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SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Systems and Infrastructures to Implement Future Building Blocks in Space Exploration and Development (2)

Author: Prof. Giovanni B. Palmerini
Sapienza University of Rome, Italy, giovanni.palmerini@uniroma1.it

ADVANTAGES AND CAPABILITIES OF AN IN-SPACE NAVIGATION INFRASTRUCTURE IN MOON AND MARS MISSIONS

Abstract

Future space activities are likely to include frequent missions toward Moon and Mars, probably involving small spacecraft. Advances in miniaturization will certainly help in maintaining remarkable payload capabilities, even within significant mass and volume constraints. An additional help in exploiting these missions and in adding value to them can be obtained by devolving some of the tasks, which are mandatory and common to all spacecraft, to an external, in-space infrastructure. Onboard systems could be simpler and lighter, and the performance granted by the infrastructure would be far better than the one achievable by the spacecraft itself. This approach can be applied - straightforward - to communication and navigation functions.

This paper investigates the characteristics and the capabilities of such a kind of in-space navigation architecture in the cases of missions to Moon and Mars, specifically dealing with the phases of the mission where the spacecraft are close to the targeted celestial body (entry, descent, ascent, possible surface exploration). The goal is to provide to each spacecraft/user the information needed to navigate in a way as much as possible independent from Earth, to limit the burden of ground-based tracking. The solution can be either provided by sources on the lunar or martian ground, as well as by small constellations of platforms orbiting the targeted celestial body. In lunar case, some aiding can be provided by faint signal of existing/designed GNSS constellations servicing the Earth. The working principle of the function provided by the infrastructure would be likely based on the hyperbolic navigation, a traditional technique already applied in the 60's and 70's Loran and TRANSIT systems. This approach, even at the cost of limited performance with respect time-of-arrival principle (adopted as an example in GNSS) does require a simplified sources' segment, and seems therefore more adequate also with respect to the expected number of spacecraft/users. Accuracy and sources' availability problems could be partially solved by up-to-date estimation methods. Additionally, the same navigation infrastructure could provide significant data-relay capabilities.

As an example, the scheme of an autonomous navigation capability – all along the mission - for a lunar-bound spacecraft is discussed in detail. Navigation shall make use of the GNSS infrastructure in proximity of the Earth and during the transfer, and of the lunar navigation infrastructure in proximity of the Moon. The performance attainable in the different phases are evaluated, as well as the way they would affect the mission design.