HORIZON 2020

Solar Sailing for Space Situational Awareness In the Lunar System

Informe

Información del proyecto

S4ILS

Identificador del acuerdo de subvención: 658645

Sitio web del proyecto

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Proyecto cerrado

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Periodic Reporting for period 2 - S4ILS (Solar Sailing for Space Situational Awareness In the Lunar System)

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Resumen del contexto y de los objetivos generales del proyecto

The 21st of May 2010 saw the dawn of a new era in space propulsion when the Japanese Space Agency launched its IKAROS spacecraft. Twenty days into the mission, IKAROS unfurled a 14x14 m2 solar sail that would take the probe on a six-month voyage to Venus. A solar sail rides on sunlight the way that sailboats ride on the wind. Therefore, propelled solely by the solar photons reflecting off the 7.5 micrometer thin, highly reflective membrane, IKAROS was the first to demonstrate a notion that had been around for nearly a century: that spacecraft can be propelled through space by sunlight.

Solar Sailing for Space Situational Awareness In the Lunar System (S4ILS) has exploited the potential of this new, elegant and truly exciting field of space propulsion. While it is often proposed as a propulsive means for missions around the Sun or in the Sun-Earth system, S4ILS has demonstrated its potential much closer to home, in the Earth-Moon system, opening up radically new possibilities in spaceflight. As an enabler of diverse products and services that are crucial to modern day society (navigation, communication, Earth observation), spaceflight is extremely vulnerable to threats from space objects and space weather events. Combining the potential of solar sailing and the need to keep ground and space assets safe from natural and man-made threats from space, the overall objective of the S4ILS project has been to deliver, for the first time, radically new solar sail periodic orbits in the Earth-Moon system and utilize these for the benefit of space situational awareness.

Concrete results include a catalogue of new families of solar sail periodic orbits at the Lagrange points of the Earth-Moon system (e.g. Lyapunov orbits, halo orbits, vertical Lyapunov orbits, and so on) as well as radically new orbit families around Earth (e.g. “flower-shaped” and “clover-shaped” orbits). A constellation of two solar sail clover-shaped orbits can provide unprecedented capabilities for space weather observations as they enable a continuous view of the entire (Ant)Arctic region. As such, the constellation provides uninterrupted observations of the entire auroral oval and the direct response of the magnetosphere to changes in the solar wind. The view will also allow the detection and imaging of rarely observed phenomena such as transpolar arcs and cusp spots to further the understanding of the cause for and relation between these phenomena.

By transferring the techniques developed for the Earth-Moon system to other dynamical systems, further new insights in the solar sail dynamics in proximity of, for example, asteroids and binary asteroids has been obtained. This has resulted in new vantage points from where to monitor these primordial rocks to better understand them for planetary defense purposes. For example, families of solar sail periodic orbits high above a binary asteroid pair have been designed to allow unique, previously unknown and geostationary-equivalent vantage points from where to monitor the asteroid(s) over extended periods of time.

Trabajo realizado desde el comienzo del proyecto hasta el final del período abarcado por el informe y los principales resultados hasta la fecha

The classical three-body system (e.g. Earth-Moon-satellite) generates five equilibrium solutions (the Lagrange points) where a satellite is stationary with respect to both celestial bodies. Natural periodic orbits can be found around these Lagrange points. By complementing the dynamics with a solar sail, the S4ILS project has found radically new families of orbits around the Lagrange points of the Earth-Moon system. These have been catalogued, using (where possible) the same terminology/denomination as used in the classical system. As such, “solar sail-versions” of, for example, Lyapunov orbits, halo orbits, vertical Lyapunov orbits, and so on, have been generated. But also some radically new orbit families have been produced, including “out-of-plane flower-shaped” orbits and “clover-shaped” orbits.

In terms of space situational awareness (SSA) applications, especially the clover-shaped orbits appear highly suitable. For example, a constellation of two mirrored clover-shaped orbits has been shown to provide almost uninterrupted coverage of the Arctic region to observe space weather events and, in particular, the auroral oval, which gives insight into the effect of space weather on the geosphere. In addition, all techniques developed for the Earth-Moon system have been translated to (binary) asteroid systems to create unique, previously unforeseen vantage points from where to monitor such asteroids over extended periods of time. Improving our knowledge on (binary) asteroid systems will increase our understanding of these primordial rocks, which will be vital for planetary defense purposes.

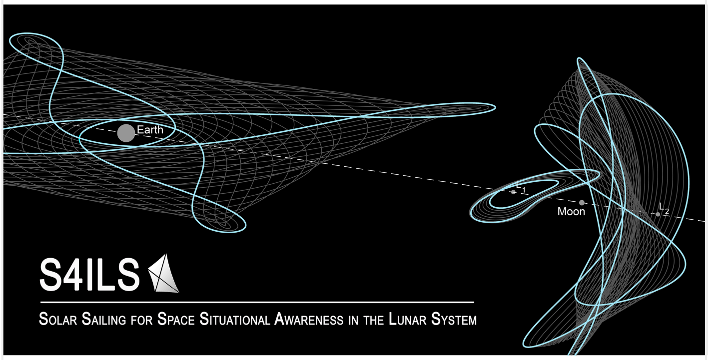
Besides the technical work on devising the above mentioned novel solar sail orbits and their applications for SSA, the dissemination of information to and communication activities with the research community and the general public have formed an integral part of the S4ILS project to maximize its impact. Examples of such knowledge transfer activities include colloquia, seminars, guest lectures, student supervision, participation in conferences, publications in peer-reviewed journals as well as the use of public websites such as the S4ILS page on the TU Delft website and dedicated pages on platforms such as ResearchGate and Facebook.

Avances que van más allá del estado de la técnica e impacto potencial esperado (incluida la repercusión socioeconómica y las implicaciones sociales más amplias del proyecto hasta la fecha)

S4ILS has, for the first time, performed a thorough and systematic investigation, calculation, and cataloguing of solar sail periodic orbits in the Earth-Moon system. As a result, all orbits devised are beyond the state of the art as no such solar sail periodic orbits in the Earth-Moon system have been generated before. Investigating the potential of these orbits for SSA has revealed capabilities unrivalled by conventional propulsion techniques. Examples include the mentioned constellation of two sailcraft in a set of “clover-shaped” orbits that can provide uninterrupted observation of the Artic region. Such continuous observations will significantly enhance our observations of the auroras and will be crucial to better understand the Sun-Earth connection and the impact of solar storms on the geosphere.

Although the road to true implementation and exploitation of these newly devised orbits for SSA is still very long, once there, it will have a profound impact on the European society and economy: enabling the monitoring of space debris and furthering our understanding of space weather events as well as asteroids that are on a collision path with Earth, will improve our abilities to keep ground and space assets safe. Destruction of power grids and power outages, the need for aviation re-routing, and malfunctioning of Earth-orbiting satellites means that the users that will ultimately benefit from this work extend far beyond the aerospace sector and include telecom operators, power/energy markets, airlines, Earth observation services, and many more.

It is these discoveries by the S4ILS project, both the generation of new orbits, their novel applications and previously undiscovered capabilities, that will put solar sailing firmly on the map and will underpin the need for further European solar sail technology development.



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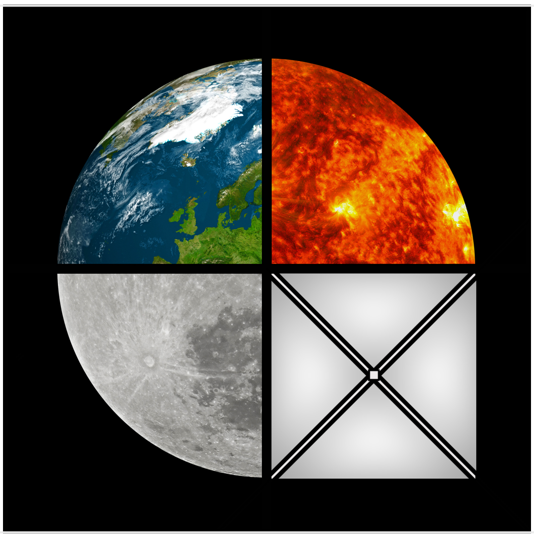

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