Fundamental Physics in Space
at
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UNIVERSIDADE DO PORTO

GPPQ Gabinete de Promoção dos Programa Quadro ID&I

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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Topics of interest

Satellite Navigation

- GALILEO-3-2015: EGNSS applications through international cooperation on fundamental physics

Earth Observation

- EO-3-2015: Technology developments for imaging and oceanographic surveillance from space

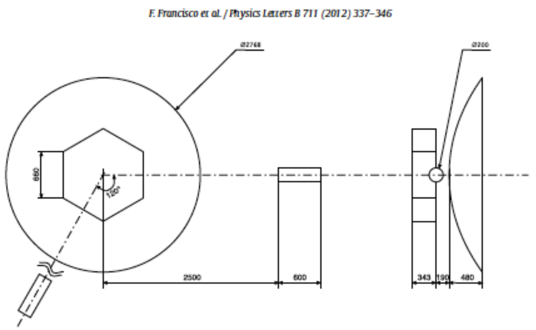
Space Exploration and Science

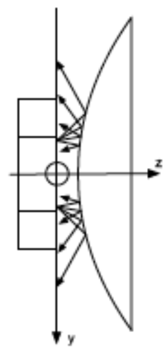
- COMPET-4-2015: Space Exploration: alternative methods of propulsion
- COMPET-5-2015: Scientific exploitation of cosmology and gravity
- COMPET-6-2015: International Cooperation in space science

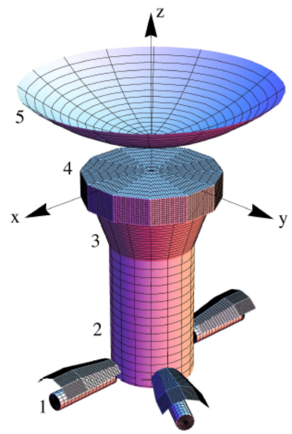
Thermal analysis of spacecraft

- Modelling and computation of small accelerations due to thermal effects

(Solution for the Pioneer and Cassini anomalies)

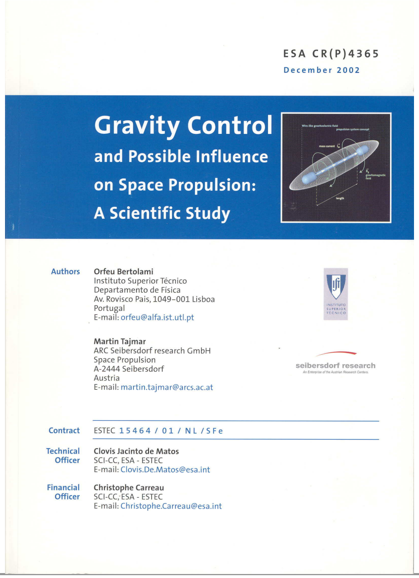






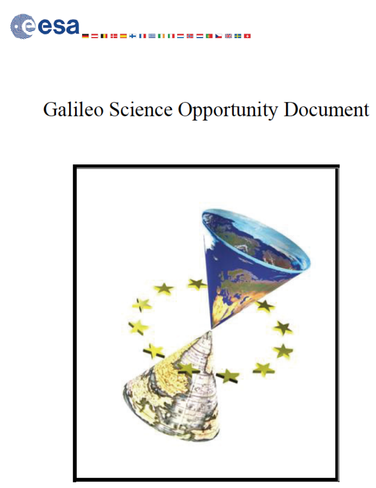
Departamento de Física e Astronomia (DFA)
FCUP

- Top research department in Portugal (about 70 PhDs, 250 papers/year, 4000 citations/year)
- DFA-FCUP Fundamental Physics in Space (3 PhDs)-collaboration with FEUP
- Co-author of Portugal's National Strategy for Space (O.B. 2004)
- Member of the Galileo Science Advisory Committee of ESA (OB, 2008-2013)

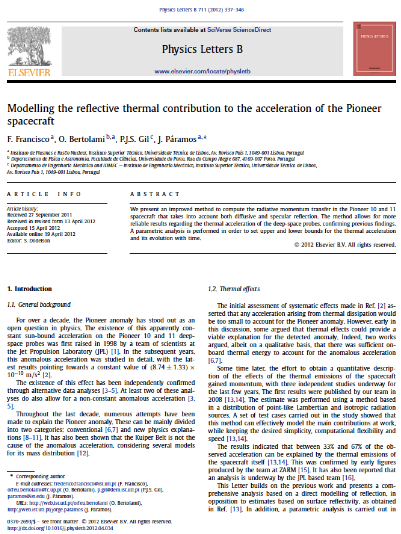

ESA CR(P)4365
December 2002

Gravity Control and Possible Influence on Space Propulsion: A Scientific Study

Authors: Orfeu Bertolami, Instituto Superior Técnico; Martin Tajmar, ARC Seibersdorf research GmbH



Galileo Science Opportunity Document


Physics Letters B

Modelling the reflective thermal contribution to the acceleration of the Pioneer spacecraft

F. Francisco, O. Bertolami, P.J.S. Gil, J. Páramos


PHYSICAL REVIEW D 90, 042004 (2014)

Modeling the nongravitational acceleration during Cassini's gravitational experiments

O. Bertolami, F. Francisco, P. J. S. Gil, and J. Páramos

Seeking

➢ Urgently seeking for means to fund a postdoctoral collaborator

JBIS, Vol. 60, pp.xxx-xxx, 2007

GRAVITY CONTROL PROPULSION: TOWARDS A GENERAL RELATIVISTIC APPROACH

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Evaluation of gravity control concepts should be examined with respect to currently known physical theories. In this work we study the hypothetical conversion of gravitational potential energy into kinetic energy using the formalism of general relativity. We show that the energy involved in the process greatly exceeds the Newtonian estimate, given the nature of general relativity. We conclude that the impact of any gravity manipulation for propulsion greatly depends fundamentally on its exact definition.

Keywords: Gravity control, general relativity, energy-momentum pseudo-tensor

1. INTRODUCTION

Access to space using currently available propulsion systems is extremely limited both in distance and in time. In recent years the interest in unconventional propulsion proposals has grown in the hope that new forms of propulsion, that increase the range of spacecraft while reducing the trip time, are discovered.

Several conceptual mechanisms have been proposed to radically improve the performance of propulsion systems, such as warp-drives [1,2], transient mass fluctuations [3], antigravity [4] or gravitational shielding effects [5]. While some of these proposals are only conceptual, others such as the gravitational shielding have been tested and proved unfruitful [6]. Many of these systems are based on the effect of the manipulation of mass and gravity in a rocket's motion. The study of the impact on propulsion systems' performance of such manipulations has been previously considered and demonstrated that even if gravity could be controlled or modified it would not lead to any breakthrough in propulsion systems [7].

Other conceptual devices (e.g. the space drive) go even further, idealizing a form of propulsion without any reaction mass that would somehow manipulate space-time and matter to create propulsive forces. One of the possible energy sources for such a device, as suggested in Ref. [8], is gravitational potential energy. For concreteness we shall argue along the energy considerations as suggested in that reference. In there, it has been proposed that these systems could not be analysed using rocketry metrics and that their full potential could only be understood in terms of the energetic considerations [8]. We understand that this energy based study should be undertaken; nonetheless it should be regarded with caution, especially when trying to estimate the potential benefits of converting gravitational potential energy into kinetic energy. Furthermore, we believe that the results of any approach in the context of the Newtonian framework should be considered with great care.

In the current work we approach this space drive problem from the general relativity point of view. For this purpose we

Nomenclature

c	speed of light = $3 \times 10^8\ m.s^{-1}$
δ	inertial mass modification factor
ε	gravitational mass modification factor
ε'	gravitational field modification factor
G	gravitational constant = $6.67 \times 10^{-11}\ m^3.kg^{-1}.s^{-2}$
I_{sp}	specific impulse
V_p	propellant velocity
G_{ik}	Einstein tensor
T_{ik}	energy-momentum tensor
t_{ik}	energy-momentum pseudo-tensor of gravitational field
g_{ik}	metric tensor
g	metric determinant
Γ^n_{lm}	metric connection
$\delta^3(\vec{r}-\vec{r}_0)$	Dirac delta function

consider the energy-momentum pseudo-tensor in order to estimate the energy in a given of space-time volume. As expected, we find that the resultant energy is considerably larger than the Newtonian estimate based on the difference in the gravitational potential between two distinct points.

Before we present our computation and discuss its implications, we review some of the results presented in Ref. [7] concerning gravity manipulation based on rocketry metrics.

2. ROCKETRY METRICS

Classical propulsion systems rely on Newton's mechanics. The

International Journal of Modern Physics D
Vol. 21, No. 4 (2012) 1250035 (14 pages)
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DOI: 10.1142/S0218271812500356

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www.worldscientific.com

TESTING THE FLYBY ANOMALY WITH THE GNSS CONSTELLATION

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Received 30 December 2011
Revised 1 February 2012
Accepted 10 February 2012
Published 5 April 2012

We propose the concept of a space mission to probe the so called *flyby anomaly*, an unexpected velocity change experienced by some deep-space probes using earth gravity assists. The key feature of this proposal is the use of GNSS systems to obtain an increased accuracy in the tracking of the approaching spacecraft, mainly near the perigee. Two

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Comparison of Space Propulsion Methods for a Manned Mission to Mars

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We assess the possibility of reducing the travel time of a manned mission to Mars using different propulsion methods and keeping the mass at departure within bounds. For the sake of comparison we used representative systems of different state of the art or proposed technologies, from the chemical engine to the "Pure Electro-Magnetic Thrust" (PEMT) concept, using a nuclear engine proposed by Rubbia. A mission architecture based on existing proposals is suggested in order to estimate the mass budget that influences the performance of the propulsion system. Pareto curves of the duration of the mission and time of flight versus mass of mission are drawn. We conclude that the ion engine technology, combined with the classical chemical engine, is the one which yields the shortest mission times with the lowest mass, and that chemical propulsion alone is the best to minimise travel time. The results obtained using the PEMT suggest that it is a more suitable solution for farther destinations than Mars.

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