

HIGHWAYS to MOON BASE

Voyager 1 (1977)

Ettore Perozzi & Sergio Ponzi

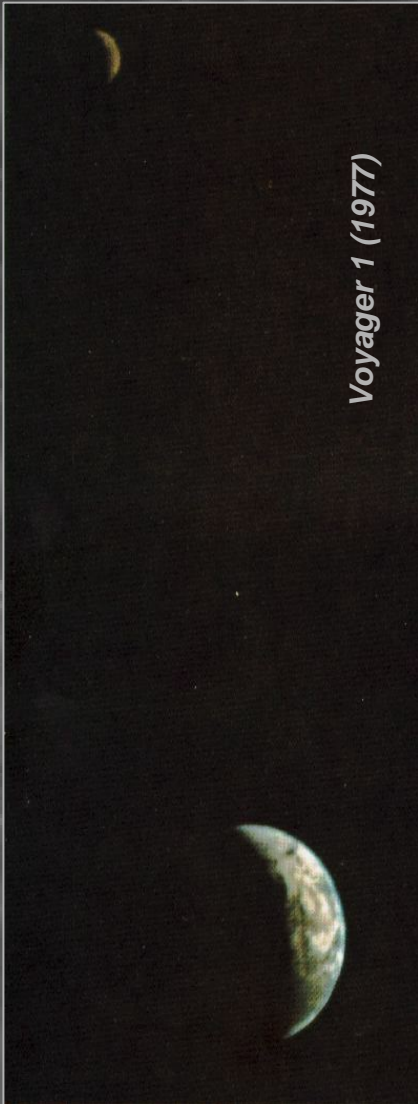
Telespazio (Roma, Italy)

Filippo Graziani & Paolo Teofilatto

Scuola di Ingegneria Aerospaziale, The University of Rome (Italy)

Giacomo Giovangrossi

Aero Sekur (Italy)



The Hohmann Way
Poicare's Conjecture
Periodic Orbits
Halo Orbits
Stable Manifolds
Exploiting Fuzzy Boundaries
Surface Deliveries
From Washington to Jamestown

Expertise



1961

GROUND SEGMENT INFRASTRUCTURES

- Ka band TLC (Italsat, Olympus, Artemis)
- C-band large diameter antennas (26-32m)
- Optical inter-Orbit data relay
- Upgrading to DSN

OPERATIONS CONTROL CENTERS

- SAX (Italian astronomy X-ray satellite)
- Italsat, Olympus, Sicral

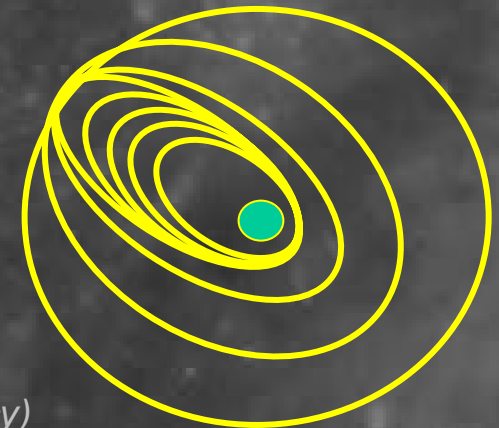
FLIGHT DYNAMICS

- Flight Dynamics Systems
- LEOP services
- Artemis mission recovery

SPACE GEODESY

(on behalf of the Italian Space Agency)

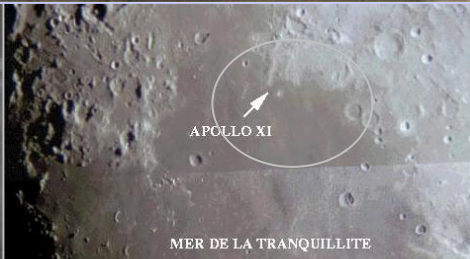
- Satellite laser tracking (LAGEOS)
- Lunar Laser Ranging Facility
- Geodetic data processing



2001



1983



APOLLO XI

MER DE LA TRANQUILLITE



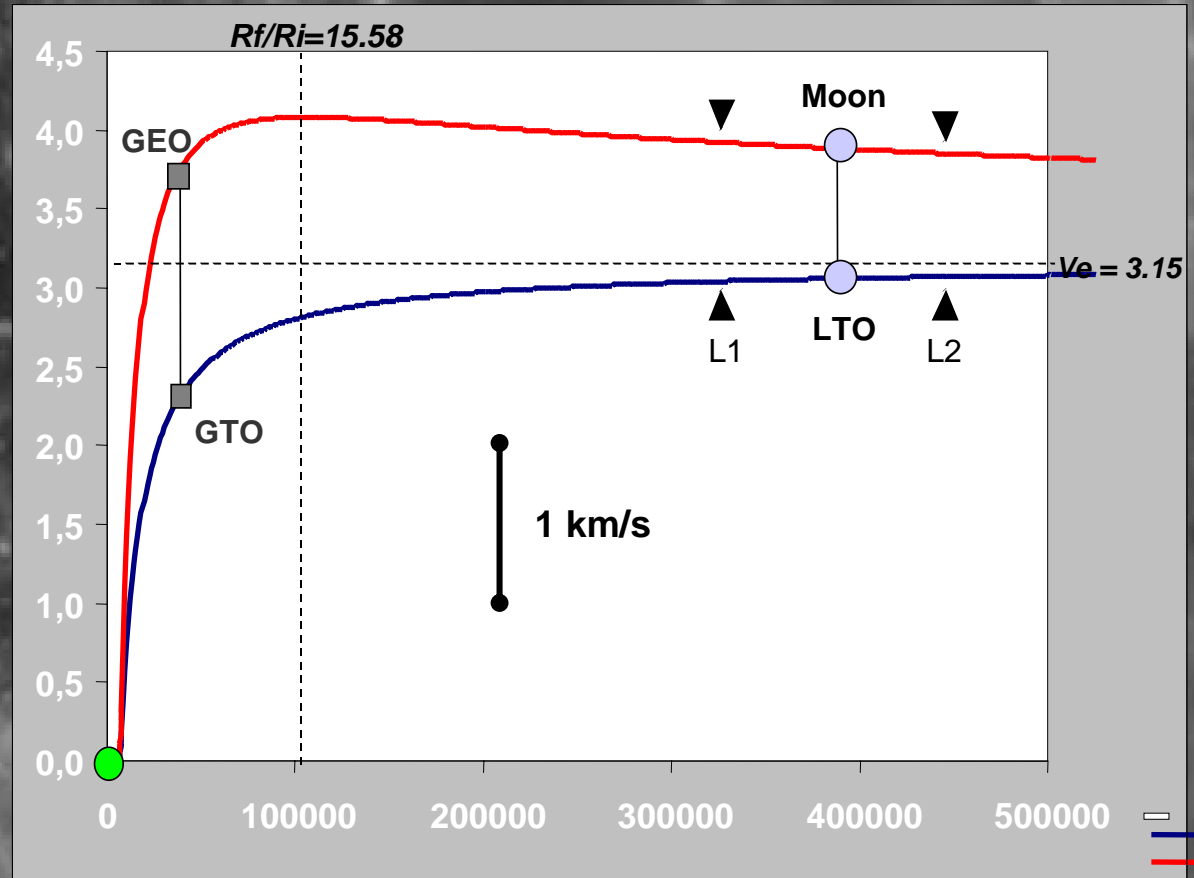
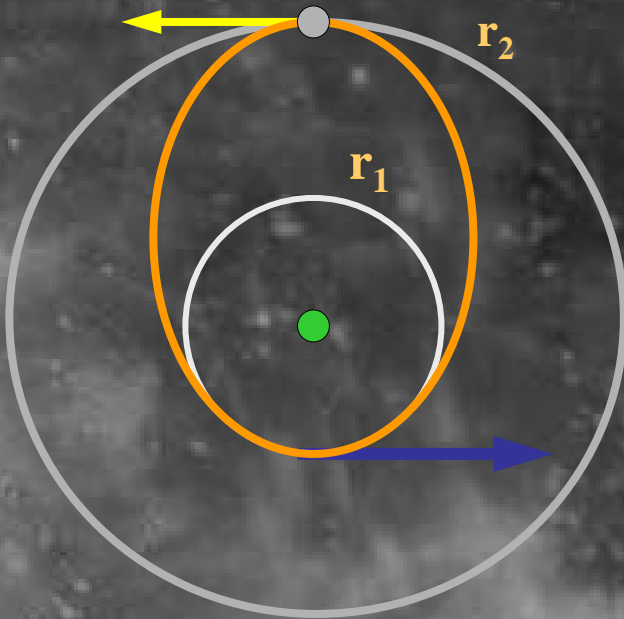
1996



1999



The Hohmann Way





Poincaré's Conjecture

Here is a fact that I have not been able to demonstrate rigorously, but which appears to me nevertheless very likely to be true.

Being given equations of the form defined in [Section] 13 and a particular solution of these equations, one can always find a periodic solution (of which the period can, it is true, be very long), such that the difference between the two solutions will be as little as one wishes during a time as long as one pleases.

Besides, that which makes periodic solutions so valuable is that they are, so to speak, the only breach through which we can attempt to penetrate what was previously thought impregnable.'



Poincaré's Conjecture

Here is my thought

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for every « gravitational drawing » exists a periodic orbit arbitrarily close to it, but possibly of very long period.

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Poincaré's Conjecture

Here is my conjecture

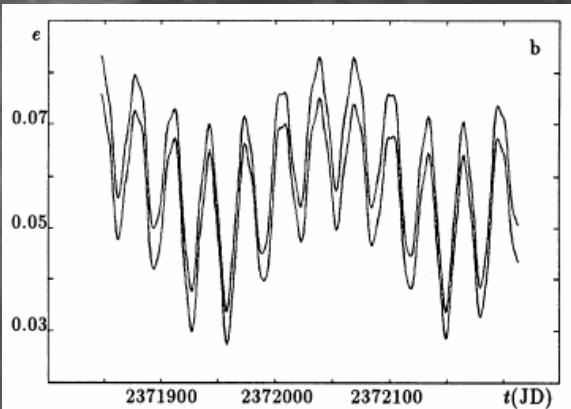
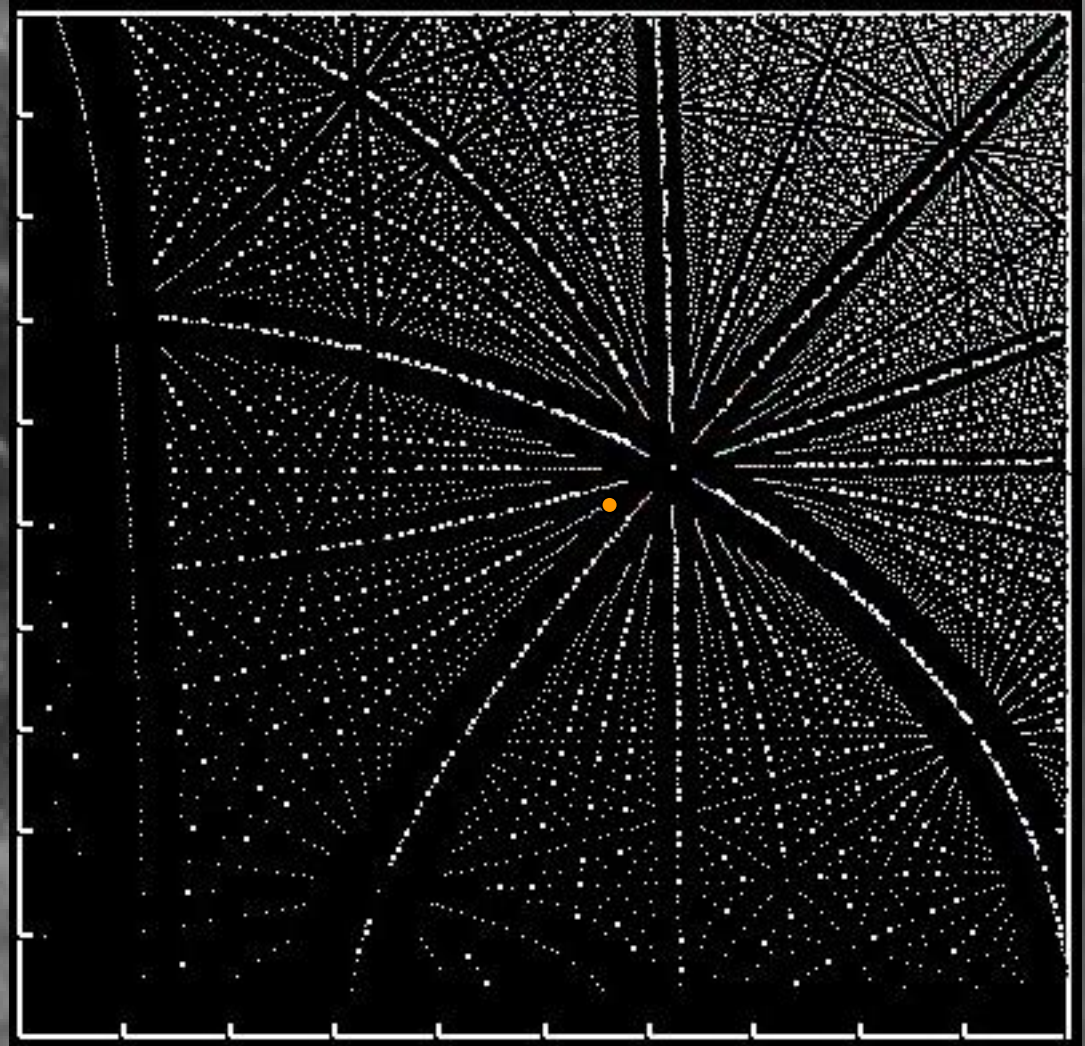
for every « gravitational drawing » exists a periodic orbit arbitrarily close to it, but possibly of very long period.

mathematics applies better to periodic solutions

Periodic Orbits

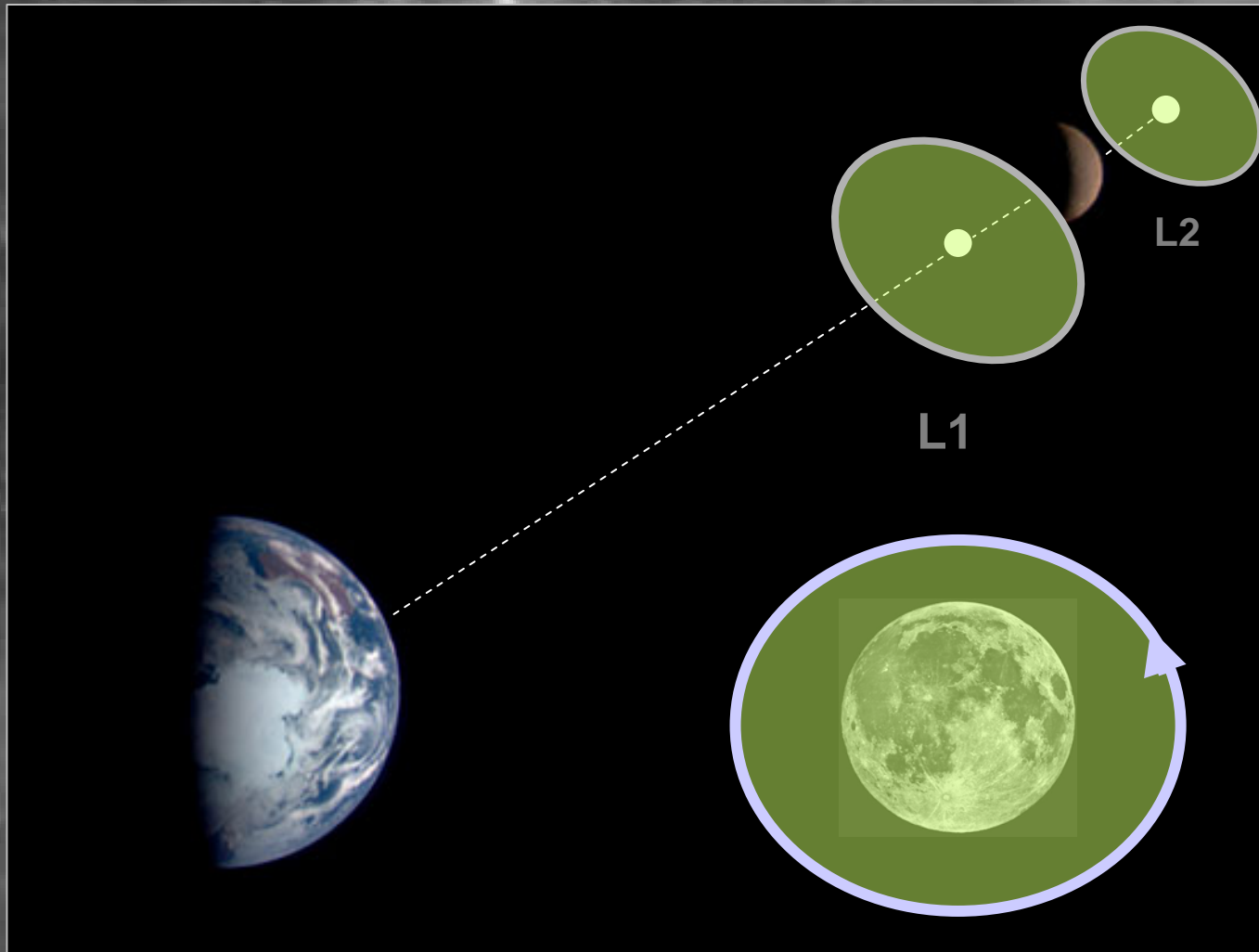


In the phase space of the three-body problem, the set of periodic orbits is dense in the set of bounded orbits



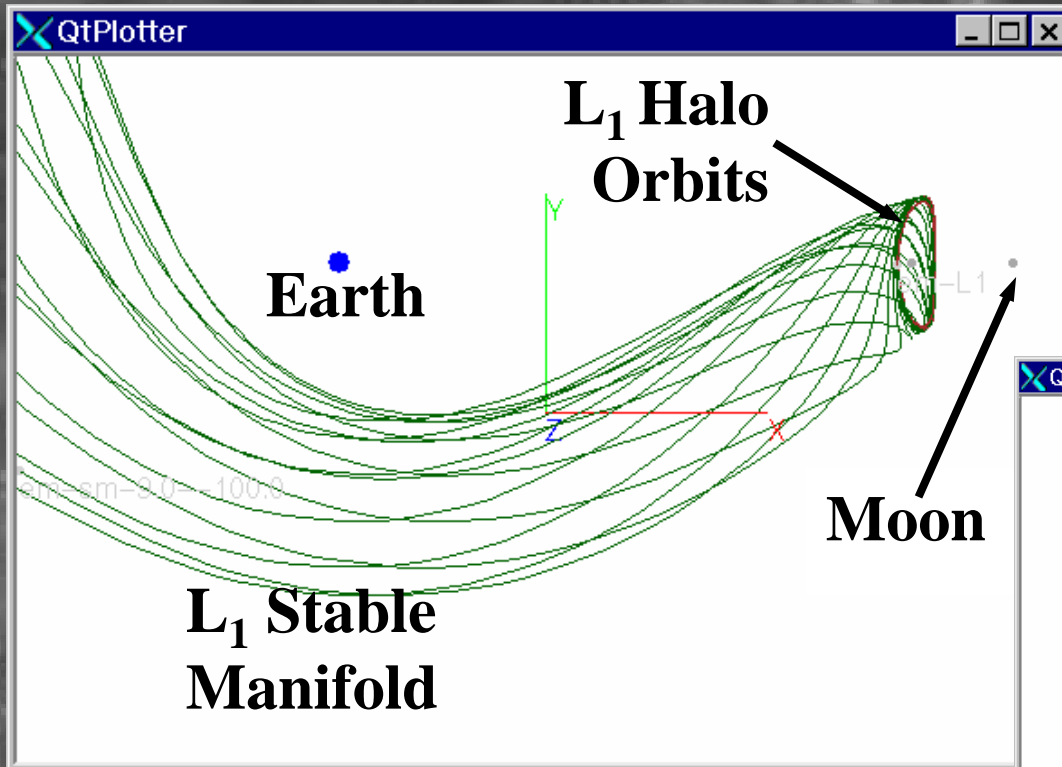
Periodic Orbits Close to that of the Moon: Valsecchi, Perozzi, Roy, Steves

Halo Orbits



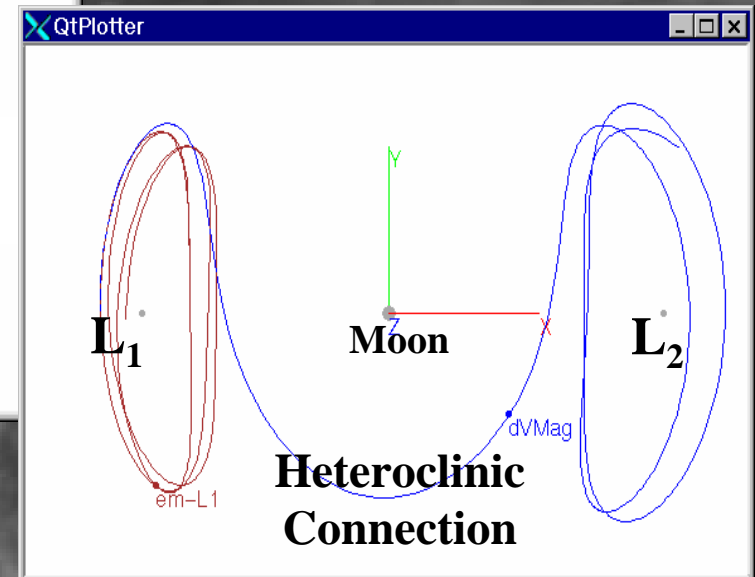
Proposed by Farquahr and Kamel in 1968 for placing a telecom satellite in L2 in order to avoid telecommunications breakdown during the Apollo missions

Stable Manifolds

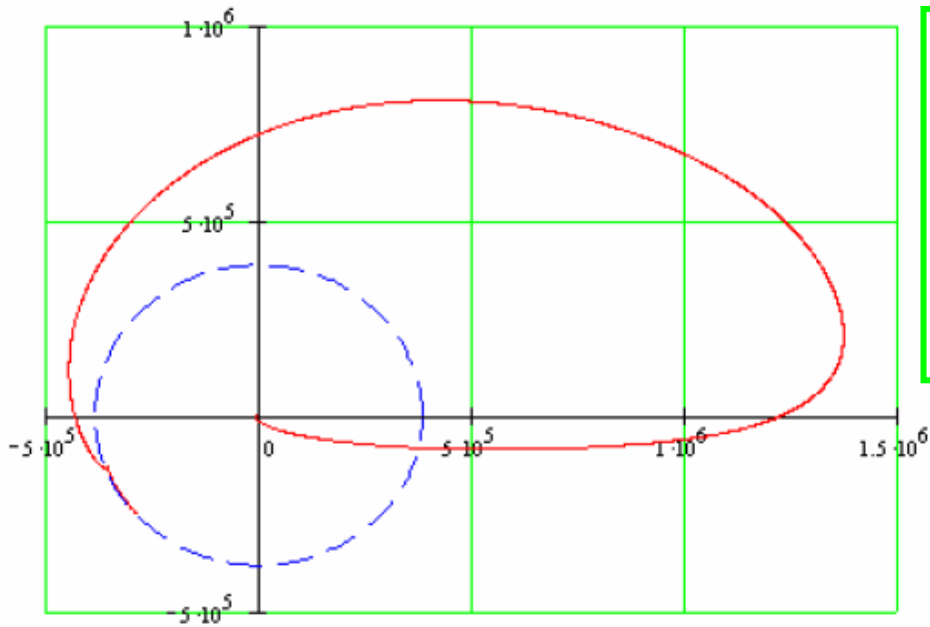


*Servicing Halo Missions
at the Lunar L₁ Gateway*

by M. Lo & M-K Chung, JPL



Fuzzy Boundaries

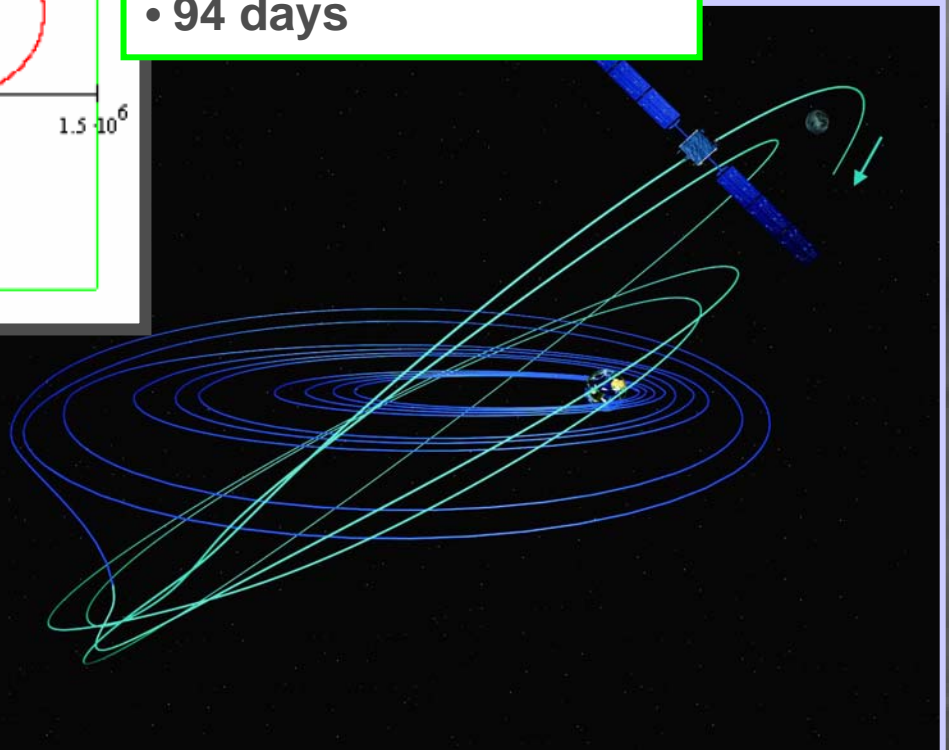


HITEN-like TRANSFER

- Sun-Earth L1
- Ballistic trajectory
- 94 days

SMART-like TRANSFER

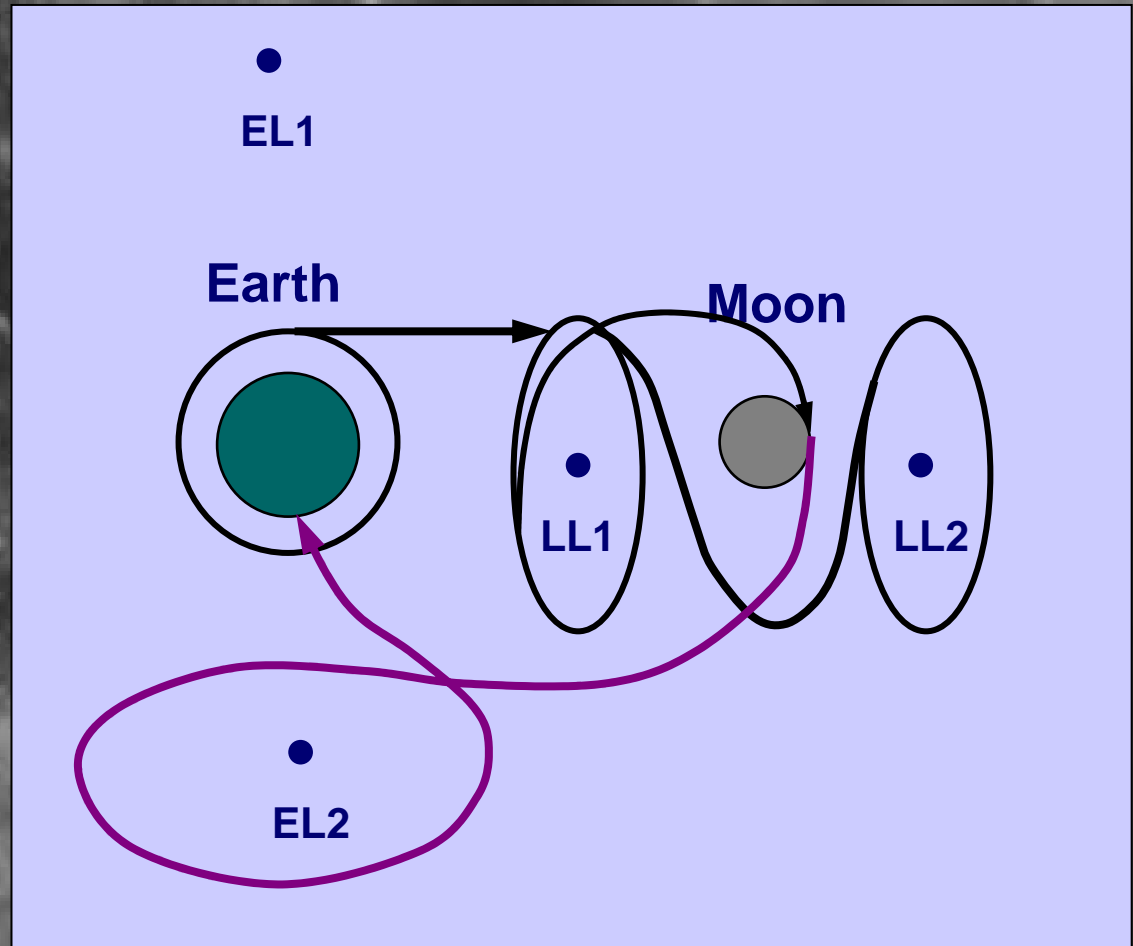
- Earth-Moon L1
- Electric Propulsion
- 400 days

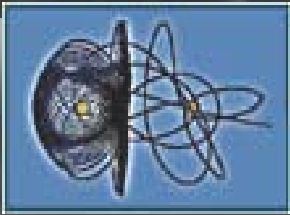


Lunar Gateway

Our Solar System is interconnected by a vast system of tunnels winding around the Sun generated by the Lagrange Points of all the planets and their moons.

The lunar L1 orbit could reach any point on the surface of the Moon within hours, thus this portal is also a perfect location for the return of human presence on the Moon.





Celmec IV



S. Martino al Cimino (VT, Italy), 11-16 September 2005

- **The Geography of Resonances**
- **L_1 , L_2 Chaotic Control**
- **Symmetric vs asymmetric periodic orbits**
- **Stability theorems**
- **Impulsive and EP Lunar transfers**
- **Nuclear and Solar Thermal Propulsion**
- **Hybrid Optimal Control**
- **Manœuvre Automaton** (*genetic algorithm + direct optimizer*)

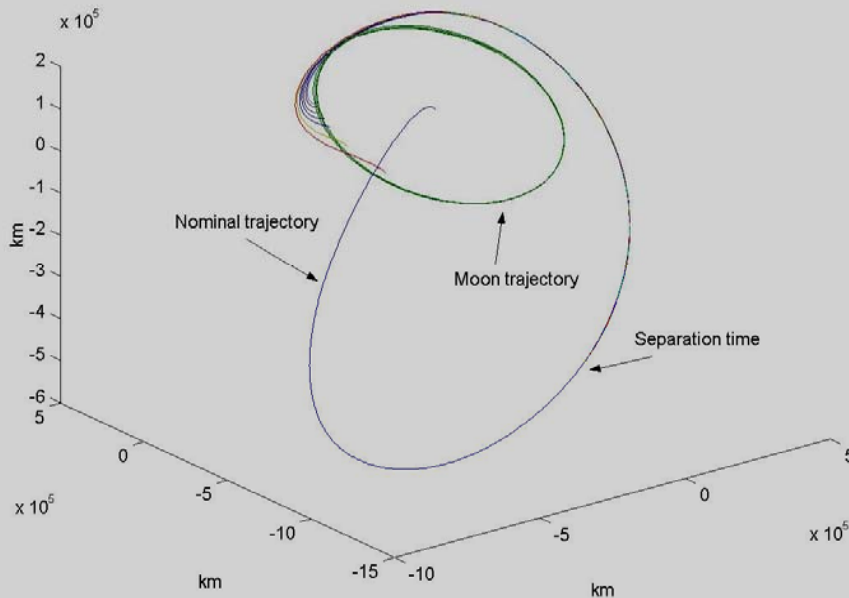
Organising Committee: Celletti, Perozzi, Milani, Valsecchi

Lunar Constellations

Take advantage of the weak stability dynamics in order to deploy a constellation of lunar spacecrafts with a small ΔV

$\Delta V = \pm 20 \text{ cm/s}$ at separation

springs



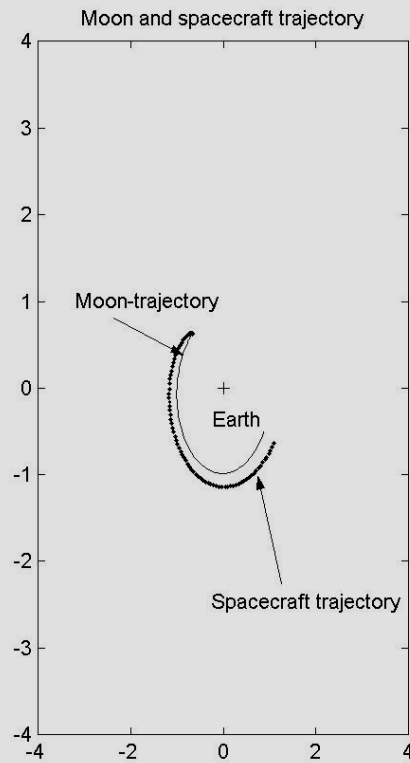
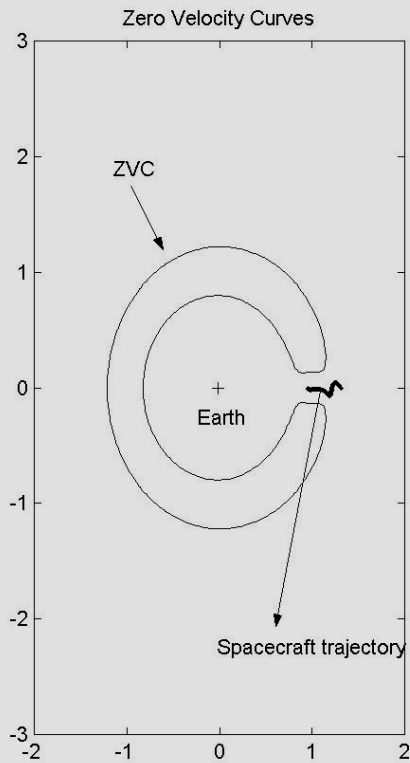
transfer time:
90 days

$$\Delta V_{\text{saved}} = [200 + 40 \times (\text{n.of.satellites})] \text{ m/s}$$

WSB

deployment

L2 Martian Gateway

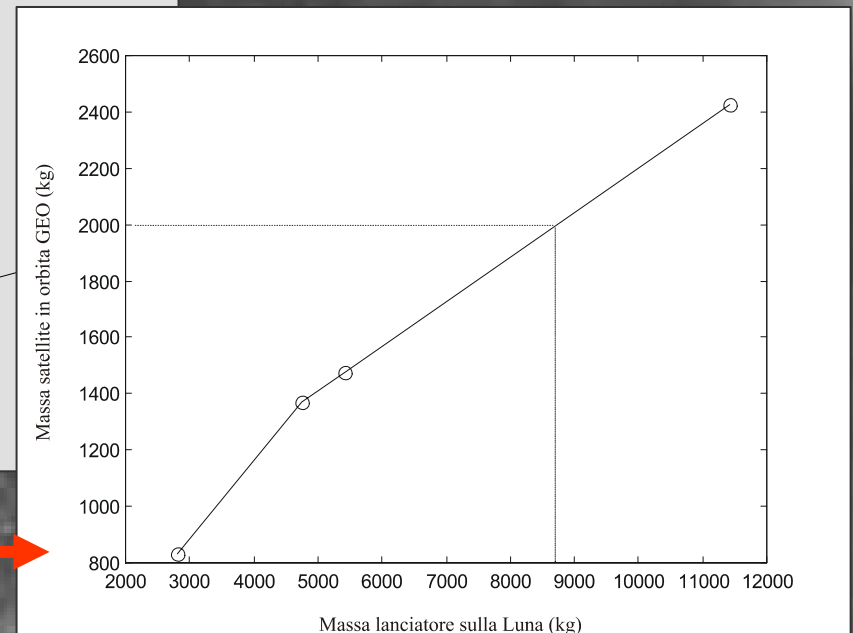
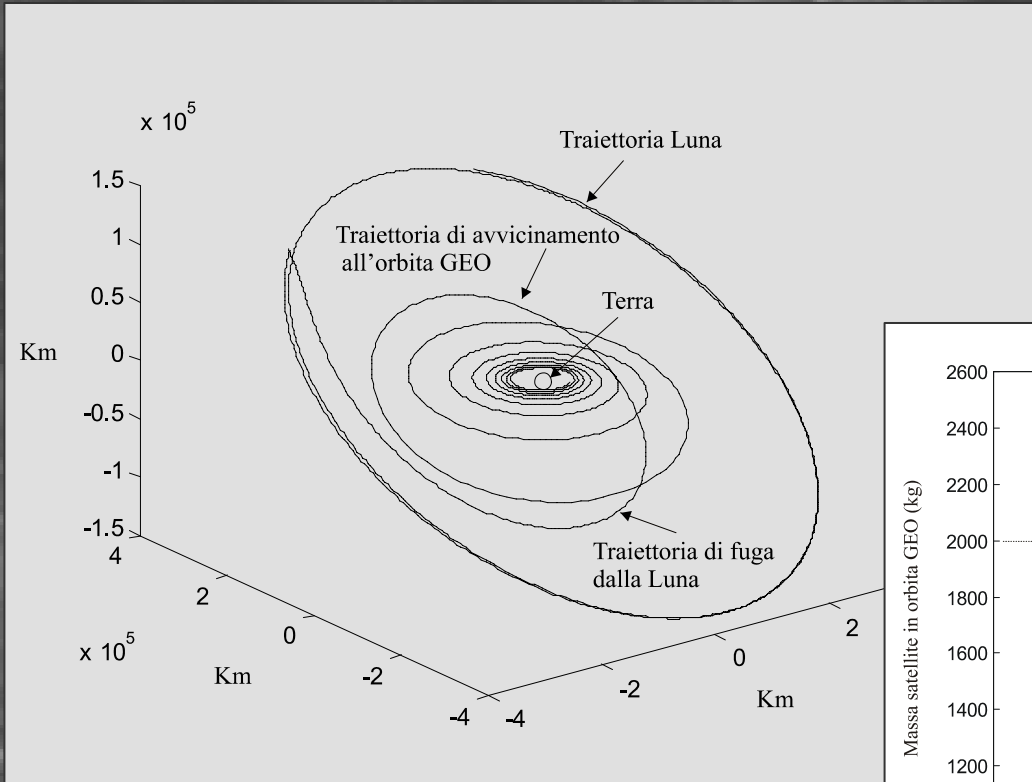


**Heavy Payload:
65 MT**

**Earth-Mars
transfer:
30 Ariane V**

**Moon-Mars
transfer:
1 Ariane V**

Moon to GEO



**Lunar launcher mass
Vs. total mass in GEO**

- **E>M>E highways**

- Fast E>M Hohmann-like transfers (manned)
- Intermediate E>M WSB transfers (manned, cargo)
- Slow E>M transfers (non-critical cargo)
- M>E resources and fuel delivery
- Lagrangian points homoclinic connections

- **L₁ portal**

- L₁ Halo parking lot
- space elevator terminal
- express surface delivery

- **L₂ portal**

- L₂ far side Telecom Satellite
- Interplanetary gateway

Airbag Design

Operating parameters and mass

System mass (kg)	30.266
Inflation pressure (kPa)	12
Peak pressure (kPa)	~20
Effective vent areas (m ²)	6 x 0.83
Peak lander acceleration (g)	<40



Venting Technology



non-vented system



vented system

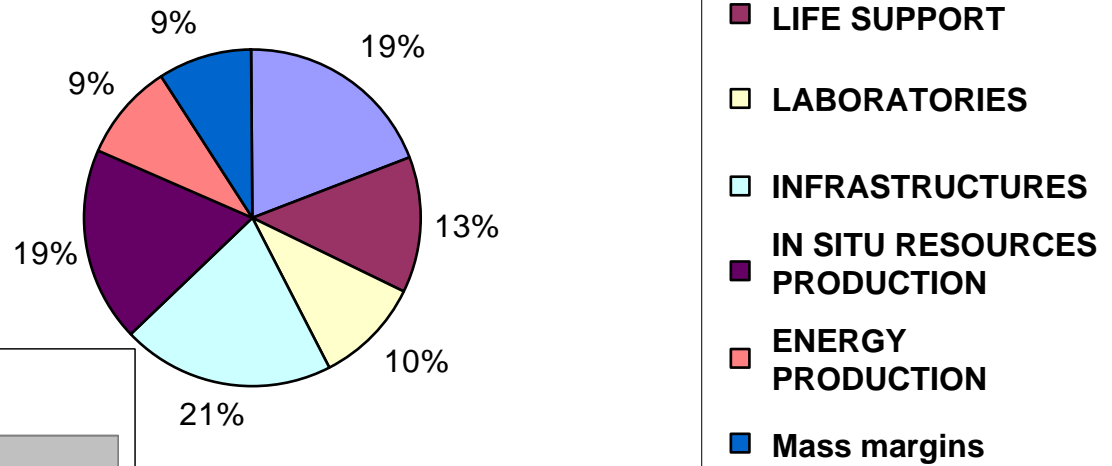
Venting Technology



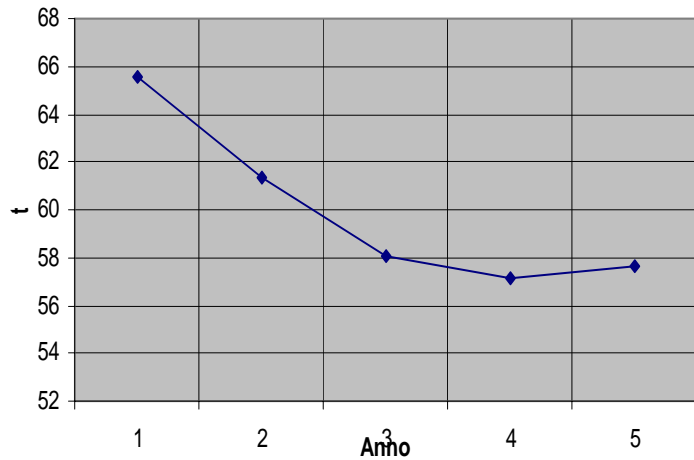
zylon textile valve

Base Under Construction

Lunar Base Mass Breakdown



YEARLY MASS TRANSPORTATION



- Yearly mass income almost constant
- Yearly mission types highly variable

