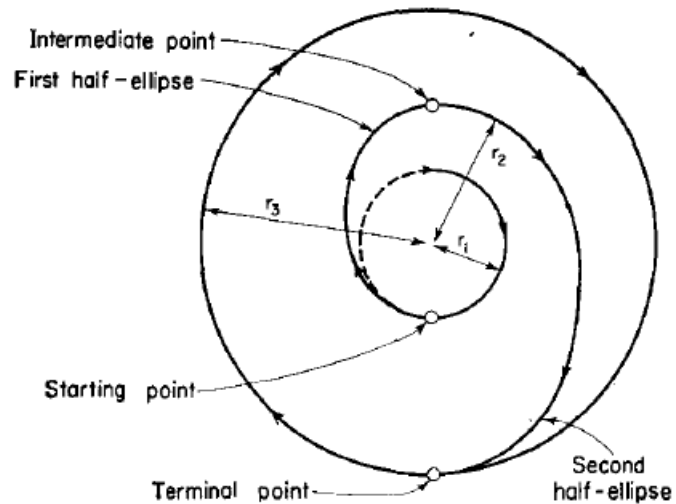


# Bi-eliptični transfer

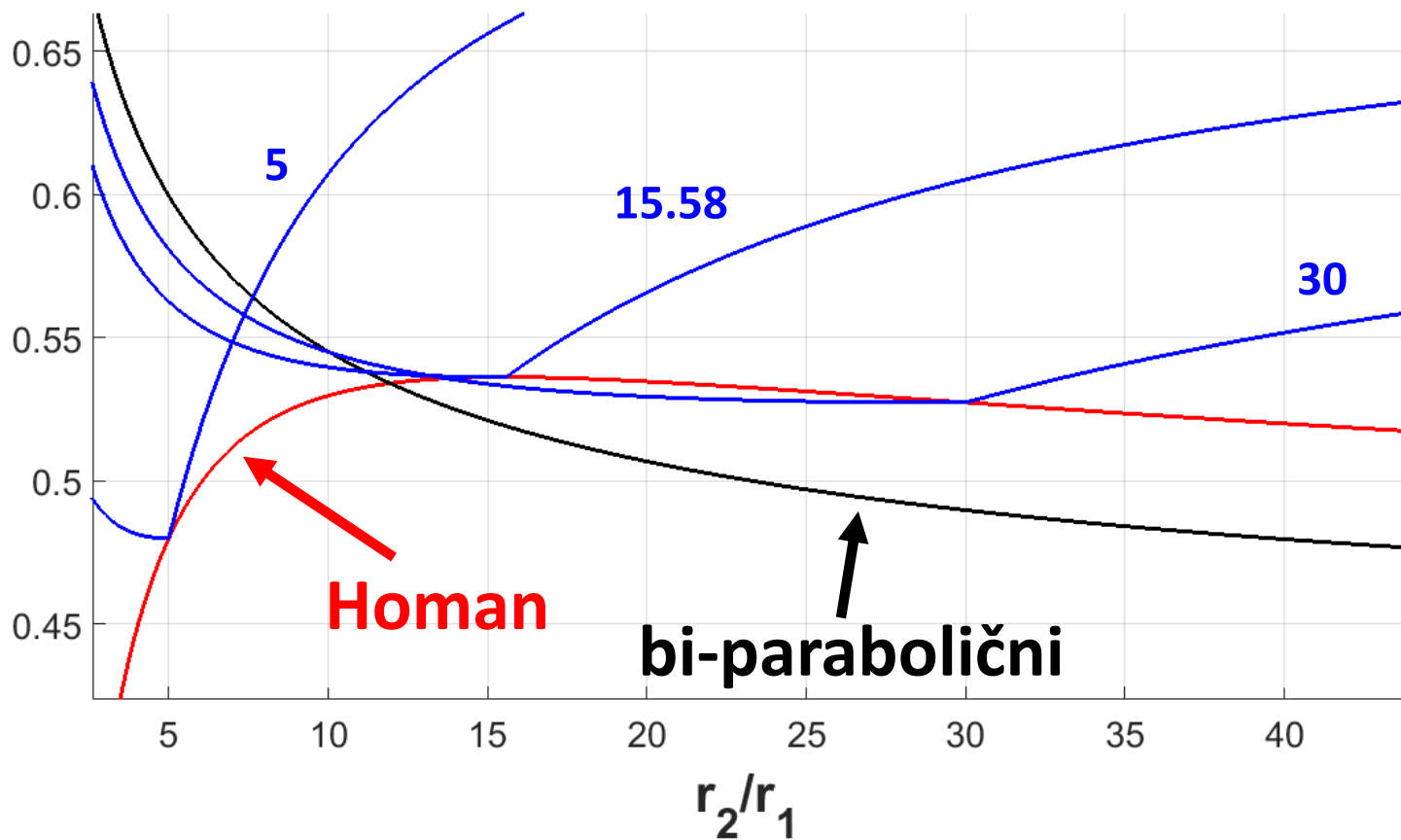
## Spoljašnji



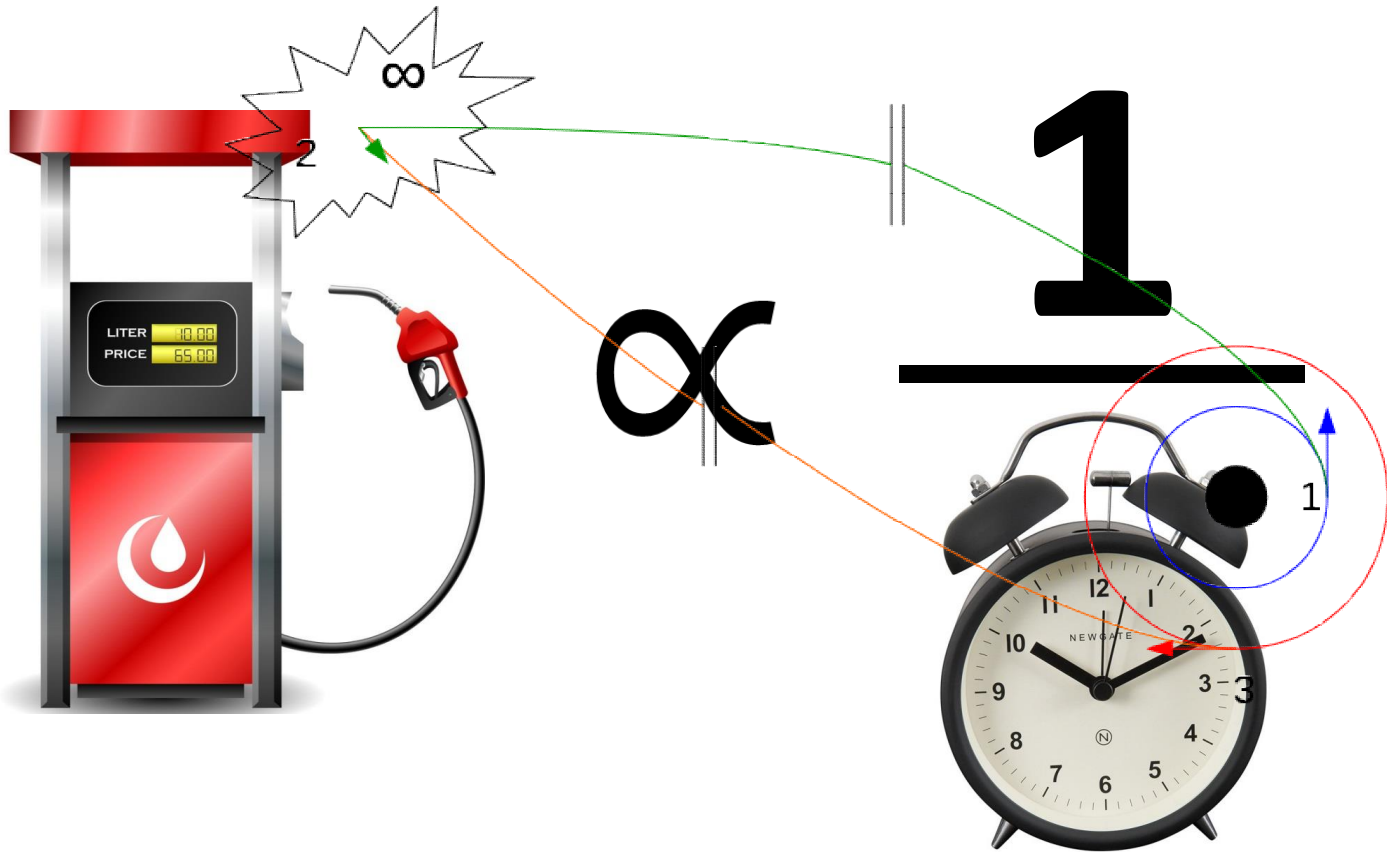
## Unutrašnji



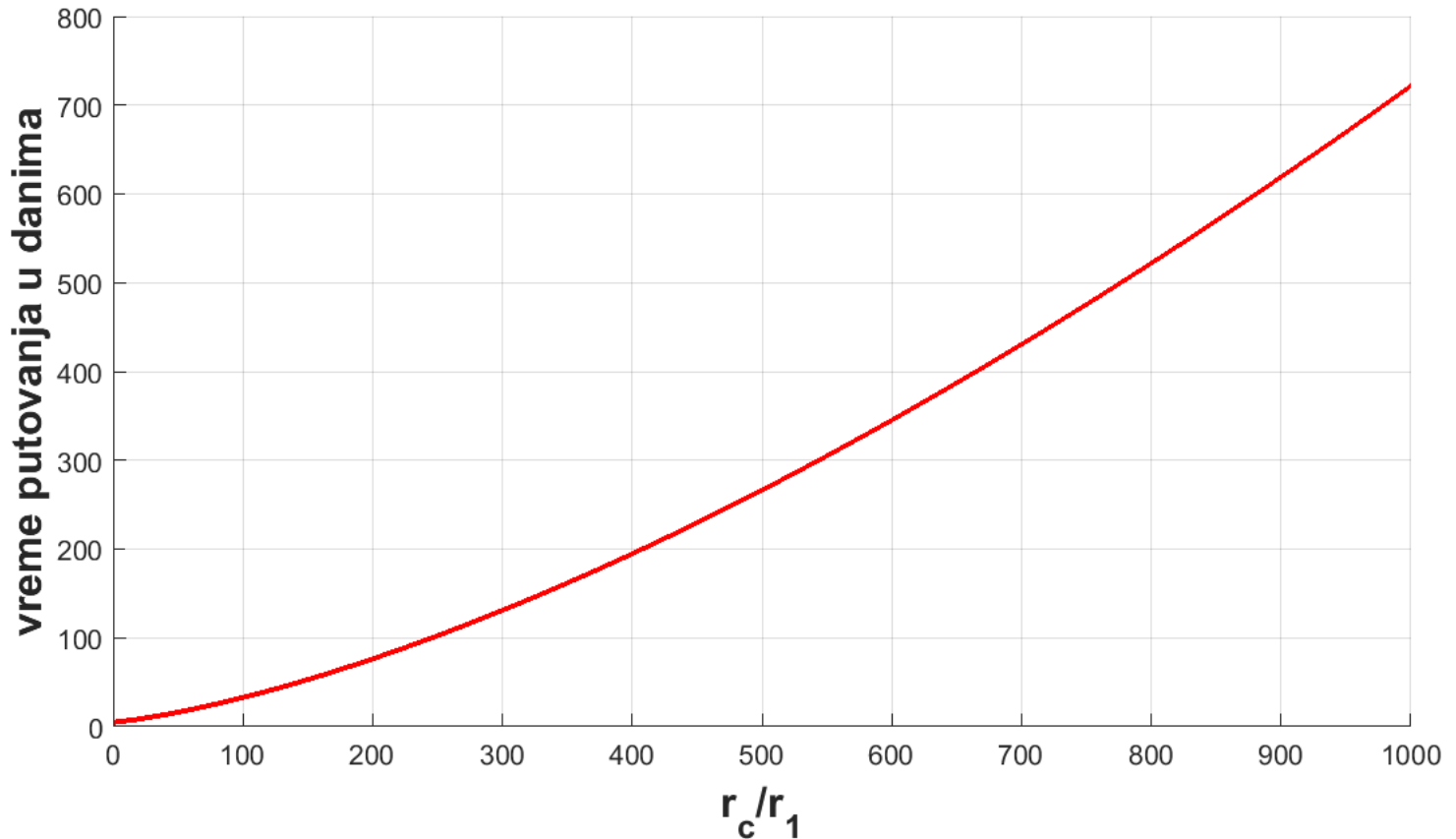
# Bi-eliptični transfer



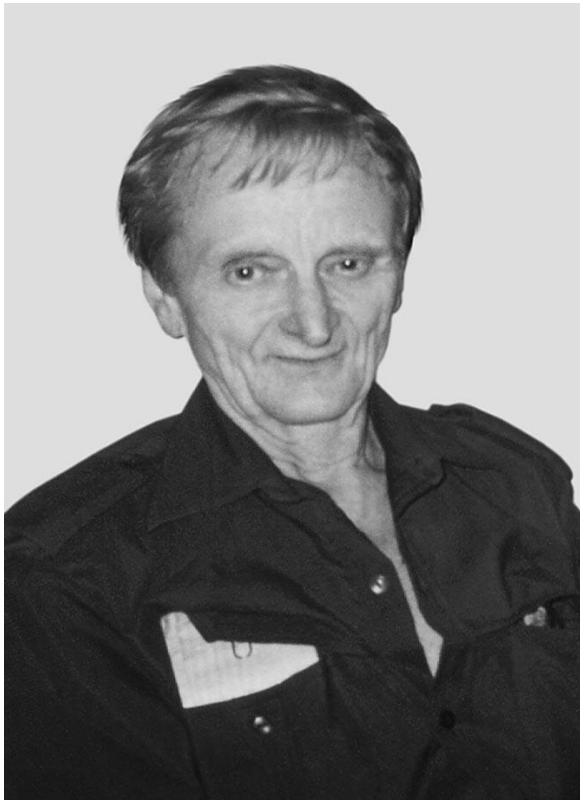
# Vreme putovanja



# Vreme putovanja



# Da li je neophodan poslednji manevar?



V. A. Egorov discovered the following remarkable fact: for any *Moon* intercept trajectory the entry velocity in the Moon's sphere of influence,  $|\mathbf{v}'_{in}|$ , calculated relative to the *Moon*, is always larger than the selenocentric escape (parabolic) velocity at the boundary of the sphere of influence. This escape velocity,  $V'_p = 0.383$  km/s, guarantees that the projectile will unavoidably leave the Moon's sphere of influence. Since  $|\mathbf{v}'_{in}| > V'_p$ , our projectile will either fall on the *Moon*, or necessarily leave the Moon's sphere of influence, passing by and around the *Moon* on a hyperbolic trajectory.

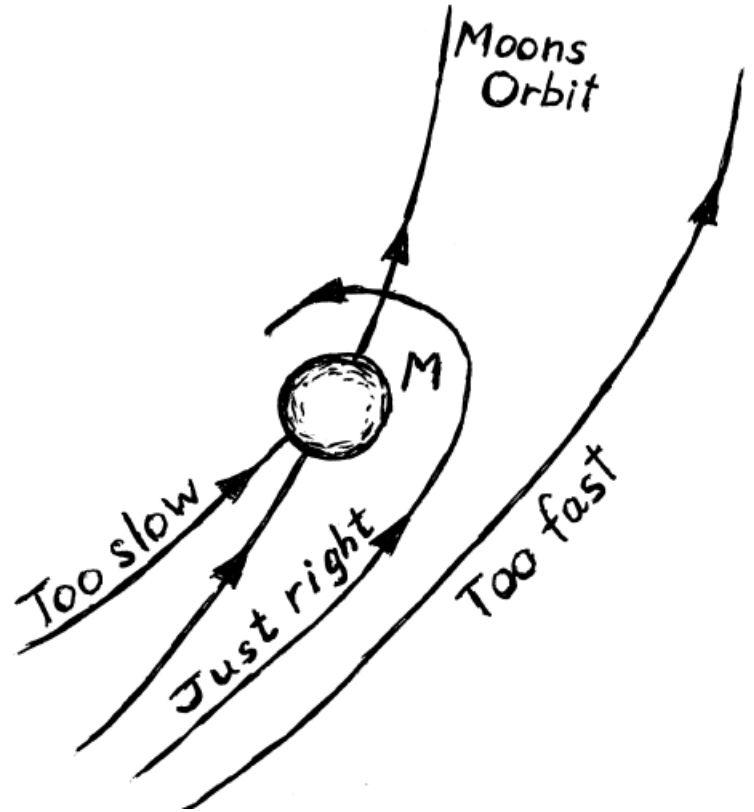
Vsevolod Aleksandrovich Egorov  
1930 - 2001

# Može još jeftinije





# Weak Stability Boundary (WSB)



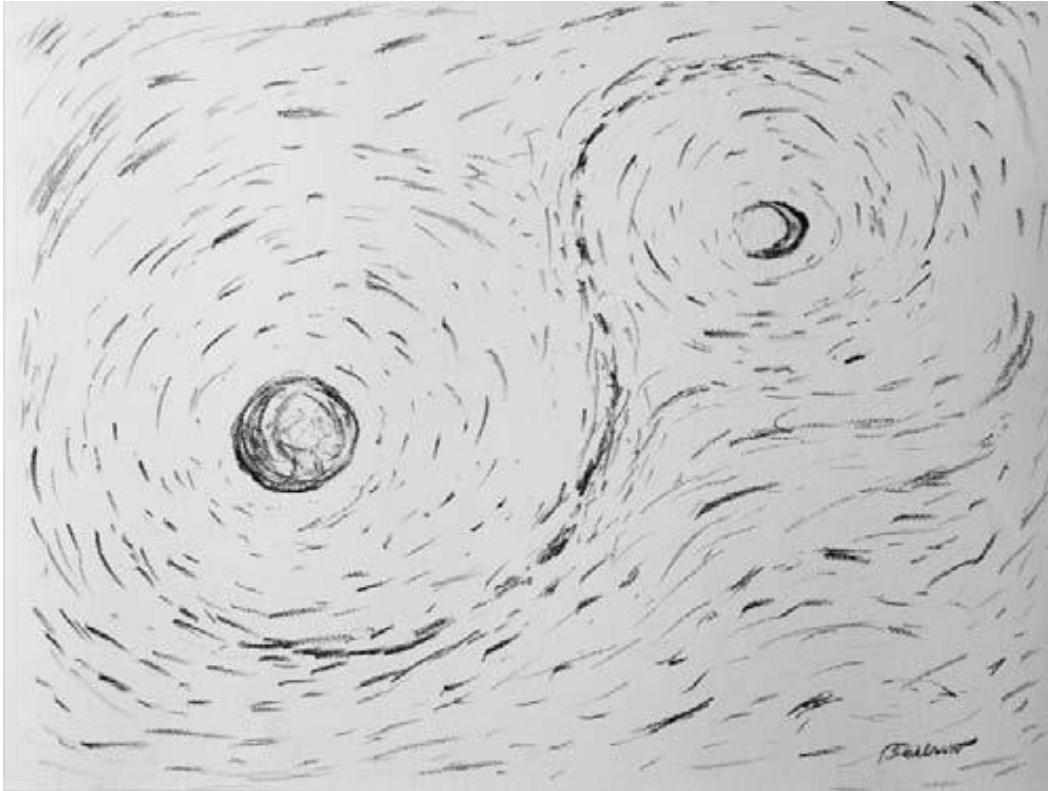
# Weak Stability Boundary (WSB)



*Dreams*

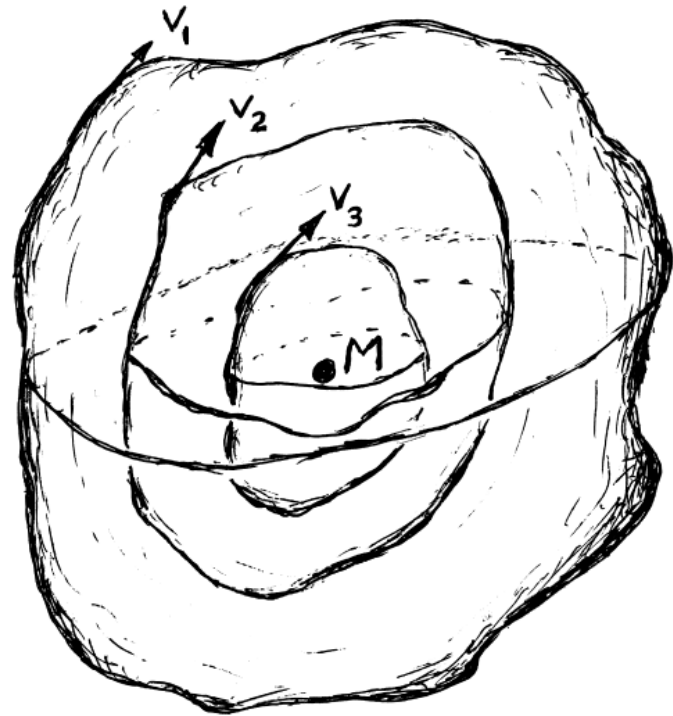
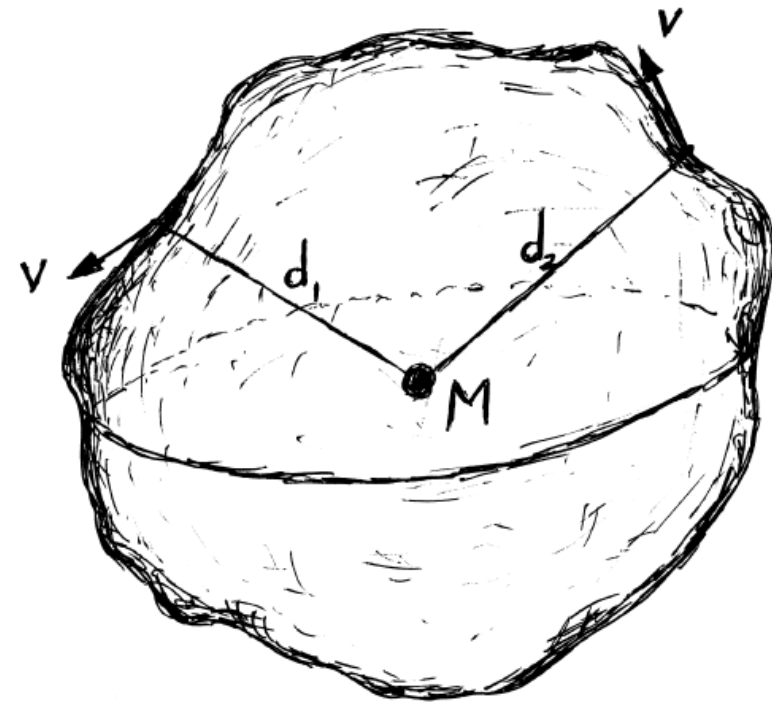
(Edward Belbruno, oil on canvas, 36" × 48", 2003.)

# Weak Stability Boundary (WSB)

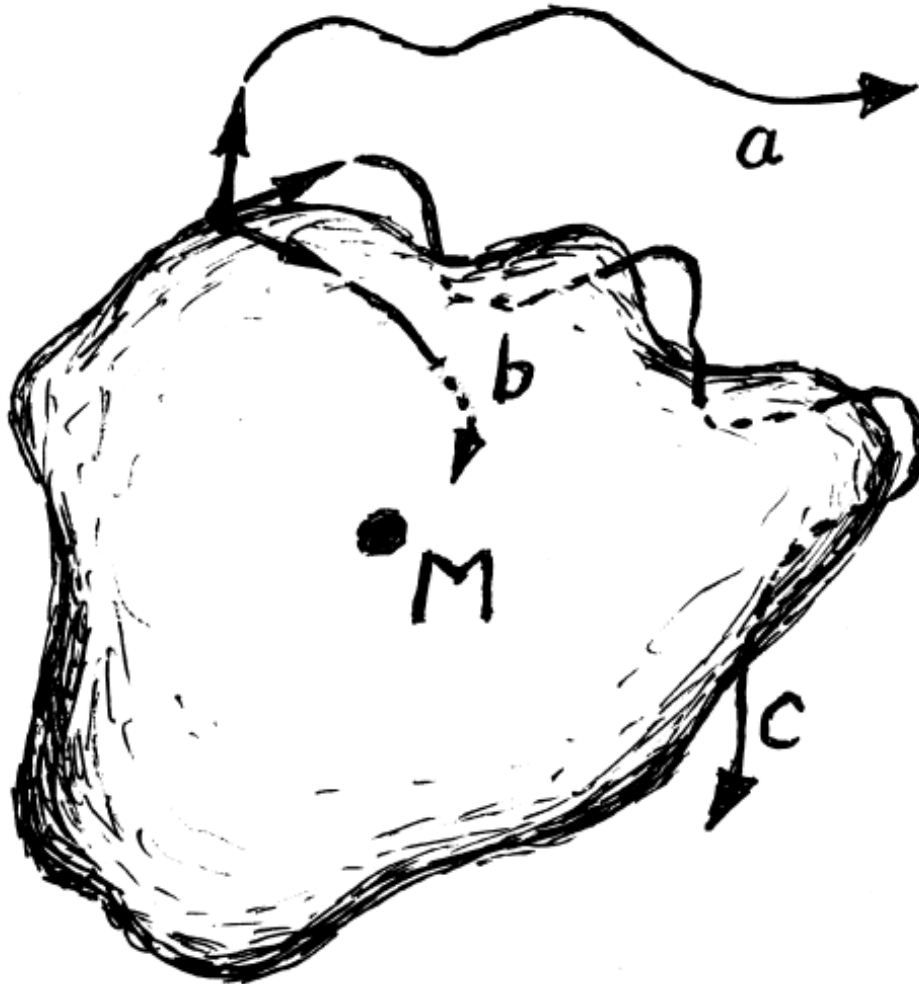


**Picture of Earth-Moon system  
(Edward Belbruno, pastel on paper, 11" × 14", 1986)**

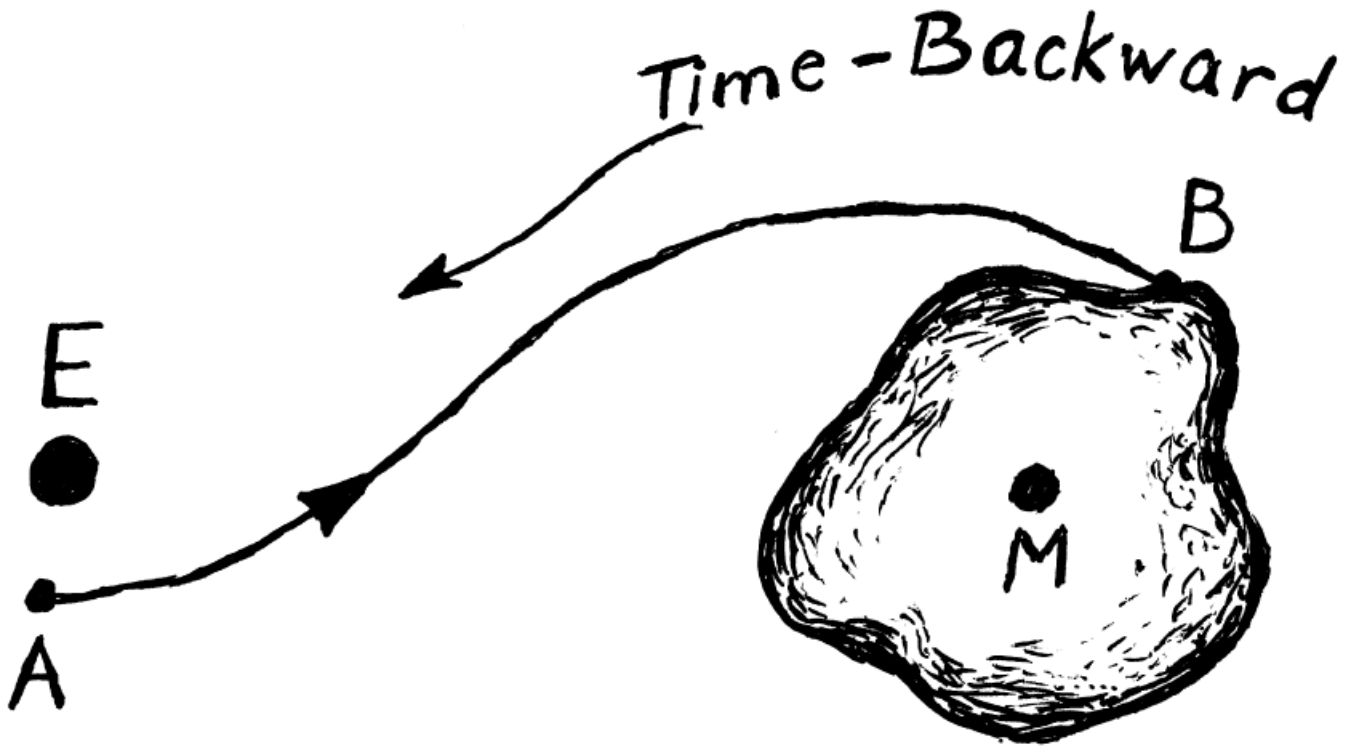
# Weak Stability Boundary (WSB)



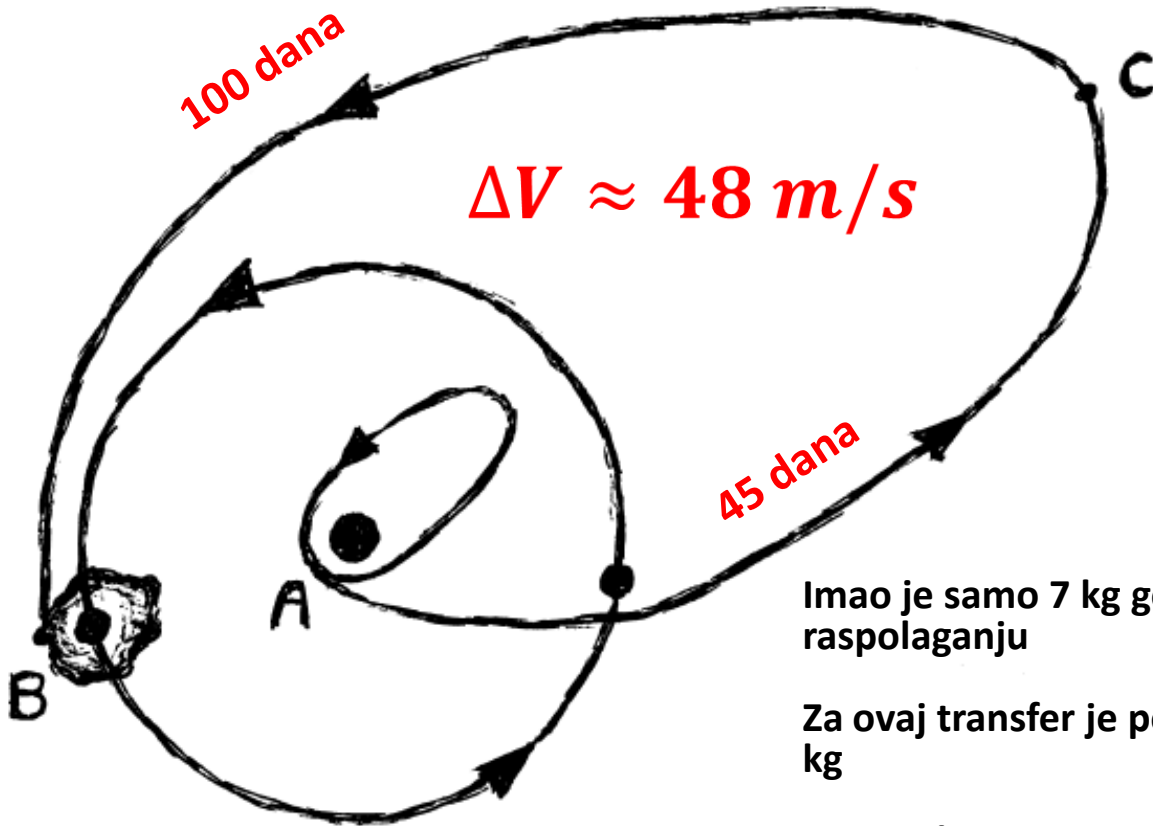
# Haotično kretanje u blizini WSB



# Putanja za Hiten



# Putanja za Hiten

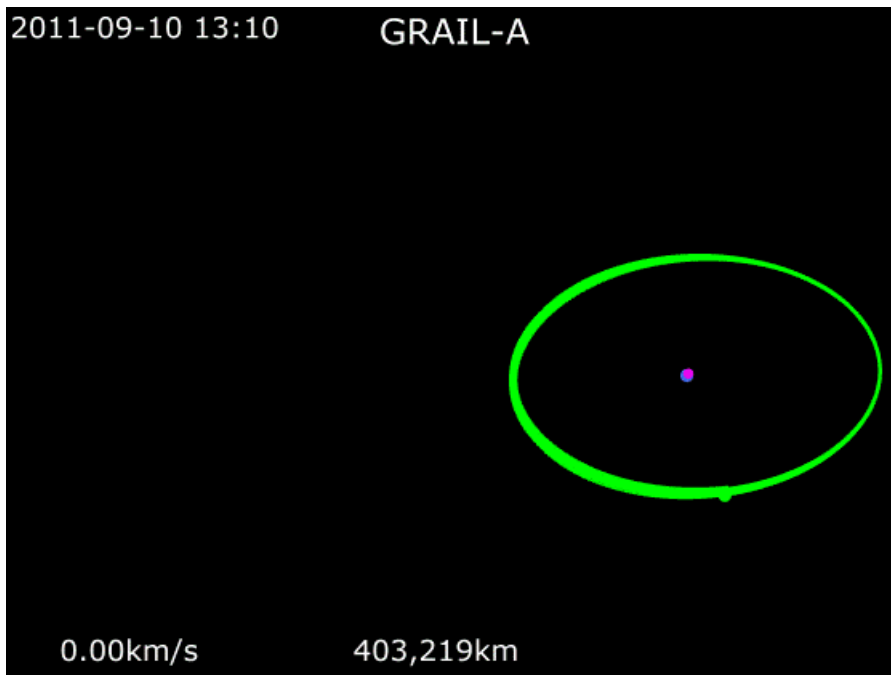


Imao je samo 7 kg goriva na raspolaganju

Za ovaj transfer je potrošio samo 3 kg

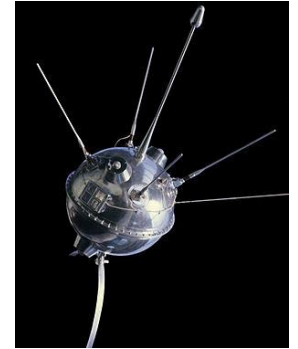
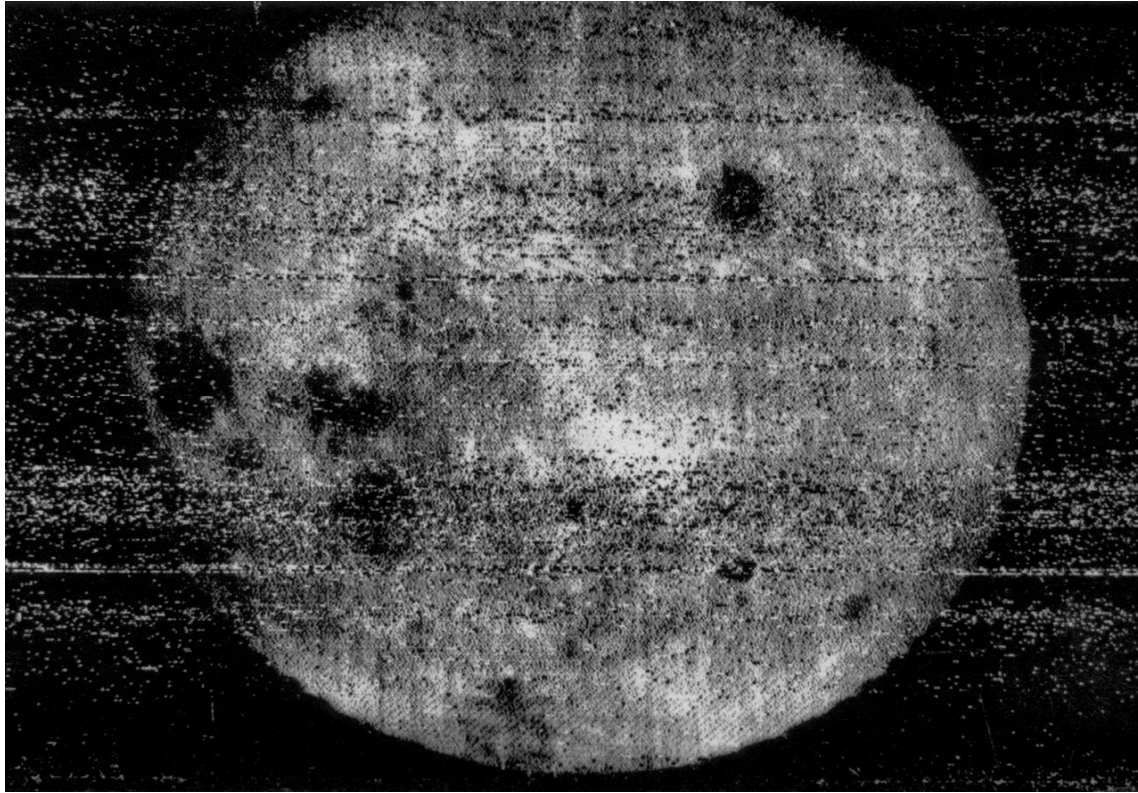
Preostalo gorivo je iskorišćeno da se provoza do L4, L5 i nazad do Meseca

# Putanja za GRAIL misiju





# Prvenci

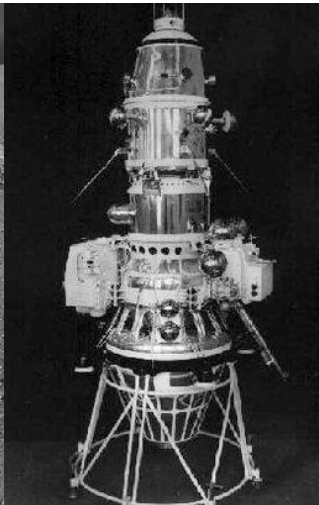
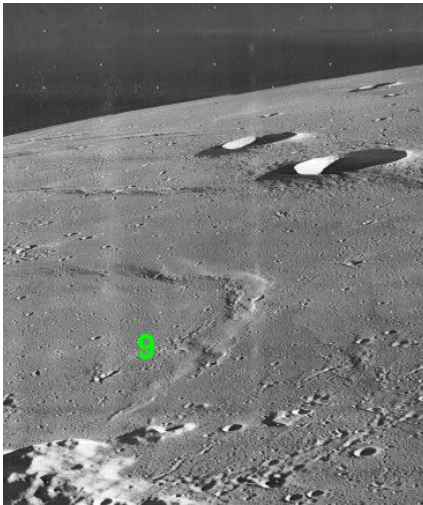


**Luna 3 (4. oktobar 1959.) – prvi pogled na dalju stranu Meseca**

# Prvenci

Luna 4-14  
1500 kg, Molniya

Luna 9 (3. februar 1966.) - prvo meko sletanje



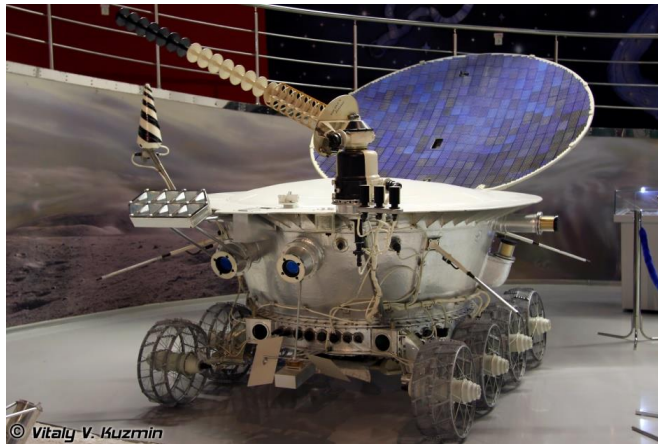
Luna 10 (3. april 1966.) – prvi Mesečev satelit

# Prvenci

Luna 15-24  
5700 kg, Proton

Luna 16 (21. septembar 1970.)

prvi robotizovani povratak uzorka sa Meseca na Zemlju



© Vitaly V. Kuzmin

Luna 17 (17. novembar 1970.)– prvi rover (lunohod)

# Prvenci

**Ranger 4 (30. jul 1964.)- prvi američki objekat na Mesecu**



**Surveyor 1 (2. jun 1966.)- prvi američki objekat koji je meko sleteo na Mesec**

# Prvenci

Zond 5 (14. septembar 1968.) - prva živa bića u blizini Meseca i prva uspešna cirkumlunarna misija



Bezbedno vraćeni  
na Zemlju!



Secirane 3 nedelje  
nakon sletanja 😞

# Prvenci

**Apolo 8 (21. decembar 1968.)- prva ljudska misija ka Mesecu**

**Frenk Borman**

**Džejms Lovel**

**Vilijam Anders**



# Prvenci

**Apolo 11 (20. jul 1969.)- prvi ljudi na Mesecu**

**Nil Armstrong**

**Edvin Oldrin**

**Majkl Kolins**



# Da li je Armstrong napravio lapsus?



One small step for **a**  
man, one giant leap  
for mankind





# Prvenci

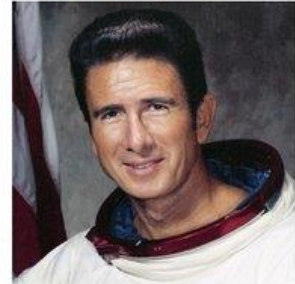
**Apolo 17 (19. decembar 1972.)- prvi naučnik na  
Mesecu**

**Eugen Kernak  
Ronald Evans  
Harison Šmit**



# The Moonwalkers

## šetači po ozarju



# The Moonwalkers

## šetači po ozarju



Flight Test and  
Flyby Missions



Luna 1



Ranger 1  
Ranger 2



Luna 4



Pioneer 4

Orbiters



Luna 3

Landers and Impacts



Luna 2



Ranger 3  
Ranger 4  
Ranger 5



R  
R

1959

...

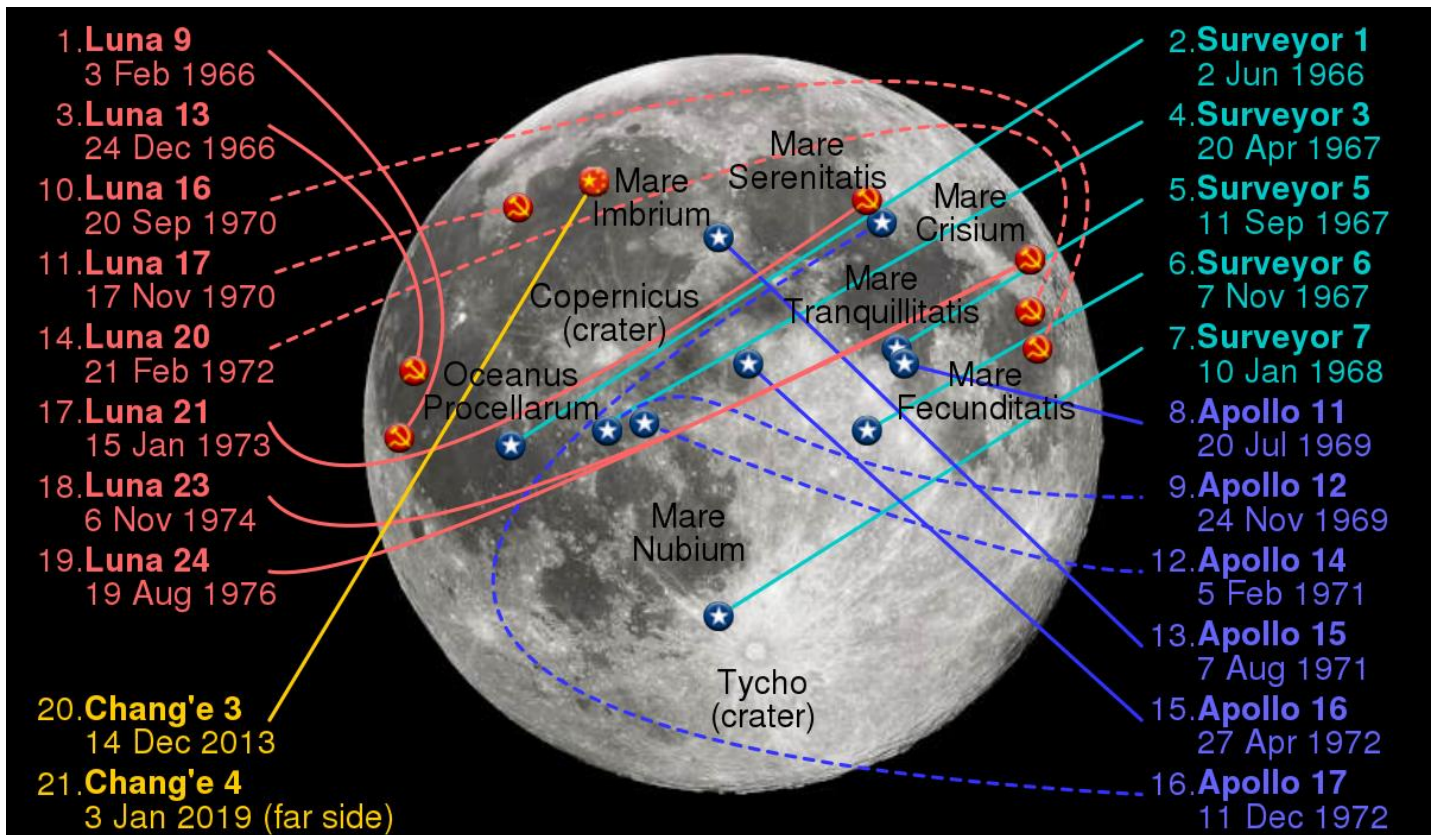
1961

1962

1963

1964

# Uspešna meka sletanja



# Trenutno stanje saobraćaja na Mesecu

**5 operativnih aparata u orbiti**

**2 operativna aparata na površini**

# **Naučni eksperimentni na Apolo misijama**

## **Apollo Lunar Surface Experiments Package (ALSEP)**

**Active Seismic Experiment (ASE)**

**Passive Seismic Experiment (PSE)**

**Charged Particle Lunar Environment Experiment  
(CPLEE)**

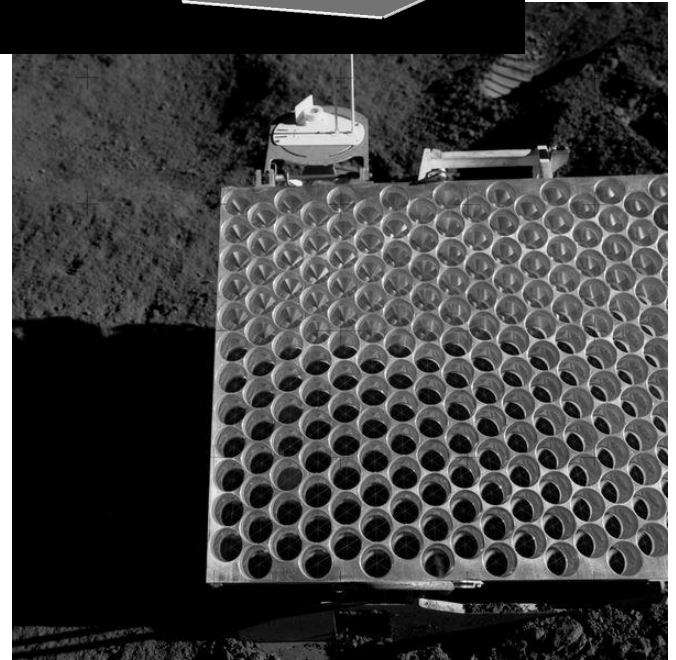
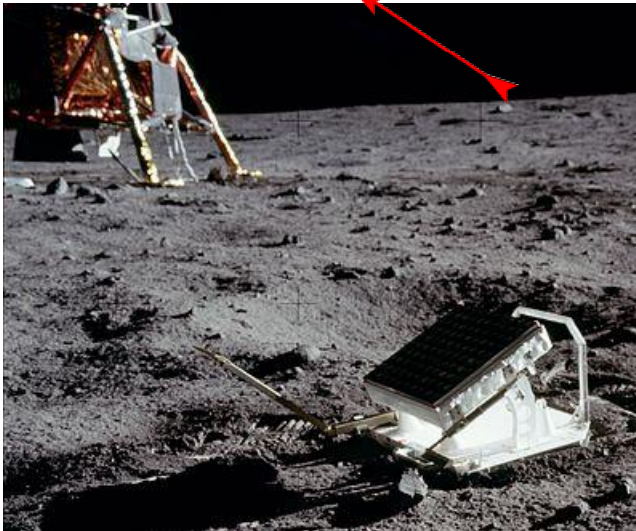
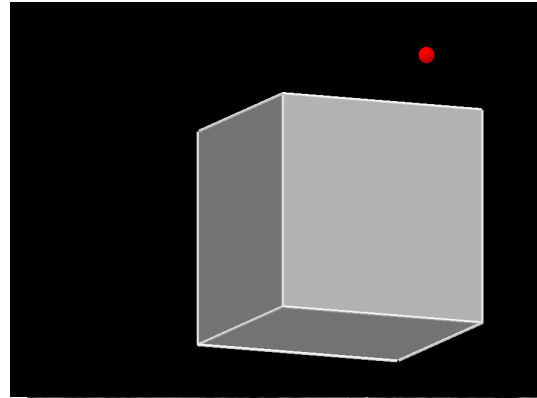
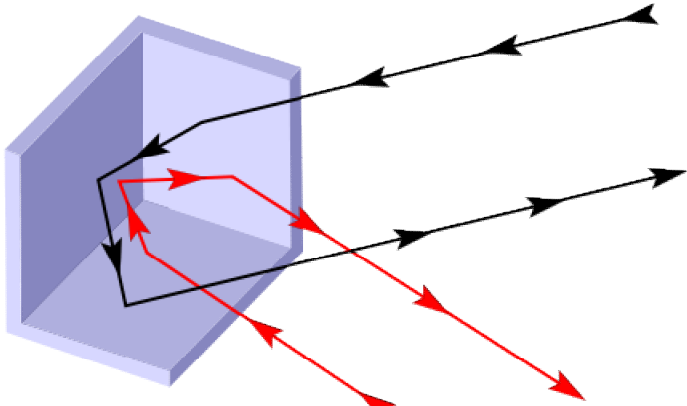
**Heat Flow Experiment (HFE)**

**Laser Ranging Retroreflector (LRRR)**

**Lunar Atmosphere Composition Experiment  
(LACE)**



# Lunar Laser Ranging experiment



# Lunar Laser Ranging experiment

**Mesec se udaljava od Zemlje oko 38mm godišnje**

**Stabilnost gravitacione konstante**

**Nordtvedtov efekat**

**Princip ekvivalentnosti**

**Opšta teorija relativnosti**

# Šta je sve doneto sa Meseca

Misija	Godina	Količina
Luna 16	1970	100 g
Luna 20	1972	30 g
Luna 24	1976	170 g
Apolo 11	1969	21 kg
Apolo 12	1969	34 kg
Apolo 14	1971	43 kg
Apolo 15	1971	77 kg
Apolo 16	1972	95 kg
Apolo 17	1972	110 kg

**~380 kg**

# Povratak na Mesec



**Artemis**

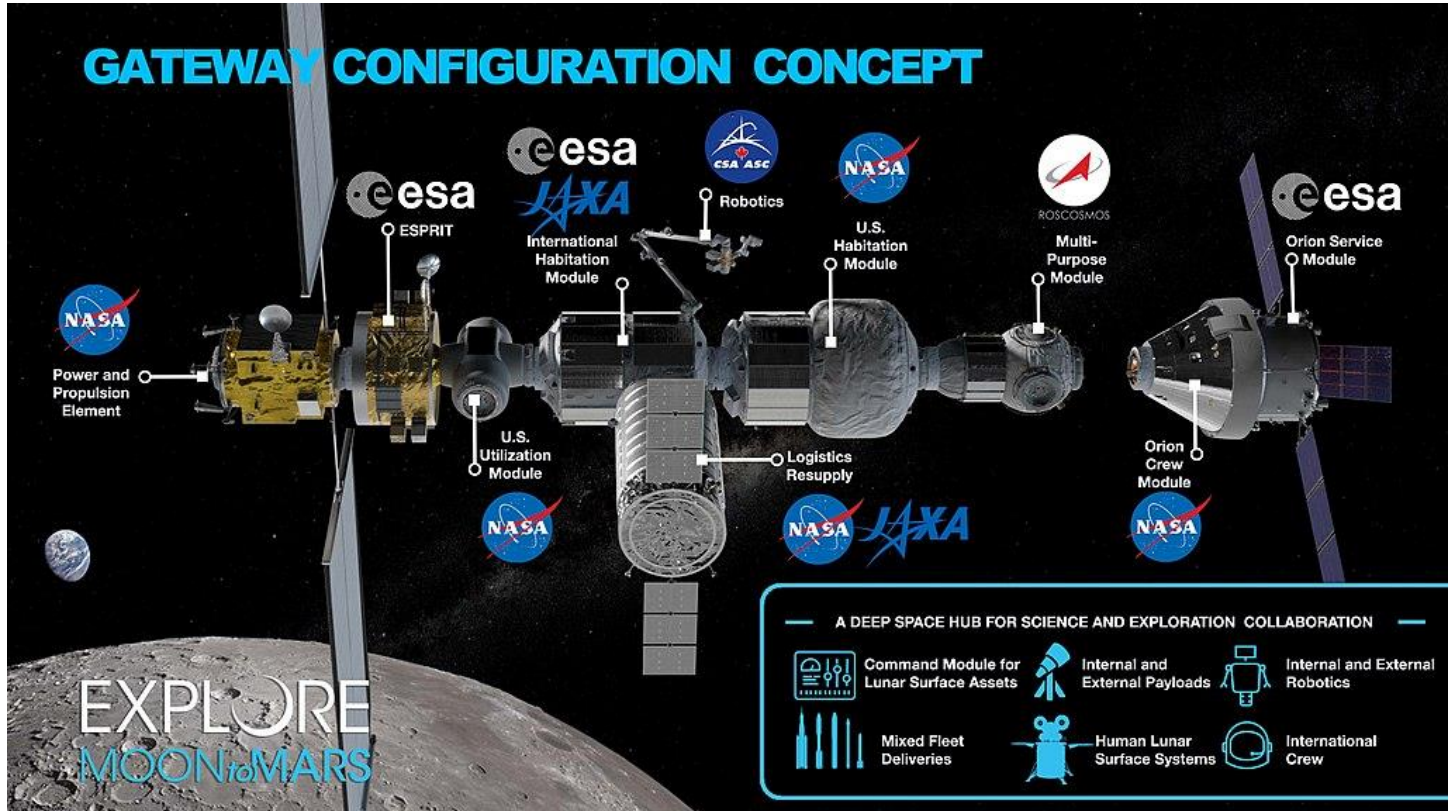


**Luna-Glob**

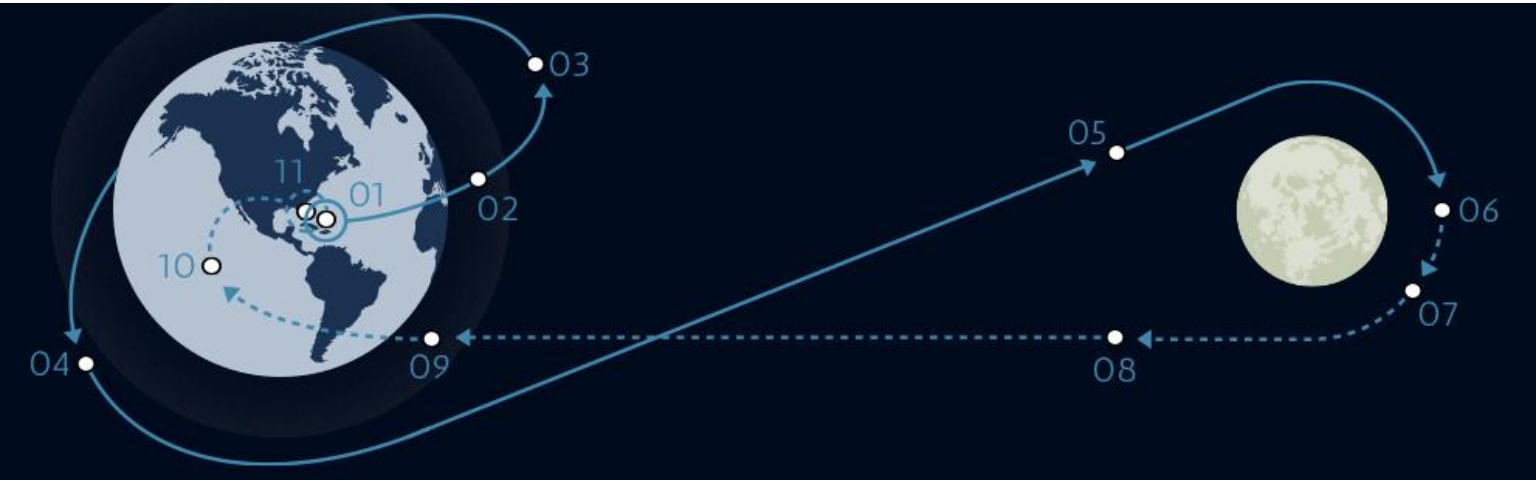


**CLEP**

# Povratak na Mesec



# Dear Moon



**Hvala na pažnji**