SPACE MANIFOLD DYNAMICS

Tides and motions in planetary systems

en l'honneur de Sylvio Ferraz-Mello

08–10 apr 2026
PARIS

ettore perozzi

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Sputnik Sylvio

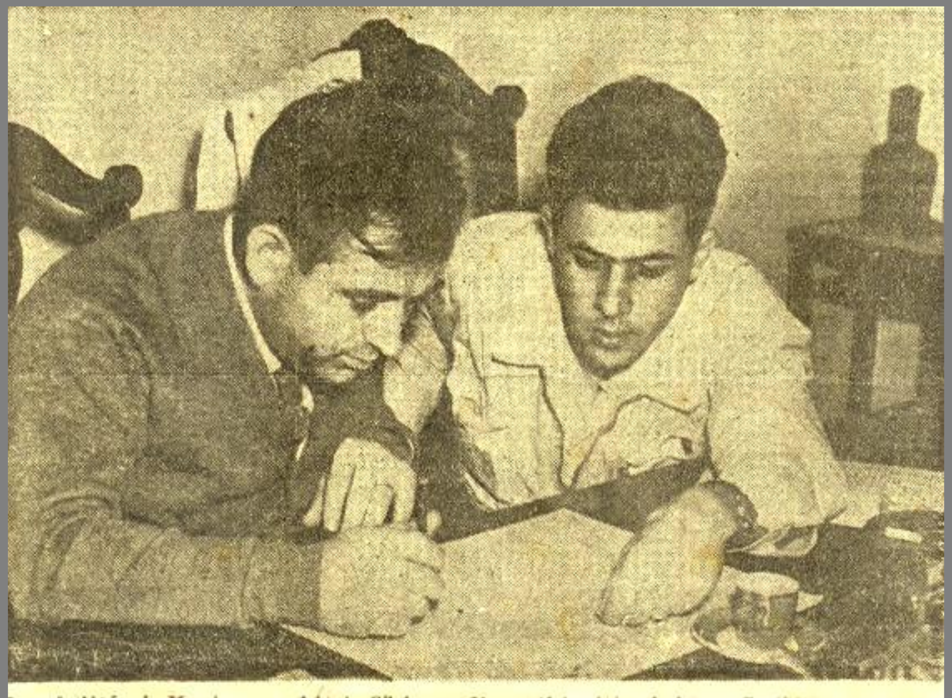
ULTIMA HORA

Captados em São Paulo os sinais do satelite

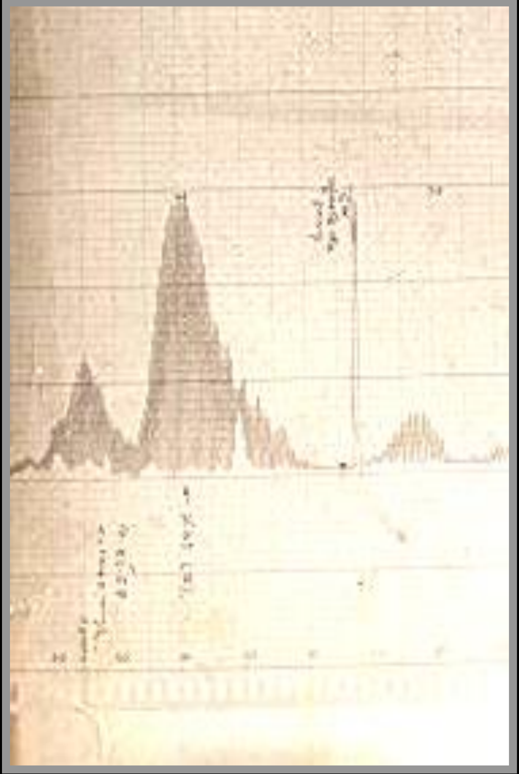
Quando encerravamos o expediente desta edição, eramos informados de que a equipe que trabalha no Observatorio sob a orientação de seu diretor, o prof. Abrão de Morais, havia obtido exito em seus esforços no sentido de captar as emissões do satelite artificial lançado anteontem. Por três vezes foram ouvidos sinais, em transmissões que duraram cerca de dez minutos, em sua fase de intensidade maxima. A frequencia através da qual se fez a recepção foi a de 20.005 quilociclos. Segundo nos esclareceu o prof. Abrão de Morais, não é possivel por ora, no Observatorio, captar as transmissões na frequencia de 40 megaciclos, a que fazem referencia os telegramas procedentes de Moscou — isso devido ao fato de os receptores comuns não alcançarem essa frequencia. Já estão sendo feitas porem as necessarias adaptações — acrescentou — para possibilitar a recepção em 40 megaciclos.

Ainda segundo o diretor do Observatorio, os sinais emitidos parecem provir de um transmissor poderoso.

A equipe que vem trabalhando com o prof. Abrão de Morais compõe-se dos profs. Luis de Queirós Orsini e Helio Guerra Vieira, da Escola Politecnica, e Silvio Ferraz de Melo, do proprio Observatorio.



O prof. Abrão de Morais e o assistente Silvio, no Observatório Astronômico e Geofísico, atravessaram a madrugada e a tarde de ontem à espera de que o "Sputnik II" desse sinal de vida, anotando todos os dados científicos de interêsse. D.N. - 5-XI-57 - 1ª ed. - 1ª pág.



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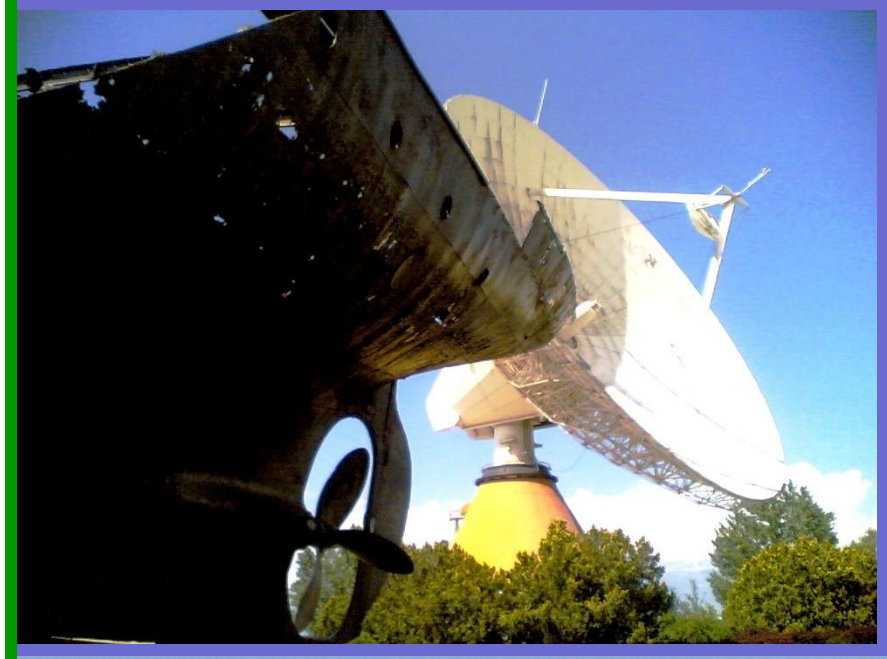

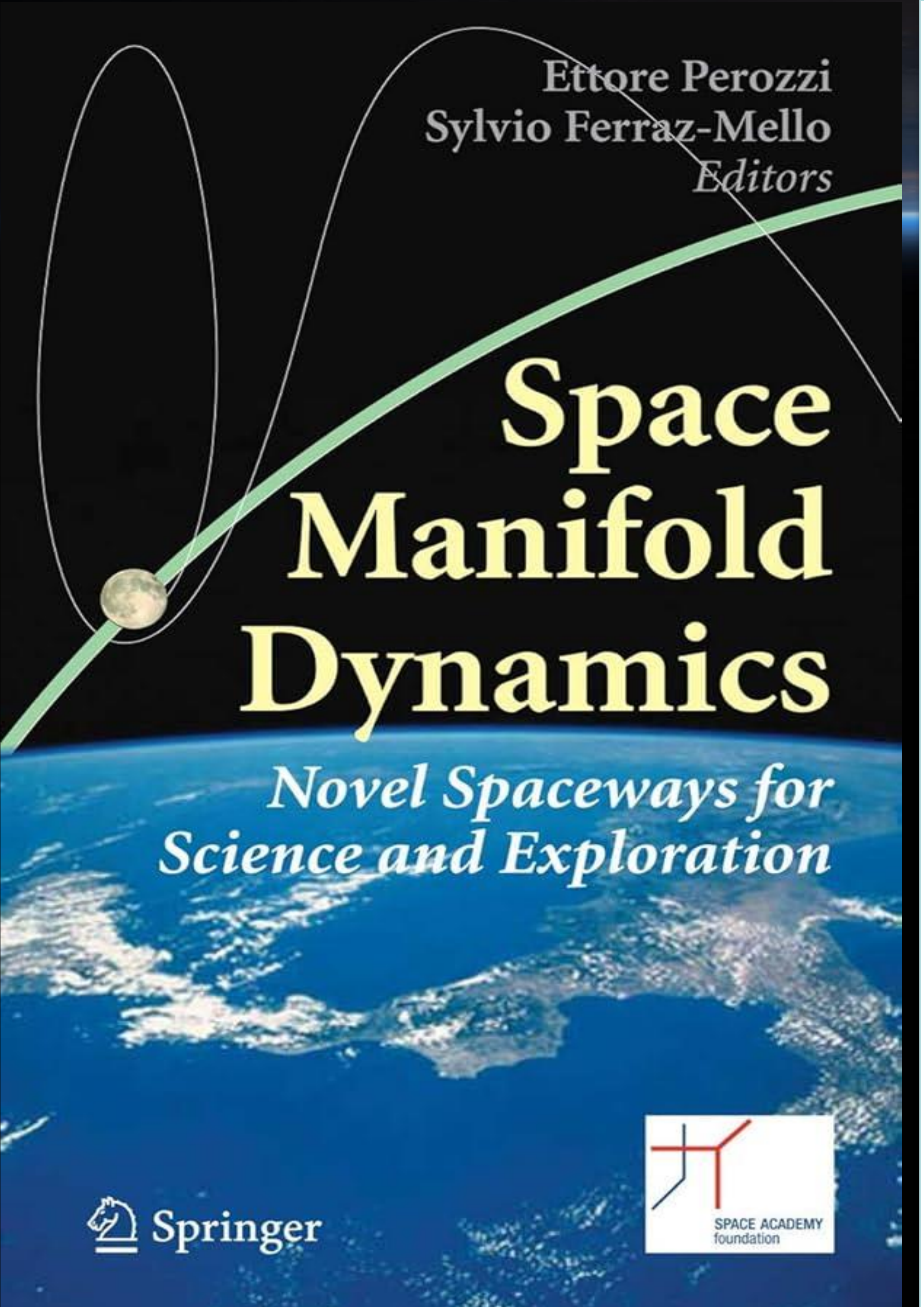

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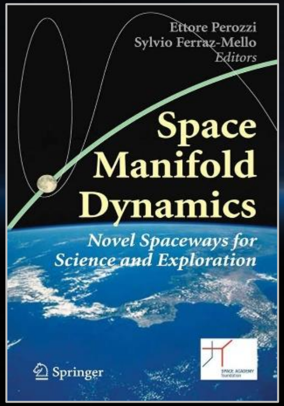


recommendations

During the final panel discussion, the participants to the workshop “Novel Spaceways for Scientific and Exploration Missions” have produced a commonly agreed list of strategic considerations and of specific actions to be undertaken for fully exploiting the potential benefits for the scientific, exploration and technological programs of the major space agencies.

Introductory statements:

There is the need of establishing a *strong and continuous link* among the research, the industrial communities and the space agencies, even at a basic level (e.g. regular organization of workshops and schools).

The terminology “*Space Manifold Dynamics”* (SMD) is adopted for referring to the dynamical systems approach to spaceflight dynamics, thus encompassing more specific definitions (stable/unstable manifolds, Lagrange trajectories, weak stability boundary, etc.);

Topics deserving immediate attention:

***filling the gap* between industry and research on specific issues used to investigate space manifold dynamics (e.g. apply new methods, translating mission requirements into theory)**;

***focus on the effect of dissipative systems* on SMD in terms of outcomes, methods and applications (e.g. low-thrust engines, non-gravitational forces, tethered systems);**

***explore the “geography” of the solar system* using novel dynamical approaches, such as mapping techniques and lagrangian trajectories;**

***build the “cartography”* associated to the utilization of the near-Earth space (e.g. periodic orbits, lunar transfers);**

***define the concept of “mixed approach”* to space mission design, i.e. dividing a complex trajectory into sections for which a given methods applies better (e.g. traditional ballistic + gravity assist for transfer trajectories, SMD for orbit insertion and satellite tour design)**;

***develop a simulation environment* to investigate the new challenges posed by manned and unmanned exploration to numerical optimization methods (e.g. flight time vs. delta-V, electric vs chemical propulsion or other alternatives);**

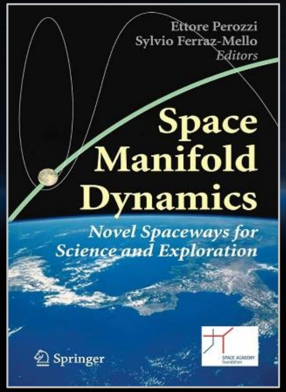
***study the impact of SMD trajectories* on human spaceflight and in particular on the radiation issue (e.g. finding “sheltered” mission profiles);**

***evaluate the consequences* of adopting a SMD approach on both, ground support and spacecraft subsystems requirements (e.g. TLC, GNC, propulsion);**

Specific actions to be considered:

***Interplanetary trajectory orbit determination* needs a new start: novel methods are required for developing new generation high-precision orbit determination operational software.**

The Workshop highlights the relevance of the generation of *high-quality planetary ephemeris* as well of other celestial and artificial bodies for both, astronomical research and space applications.



recommendation

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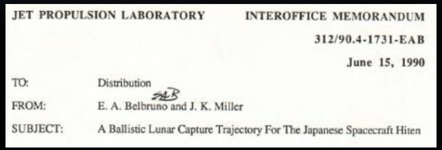
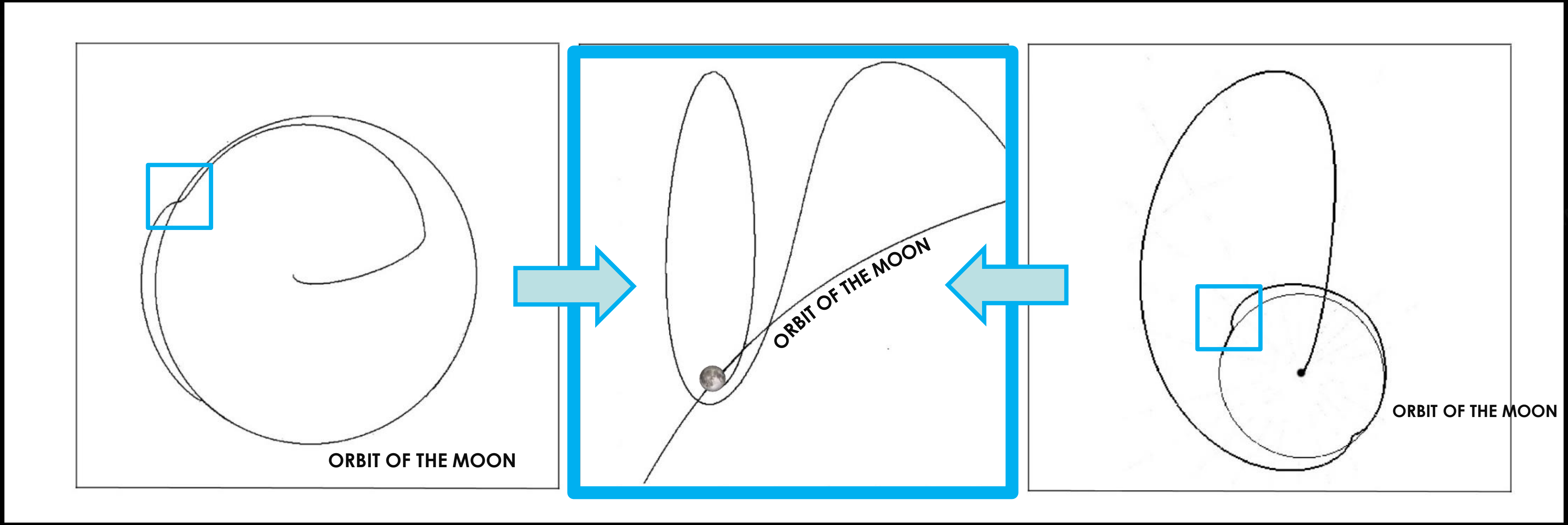
Magia mission tradeoff


JET PROPULSION LABORATORY INTEROFFICE MEMORANDUM
312/90.4-1731-EAB
June 15, 1990

TO: Distribution
FROM: E. A. Belbruno and J. K. Miller
SUBJECT: A Ballistic Lunar Capture Trajectory For The Japanese Spacecraft Hiten



SMD external transfer | lunar ballistic capture | SMD external transfer

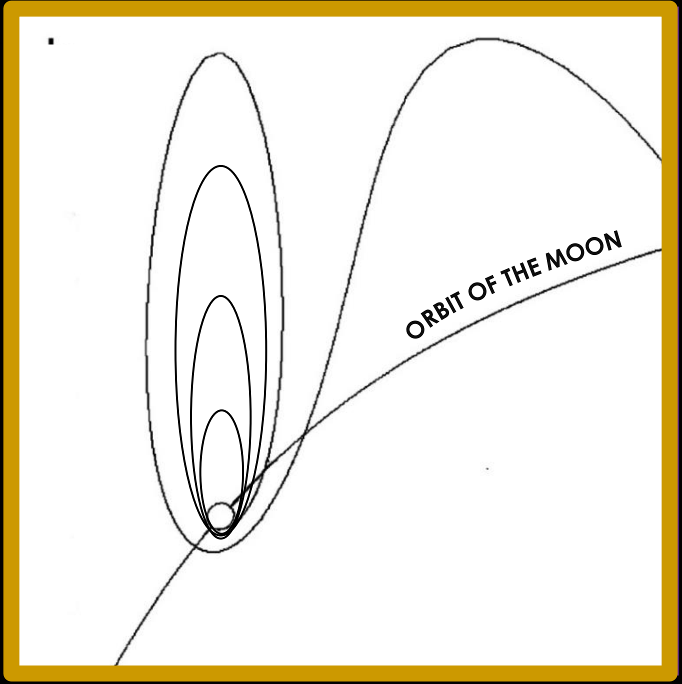
Magia mission tradeoff

Hohmann	SMD external
Transfer Time: 4 days	Transfer Time: 90 days
Total delta-V = 3.9 km/s	Total delta-V = 3.8 km/s
2 manoeuvres: TLI, LOI	2 manoeuvres: TLI, LOI
TLI=3.1; LOI=0.8, NOI=0.0	TLI=3.2; LOI=0.0; NOI=0.6
Elliptic trajectory (high LOI)	WSB trajectory (no LOI)
LOI critical	Ballistic Capture (LOI non-critical)
consolidated guidance	innovative guidance
Needs quick reaction time	Allows slow reaction time
-	Possible E-M-S cruise science
Apollo-like	Science & Exploration precursor

TLI =Trans Lunar Injection;

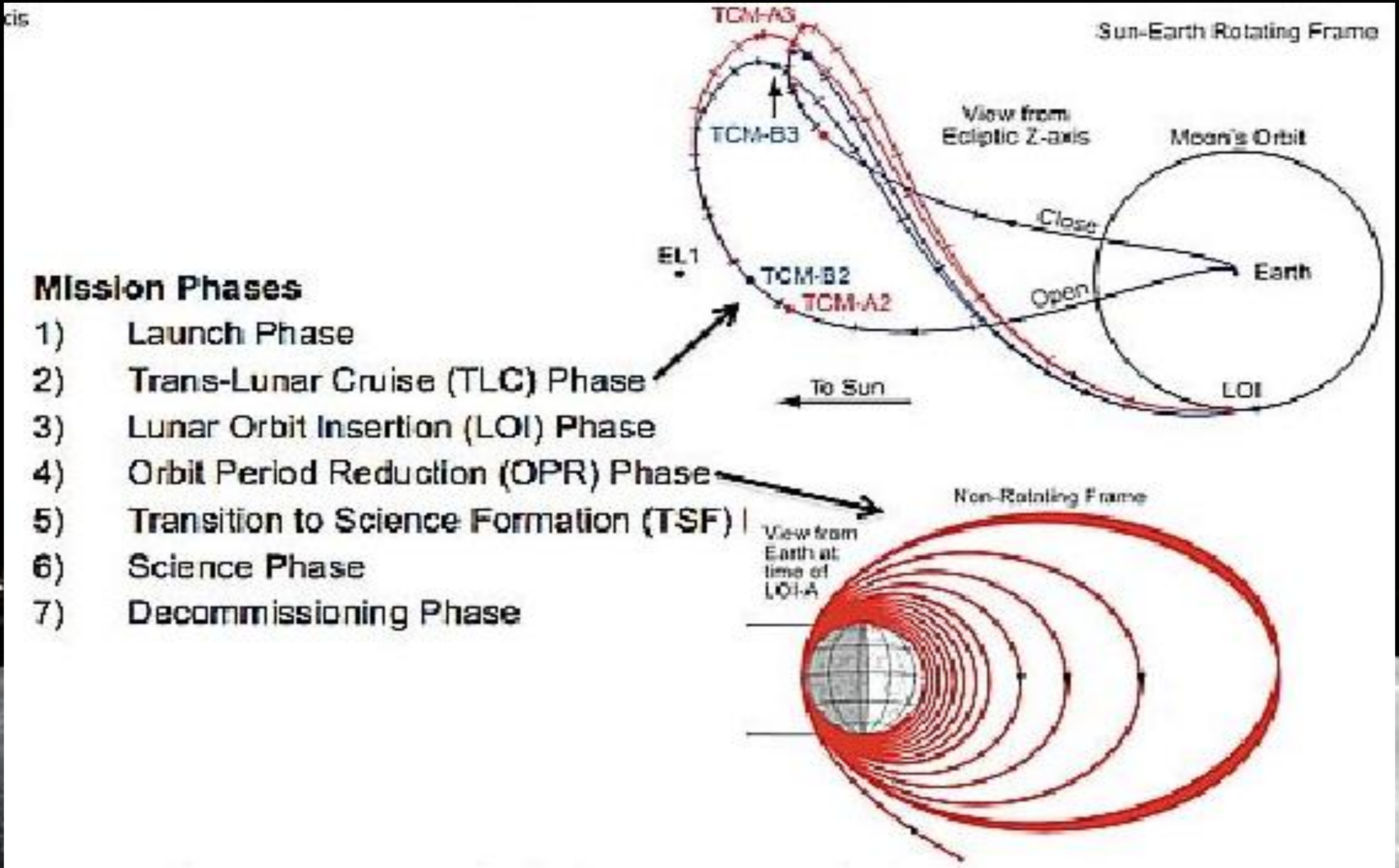
LOI = Lunar Orbit Insertion;

NOI = Nominal Orbit Insertion

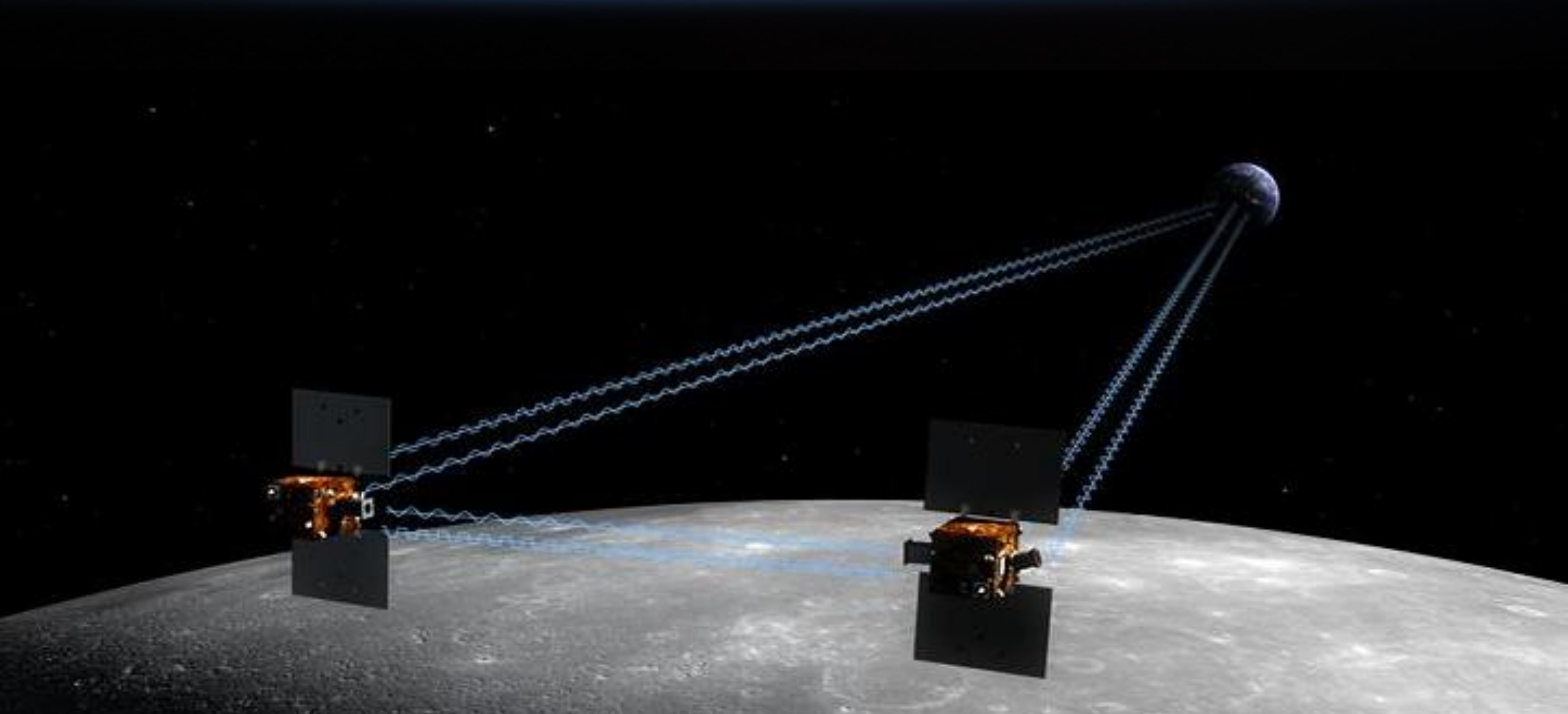


orbit circularization

GRAIL mission profile



GRAIL mission (2011-2012)



SMART-1 solar electric propulsion (2003-2005)

SEP + SMD = extremely low energy transfer

SMART-1 Electric Propulsion Operational Experience

IEPC-2005-245

D. Milligan[*] D. Gestal[†] O. Camino[‡] and P. Pardo-Voss[§]
European Space Operations Centre, Robert Bosch Str. 5, 64293 Darmstadt, Germany

D. Estublier[**]
ESA/ESTEC, Kepleraan 1, Noordwijk, The Netherlands

and

C. Koppel[††]
Snecma Moteurs, Division Moteurs-Spatiaux, Villaroche Nord, France

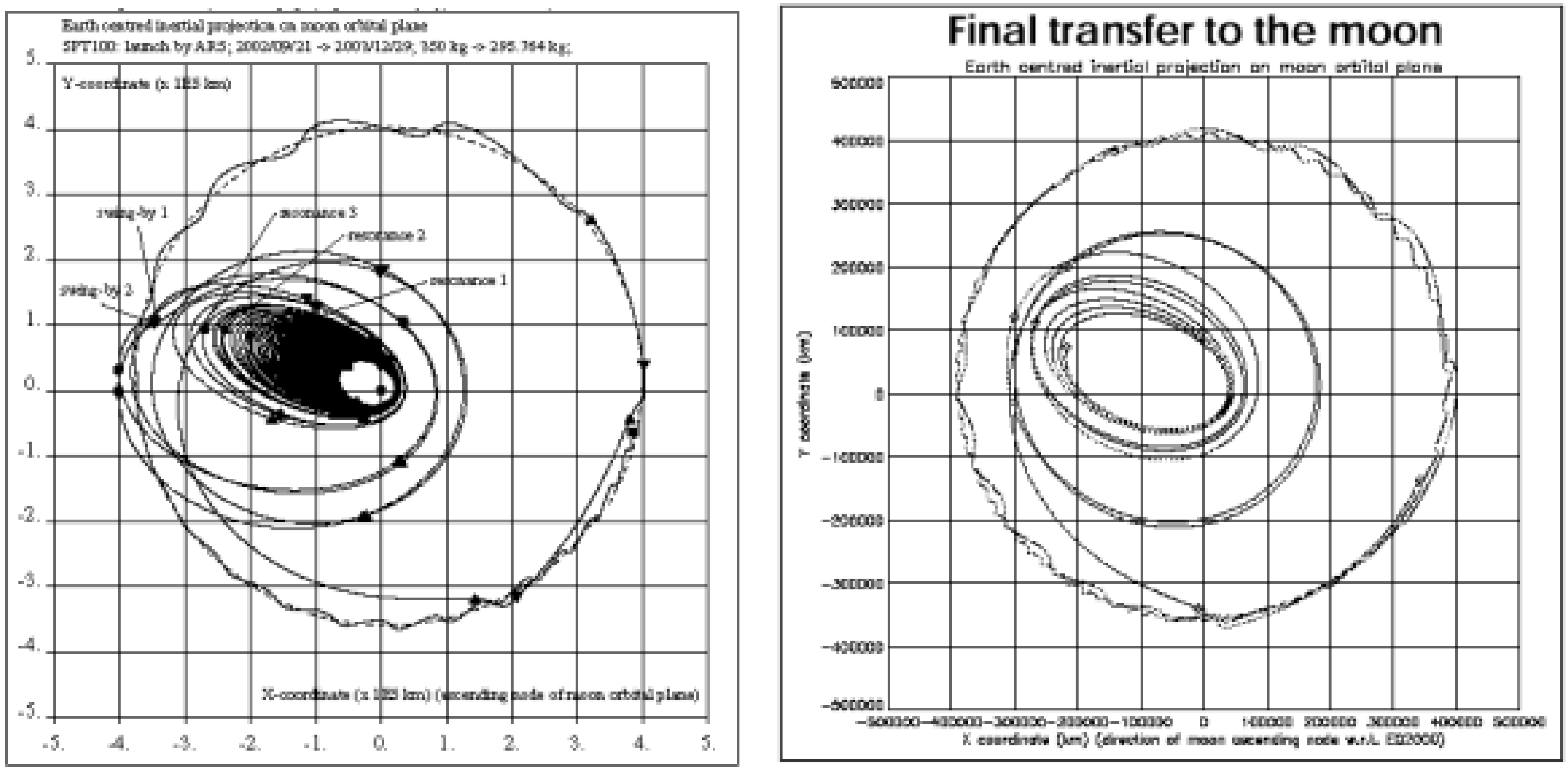
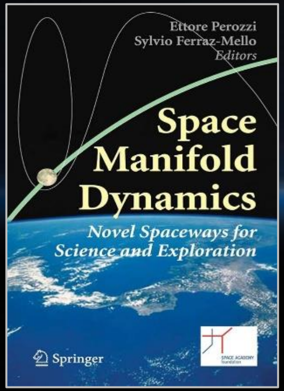


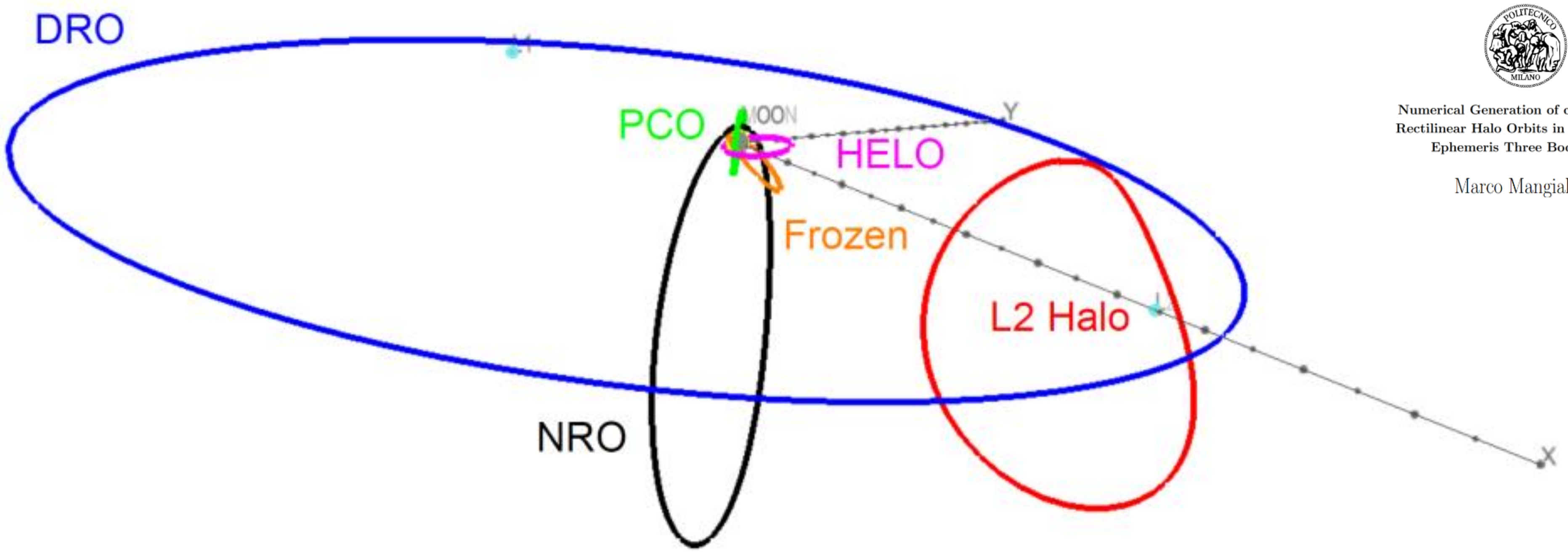
Figure 4 Comparison pre-launch planned (left) and in flight executed (right) Lunar capture strategies



recommendation

build the "cartography" **associated to the utilization of the near-Earth space (e.g. periodic orbits, lunar transfers);**

LUNAR GATEWAY L1 near rectilinear orbit

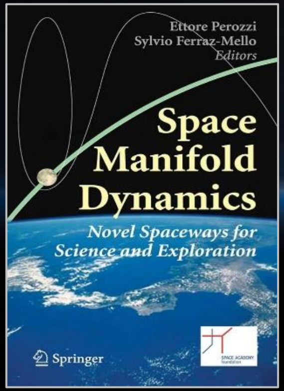


Numerical Generation of cis-Lunar Near Rectilinear Halo Orbits in the Restricted Ephemeris Three Body Model

Marco Mangialardo.

Figure 1.1: Different orbits considered for the LOP-G. Acronyms: Distant Retrograde Orbit (DRO), Prograde Circular Orbit (PCO), Near Rectilinear Orbit (NRO), Elliptical Lunar Orbit (ELO). Credit

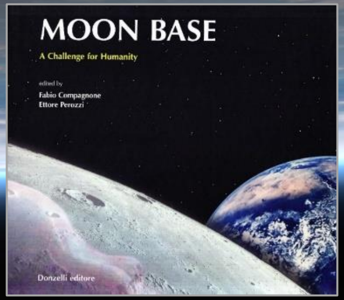
R. Whitley and R. Martinez, "Options for staging orbits in cislunar space," in *2016 IEEE Aerospace Conference*. IEEE, 2016, pp. 1–9.



recommendation

study the impact of SMD trajectories **on human spaceflight and in particular on the radiation issue (e.g. finding "sheltered" mission profiles)**

Moon Base long-term lunar exploration



Moon harbor: a LL1 halo orbiting infrastructure for manned / unmanned missions support (e.g refurbishing space relescopes, space elevator))

Low altitude lunar orbiters / landers

High altitude lunar constellations for satellite navigation

High eccentricity orbits / halo orbiters for telecommunications

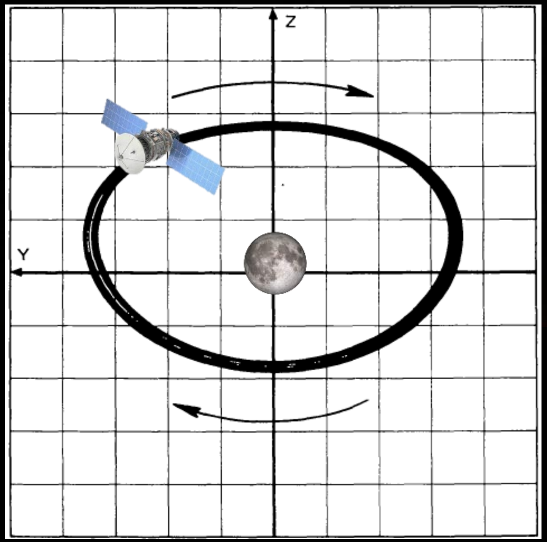
Operations safety (avoiding critical events – lunar rescue trajectories)

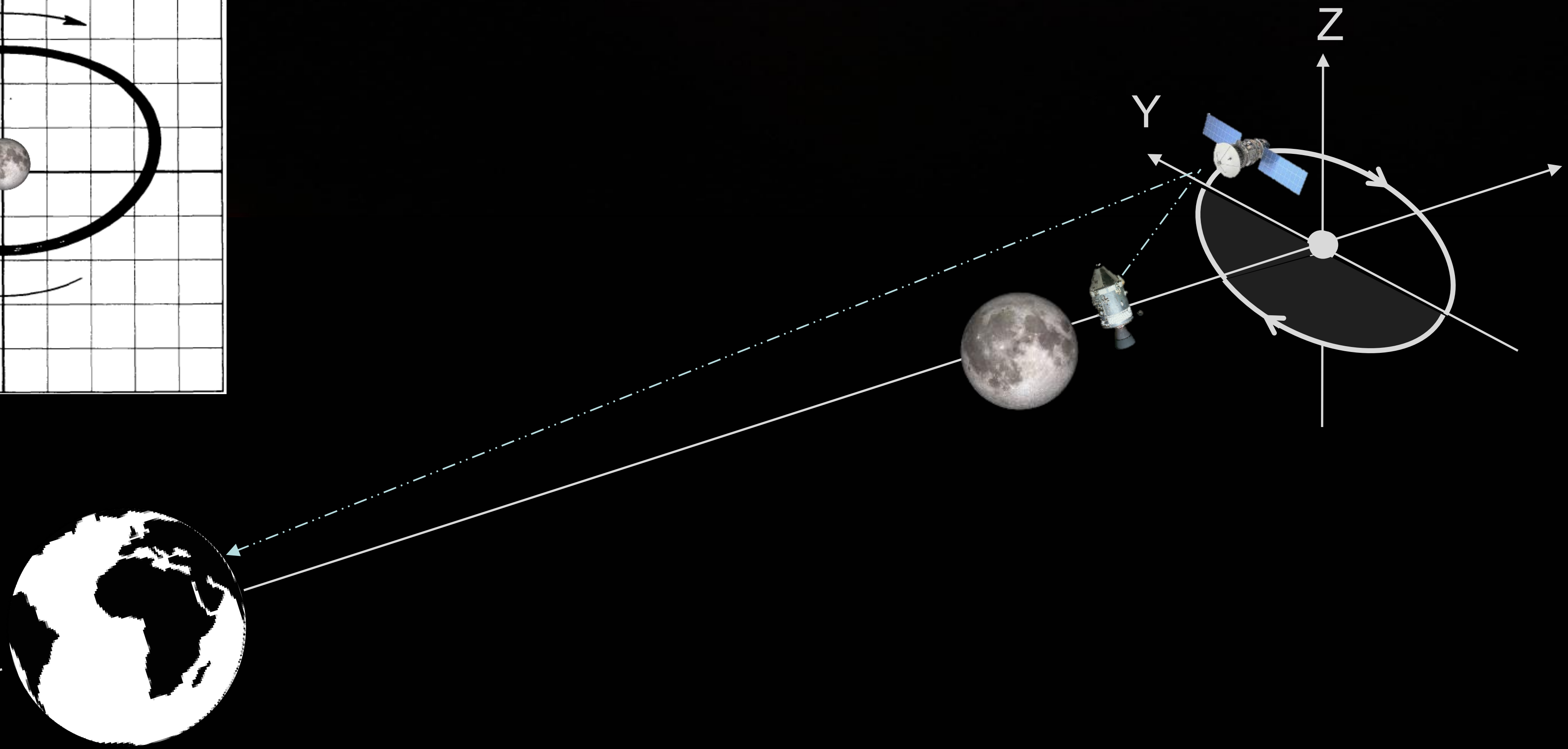
Flexibility of mission profile (e.g. different launch scenario)

Long transfers: cruise science (e.g. gravitational redshift, solar/magnetosphere interactions)

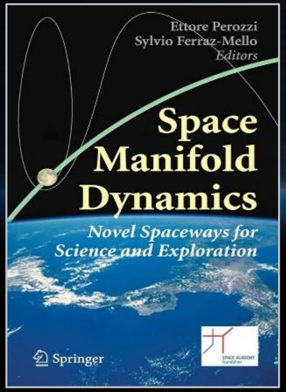
Manned vs unmanned missions (radiation issue, non–critical cargo delivery)

APOLLO L2 lunar data relay satellite





QUEQUIAO L2 lunar far side telecom satellite



recommendation

***define the concept of "mixed approach"* to space mission design, i.e. dividing a complex trajectory into sections for which a given methods applies better (e.g. traditional ballistic + gravity assist for transfer trajectories, SMD for orbit insertion and satellite tour design);**

Europa Lander proposal

Low Energy Capture into High Inclination Orbits for Ocean Worlds Missions

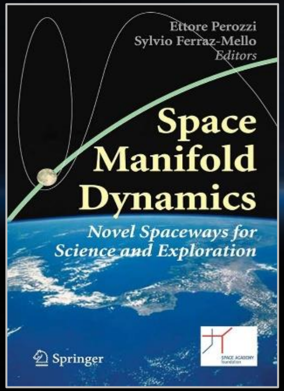
Principal Investigator: Martin W. Lo (392M)

In recent years, resonant periodic orbits and their stable and unstable manifolds have seen significant interest and use as a tool for trajectory design in multi-body systems. For

High-order resonant orbit manifold expansions for mission design in the planar circular restricted 3-body problem

, Rodney L. Anderson [b], Rafael de la Llave [a]

developing a procedure to compute intersections of the computed stable and unstable manifolds. We develop and implement algorithms that accomplish these three goals, and demonstrate their application to the problem of transferring between resonances in the Jupiter-Europa system.



recommendation

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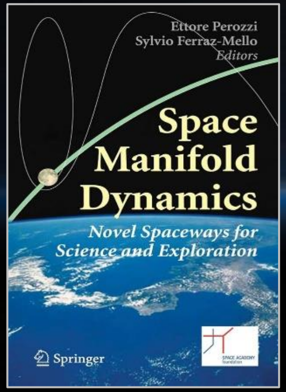

recommendation

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Celestial Mechanics & dynamical astronomy

The first edition of the journal was published under the title "Celestial Mechanics" as an initiative of the Celestial Mechanics Institute. Later in 1989, the journal changed its name into "Celestial Mechanics and Dynamical Astronomy" (CM&DA). Over the years the editors-in-chief, associate editors and authors made a big effort to keep the journal up-to-date and retain a high scientific standard.

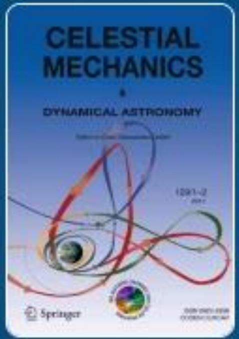
Home > Celestial Mechanics and Dynamical Astronomy > Article

Alessandra Celletti

Topical collection "50 years of Celestial Mechanics and Dynamical Astronomy"

Preface | Published: 31 March 2020

Volume 132, article number 18, (2020) Cite this article

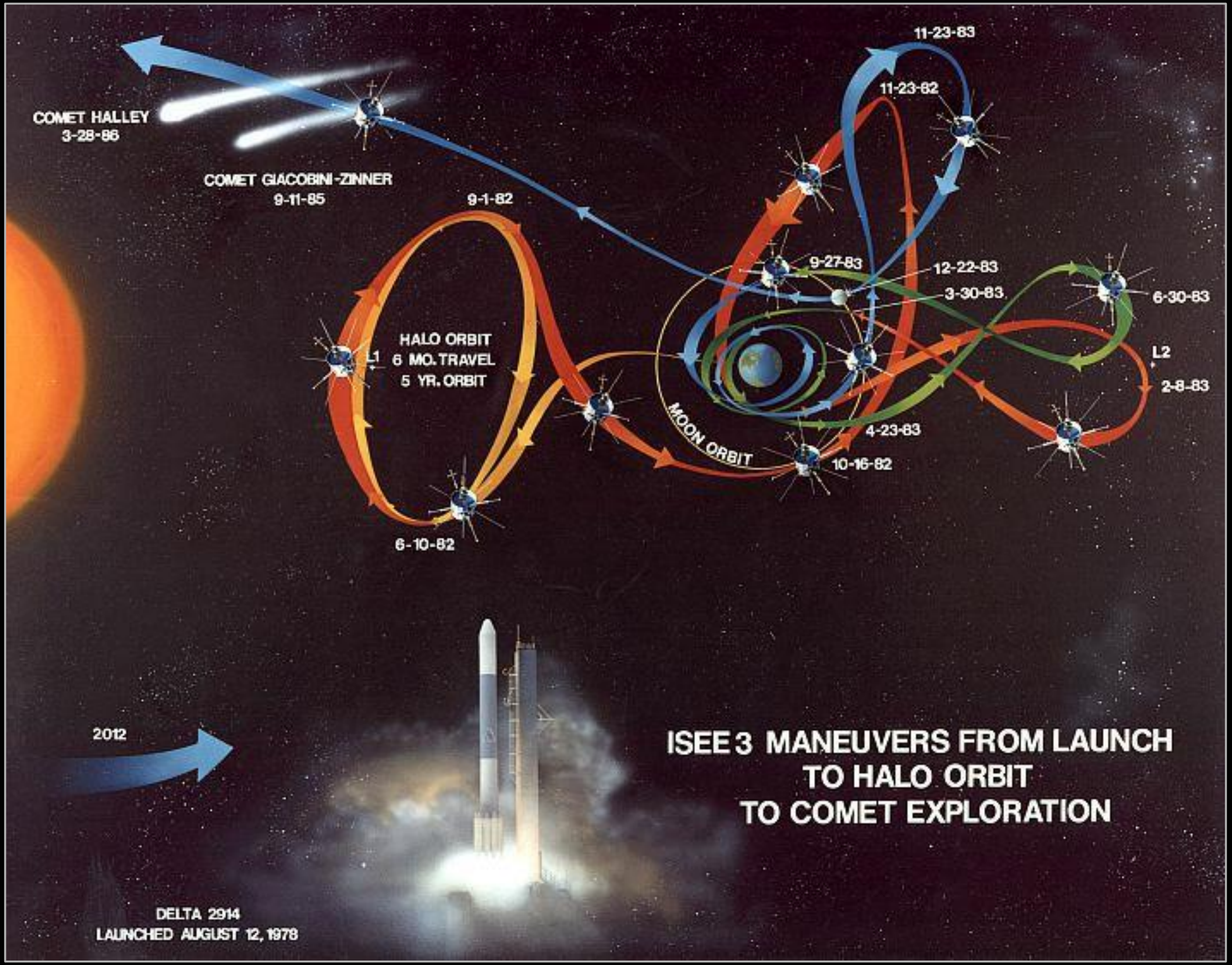


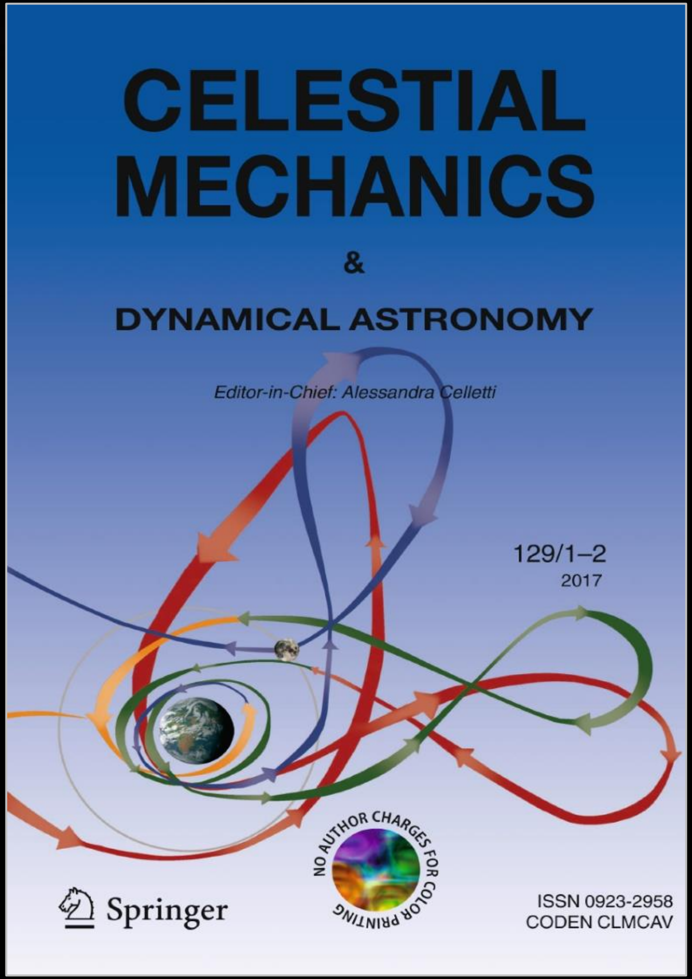
As written in 1990 by J.M.A. Danby ([CMDA 1990, vol. 50, 5–6]), the birth of the journal "Celestial Mechanics" dates back to a meeting at the Goddard Space Flight Center. The editorial of the first issue, while defining Celestial Mechanics as an old science that infers or proves "physical facts from the study of orbital behavior and other phenomena exhibited by celestial and artificial bodies," underlined the need for research in this field,

ISEE-3/ICE trajectory (1978-1982-1986)

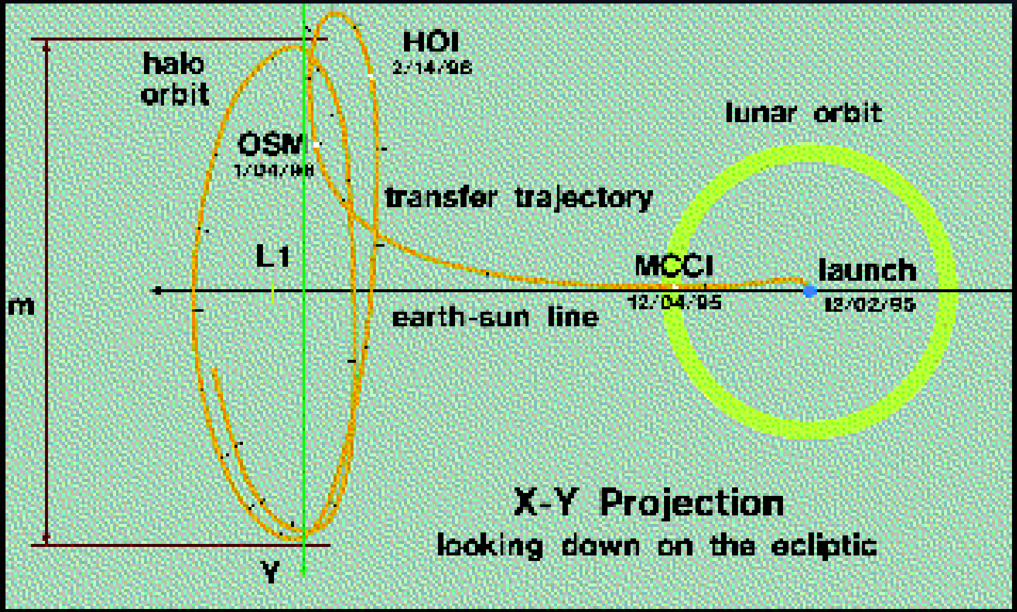
Robert W. Farquhar

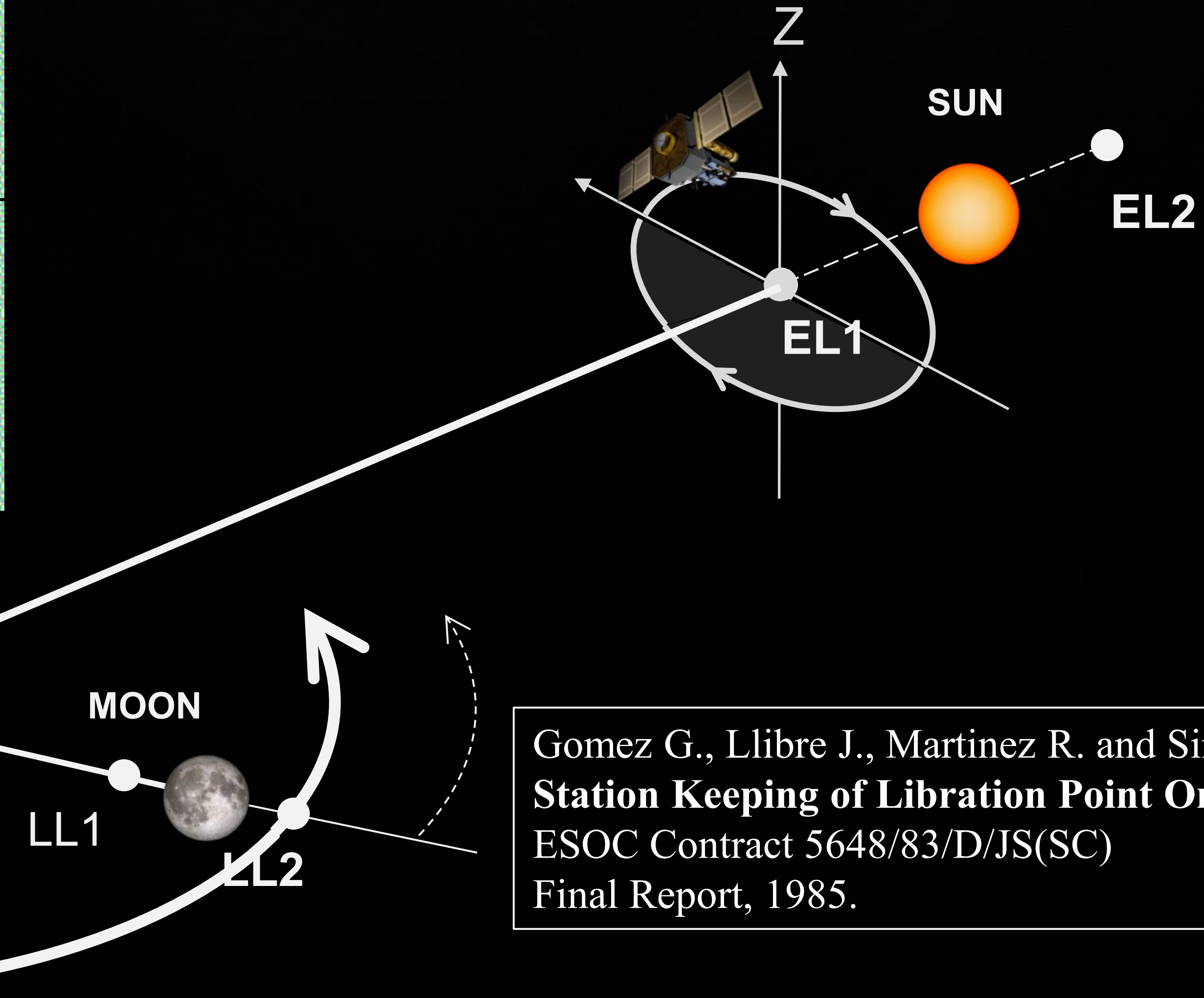
The Flight of ISEE-3/ICE: Origins, Mission History, and a Legacy





SOHO Solar Heliospheric Observatory (1985)





Gomez G., Llibre J., Martinez R. and Simo C.
Station Keeping of Libration Point Orbits
ESOC Contract 5648/83/D/JS(SC)
Final Report, 1985.

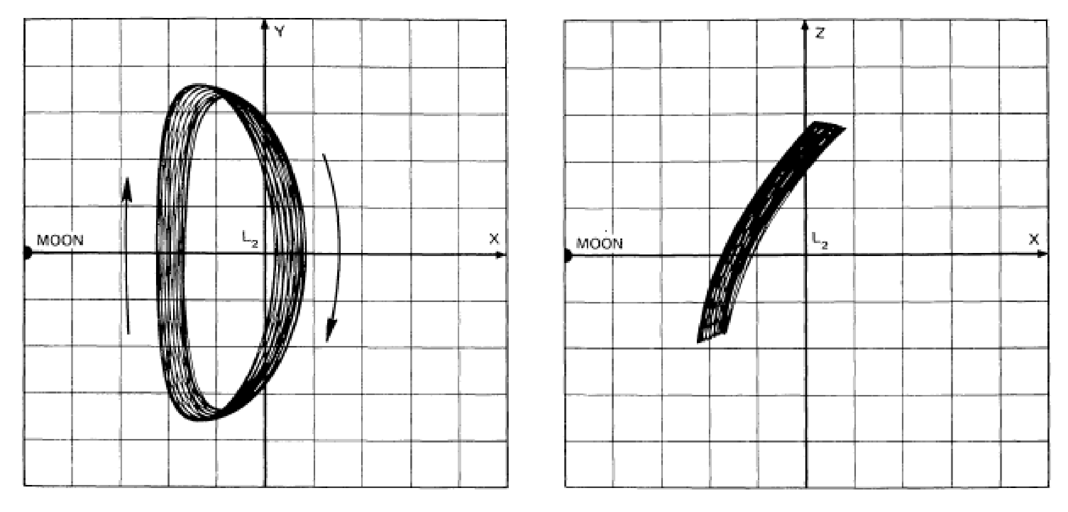
references librations vs manifolds

1973

QUASI-PERIODIC ORBITS ABOUT THE TRANSLUNAR LIBRATION POINT

ROBERT W. FARQUHAR and AHMED A. KAMEL*

Celestial Mechanics 7 (1973) 458–473.



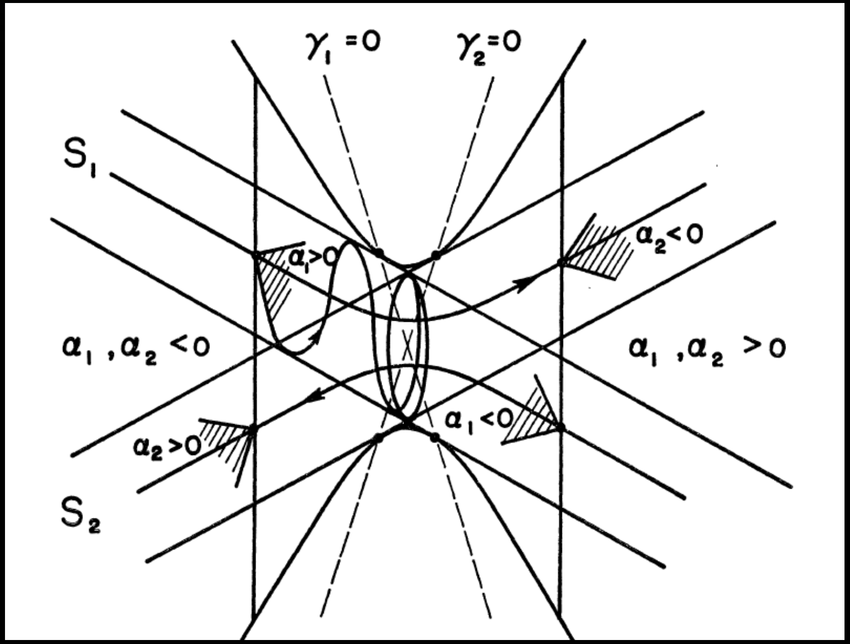
'Final Report for Lunar Libration Point Flight Dynamics Study', Contract NAS-5-11551, General Electric Co., April 1969.

1968

LOW ENERGY TRANSIT ORBITS IN THE RESTRICTED THREE-BODY PROBLEM*

C. C. CONLEY†

SIAM J. APPL. MATH.
Vol. 16, No. 4, July 1968



. CONLEY, *Notes on the restricted three body problem: Approximate behavior of solutions near the collinear Lagrangian points*, TMX-53292, NASA, George C. Marshall Space Flight Center, Huntsville, Alabama, 1965.

references librations vs manifolds

1968

130135 STAR

SPACE SYSTEMS

FINAL REPORT
FOR
LUNAR LIBRATION POINT FLIGHT DYNAMICS STUDY
(MAY 1968 - NOV 1968)
CONTRACT NO: NAS 5-11551

Prepared by
GENERAL ELECTRIC COMPANY

for
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

1966

2. Farquhar, R. W., "Stationkeeping in the Vicinity of Collinear Libraion Points with an Application to a Lunar Communications Problem," American Astronautical Society Paper 66-132, July 1966.

1961

6. Colombo, G., "The Stabilization of an Artificial Satellite at the Inferior Conjunction Point of the Earth-Moon System, "Smithsonian Contrib., Astrophys, Vol. 6, pp 213-222, 1961.

1965

NASA TECHNICAL MEMORANDUM

NASA TM X-53292
July 12, 1965

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ff 653 July 65

65 33064 (THRU) 1 (CODE) 30 (CATEGORY)

NASA

George C. Marshall Space Flight Center, Huntsville, Alabama

PROGRESS REPORT NO. 7
ON STUDIES IN THE FIELDS OF SPACE FLIGHT AND GUIDA
THEORY

This report is intended to be the first in a series whose ultimate aims include an existence proof for the "periodic" solutions discovered numerically by M. Davidson [1]. Whether or not this can be accomplished remains to be seen, but it does seem clear that a thorough understanding of the behavior of orbits near the equilibrium point will be required. More will be said about this question in later reports.

1. Davidson, M. (to be published).

references librations vs manifolds

M. C. Davidson, *Numerical examples of transition orbits in the restricted three body problem*, Astronaut. Acta, 10 (1964), pp. 308-313.

1961

The Stabilization of an Artificial Satellite at the Inferior Conjunction Point of the Earth-Moon System

By G. Colombo

It is obviously important to be able to keep an artificial satellite stable at the inferior conjunction point (L_1) of the earth-moon system, while using the minimum amount of momentum. The fact that the inferior conjunction point is an exact solution of the four-body problem (earth-moon-sun-satellite) Colombo, 1960; Klemperer and Benedikt, 1958, p. 25), if we neglect only high-order perturbations, is an advantage of this solution that makes it preferable in some ways to the triangular Lagrangian solution (L_4) of the restricted three-body problem. On the other hand, the larger

1964

Numerical Examples of Transition Orbits in the Restricted Three Body Problem

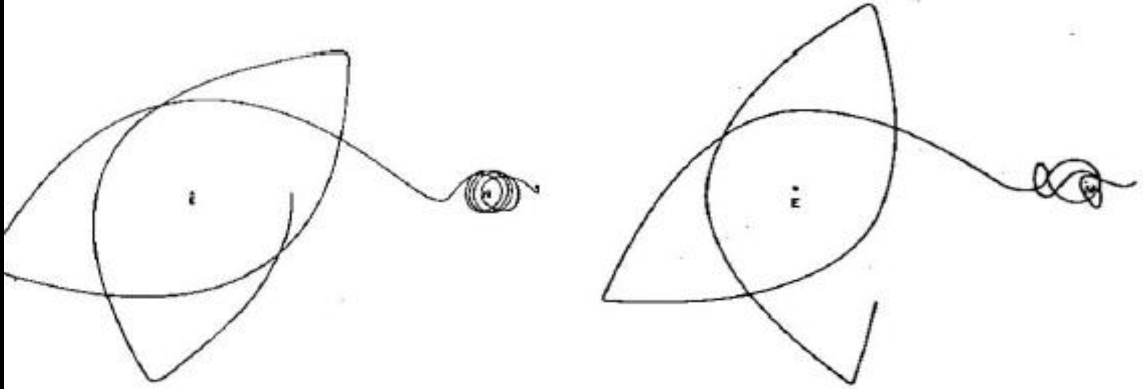
By M. C. Davidson[1]

(With 12 Figures)

[1] George C. Marshall Space Flight Center, Huntsville, Alabama, U.S.A.

(*Received October 15, 1964*)

Abstract — Zusammenfassung — Résumé



called capture, temporary capture, and [illegible]

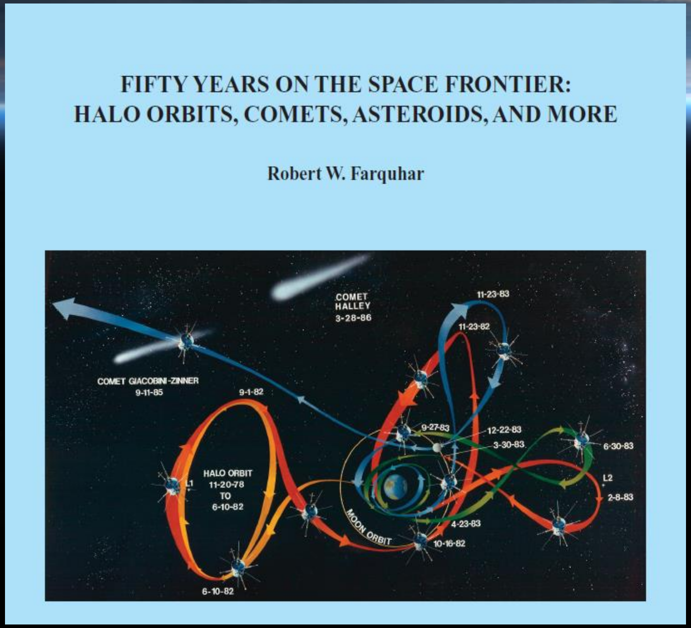
As to the literature Egorov [1] gives an approximate analysis based on the sphere of influence idea. The difficulty with such a treatment is that for such low energy orbits the motion near the libration point L_2 displays a character quite different from Keplerian motion. Actually, the estimates so obtained are somewhat misleading. Thüring [2] gives two numerical examples of transition orbits.

The orbits presented here have the common feature that they are initially [illegible] is fixed at approximately 1/82

References

1. V. A. Egorov, Certain Problems of Moon Flight Dynamics. The Russian Literature of Satellites, Part 1, pp. 115—175 (1958).
2. B. Thüring, Zwei spezielle Mondeinfangbahnen in der Raumfahrt um Erde und Mond. Astronaut. Acta 5, 241—250 (1959).

thirty years later…



2011

<<According to Martin Lo, the “discoverer” of the Interplanetary Superhighway, the ISEE-3/ICE Trajectory Team was able to find a Superhighway trajectory using conventional methods because “**when you search around the halo orbits for a transfer trajectory from Earth, your path will invariably be controlled by the halo orbit’s stable manifold**”>>.

<<Who would have guessed that the ISEE-3/ICE Team stumbled on such a momentous discovery without realizing what they had done? >>

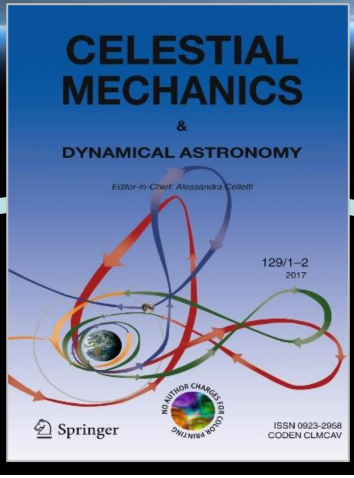
the big picture

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

Mirt C. Davidson 1964-65

Charles C. Conley 1965-68

1969



George C. Marshall
Space Flight Center,
Huntsville, Alabama

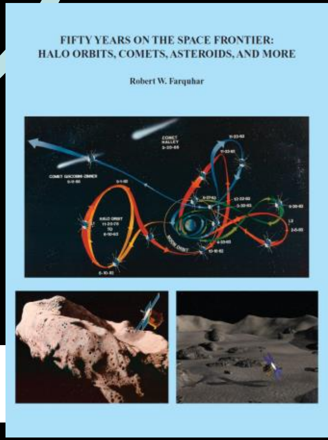
Giuseppe Colombo 1960-61

Robert Farquhar 1966-72

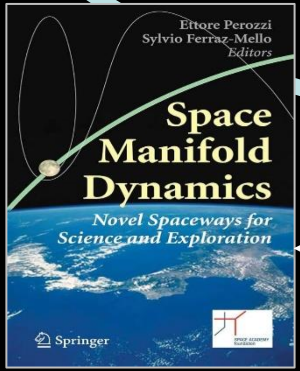
As written in 1990 by J.M.A. Danby ([CMDA 1990, vol. 50, 5–6]), the birth of the journal "Celestial Mechanics" dates back to a meeting at the Goddard Space Flight Center. The

the visionary concept of interplanetary highways that gave rise to a new branch of Astrodynamics, now known as "Space Manifold Dynamics."

Alessandra Celletti



2011



2010

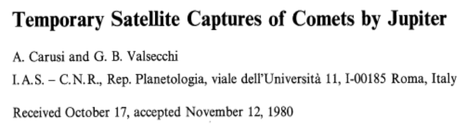
[23] Perozzi, E. and Ferraz-Mello, S., Editors, Space Manifold Dynamics, Springer, New York, Dordrecht, Heidelberg, London, 2010.

lessons learned

The birth of the journal Celestial Mechanics and of the space manifold dynamics happened almost simultaneously in space and time.

Communication problems: for at least 20 years the libration point and the dynamical systems approach did not interact

Future work: the quest for the "cross-reference paper" (e.g.

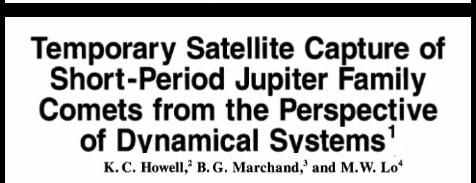


Temporary Satellite Captures of Comets by Jupiter

A. Carusi and G. B. Valsecchi

I.A.S. – C.N.R., Rep. Planetologia, viale dell'Università 11, I-00185 Roma, Italy

Received October 17, accepted November 12, 1980



Temporary Satellite Capture of Short-Period Jupiter Family Comets from the Perspective of Dynamical Systems[1]

K. C. Howell,[2] B. G. Marchand,[3] and M.W. Lo[4]

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NOTE ADDED IN PROOF: also scientific editors have communication problems!

conclusions

One cannot predict when knowledge will be applied, only that it often is

Charles Conley

Le grandi scoperte sono qualitative, la matematica seve «solo» a dimostrare

Giorgio Parisi

Le seul véritable voyage, le seul bain de Jouvence, ce ne serait pas d'aller vers de nouveaux paysages, mais d'avoir d'autres yeux

Marcel Proust

Thank you Sylvio !