THE ESPaCE CONSORTIUM AS A EUROPEAN PRODUCER OF SPACECRAFT AND NATURAL MOON EPHEMERIDES

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ABSTRACT

The consortium ESPaCE (European Satellite Partnership for Computing Ephemerides) is composed of seven European institutes: IMCCE (Institut de Mécanique Céleste et de Calcul des Ephémérides, Paris Obs.), ROB (Royal Observatory of Belgium), TUB (Technical University of Berlin), ERIC (European Research Infrastructure Consortium formerly known as JIVE : Joint Institute for VLBI in Europe), TUD (Delft University of Technology), French space agency (CNES) in France and German Aerospace Center (DLR) in Germany. The objective of the consortium, initiated under an FP7-European project is to provide new accurate ephemerides of natural satellites and spacecraft. For this goal astrometric data issued from ground-based observations as well as from space observations are being analyzed and reduced. On the other hand emerging technologies, specifically VLBI and interplanetary laser ranging, applied to the positioning of spacecraft are also studied. The ESPaCE project addresses also data related to gravity and shape modeling, control point network and rotational parameters of natural satellites. The accuracy improvement of these ephemerides makes them a powerful tool for the analysis of space missions, the preparation of future missions, or for the determination of planetary physical parameters. Among relevant sub-products for space missions, we note the delivery of updated ephemerides of the Mars moons Phobos and Deimos derived from data by the Mars Express mission. In addition, the ESPaCE ephemerides of the Galilean moons are regularly updated in the context of the upcoming JUICE mission.

1. INTRODUCTION

Since June 2011 the European Satellite Partnership for Computing Ephemerides (ESPaCE), an EU FP7 project [1], develops different methods aiming at renewing and improving the accuracy of ephemerides of natural satellites and spacecraft. Data from several past space missions as well as from large collections of ground-based observations are gathered to complete current data collections. Particular attention is given to space imagery, radio science, and new techniques such as s/c laser tracking or VLBI. Further studies include the definition of reference frames and coordinate networks that allow improvement of spacebased astrometric observations.

2. RESULTS OBTAINED

2.1. Digitization

Digitization of photographic plates leads to accurate astrometric data by using modern digitizing machine and accurate stellar catalogues. The DAMIAN digitizing machine at the Royal Observatory of Belgium allowed us to measure 440 USNO plates (1969-1997) of Mars satellites and 617 plates (1974- 1999) of the Saturn satellites from USNO (D. Pascu, private comm.) and 384 plates (1926-1945) of the Saturnian satellites from SAO, South Africa. The next step will be the digitization of other plates, such as those available in European observatories.

2.2. Astrometry

In the frame of ESPaCE, Phobos and Deimos space astrometry from Mars Express SRC images has been performed for 83 Phobos flybys and 53 Deimos approaches (2005-2011) leading to astrometry at less than four kilometres of accuracy [2]. On the other hand, photographic plates of the Martian system digitized with the DAMIAN machine yield to accuracy better than 50 mas [3]. Likewise, observations of the natural satellites mutual events lead also to accurate astrometric measurements. Such events for the Jovian satellites have been analysed and published for the six periods before 2009. For the 2009 period, more than 500 observations have been collected and reduced [4]. The Uranian satellites mutual events observations done in 2008 have been, also [5].

2.3. Radio science

Radio science allows us to improve our knowledge of the orbital motion of spacecraft orbiting planets. The precise orbit determination process requires fitting a model of the motion of the spacecraft to the radio- tracking performed by Earth-based stations on the basis of Doppler shift of the carrier radio frequency or ranging measurements. Improved positions and velocities of the spacecraft along its orbit are fundamental for the precise astrometric reduction of space imagery [6]. Such data are provided for the Mars Express, Viking 1&2, Mariner 9 missions. They will be provided in the future for the Galileo and Voyager-2 spacecraft.

2.5. Coordinates and reference systems

Astrometry from space imagery significantly benefits from good knowledge of the satellites shape, orientation, and gravity. Therefore in ESPaCE a work package is dedicated to the providing of such data. In this frame, Phobos shape and topographic models have been carried out as well as a control point network and a gravity model.

2.6. VLBI

The VLBI technique provides the most accurate astrometric data on the position of celestial radio sources with the accuracy reaching microarcseconds. This technique can be applied not only to natural celestial radio sources but to human-made too [7]. Recently, the ESPaCE collaboration demonstrated the latest more accurate modification of the VLBI-tracking algorithms in observations of ESA's Venus Express (VEX). These observations were conducted with radio telescopes in Finland, Sweden, Italy, Germany and Russia and processed at the Joint Institute for VLBI in Europe (JIVE) in the Netherlands [8]. The technique is now undergoing preparation for prospective planetary missions such as JUICE [9].

2.7. Laser ranging

Interplanetary laser ranging is being investigated in the project as a future technology to enable mm- to dm-level range measurements over interplanetary distances, supplementing the existing radiometric tracking techniques. A simulation tool is being developed within the Tudat software suite, capable of performing bottom-up link simulations of range measurements directly from mission, system and environment characteristics. Using the simulated data in an orbit determination process allows us to ascertain the added value of a one- or two-way laser ranging system with Doppler and VLBI measurements, as well as the synergy with these systems. Validation steps have been performed using, among others, the available data of the LAGEOS satellite. One-way laser ranging measurements to LRO have been processed and matched, and will be compared to simulated measurements to validate the hardware models involved in transponder ranging. Upcoming simulations will allow us to determine the potential of both the use of existing laser altimeter systems for tracking purposes, as well as that of dedicated missions with purpose-designed hardware.

2.8. Ephemerides for space missions

New ephemerides of the satellites of Mars and of the main satellites of Jupiter, Saturn, Uranus are provided in SPICE format. Ephemerides of the Lagrangian Saturnian moons are provided, also. They benefited from the large amount of work done on photographic plates and space mission data (Mariner 9, Viking 1 & 2, MEX, Cassini) in the ESPaCE network. Such new ephemerides are a keypoint for the success of specific experiment with space missions like MEX and JUICE.

All our ephemerides of the orbit of the moons are available here: **ftp://ftp.imcce.fr/pub/ephem/fp7-espace**

3. CONCLUSION

The goal of ESPaCE is basically to provide new ephemerides of the Martian, Jovian, Saturnian, Uranian satellites, as well as of the space probes. More, the update and maintenance of several databases related to astrometry and coordinates and reference systems for several satellites is considered, also.

4. ACKNOWLEDGMENTS

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