COMPASS Report Summary

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Periodic Reporting for period 1 - COMPASS (Control for Orbit Manoeuvring through Perturbations for Application to Space Systems)

Reporting period: 2016-08-01 to 2018-01-31

Summary of the context and overall objectives of the project

The use of Space is crucial to life on Earth thanks to the services provided by space assets and the development of technologies, science and space exploration. Current and future space activities are enabled by Space transfer that allows reaching and controlling operational orbits. Moreover, they are safeguarded by Space situation awareness that mitigates the hazards caused by asteroids or space debris generated from the break-up of abandoned satellites.

The motion of spacecraft in all these applications is governed by the gravity of the primary body, but it is also strongly influenced by external forces due the gravity of the Moon and the Sun, atmospheric drag, solar radiation pressure, and so on. In the conventional models for accurate orbit propagation, these external forces are traditionally seen as perturbations that need to be counteracted by orbit manoeuvres, thus increasing fuel requirements.

In the COMPASS project we leverage the dynamics of these natural orbit perturbations and develop novel techniques for orbit manoeuvring by “surfing” through orbit perturbations. With this approach we see the entire landscape of the dynamics of orbit, so we can design the best way through that landscape; using orbit perturbations as natural features not accelerations we need to fight.

The potential impact of the COMPASS project will be to significantly reduce the current extremely high space mission costs, thus creating new opportunities for space exploration and exploitation, and space debris mitigation.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

During the first 18 month of the project, the use of semi-analytical techniques for the modelling of orbit perturbations and tools of dynamical systems theory laid the foundation for a new understanding of the long-term orbit dynamics of the spacecraft in a planet-centred environment or in an interplanetary orbit around the Sun, where a model accounting of the forces of all the planets in the Solar System is needed.

Different fields of application have been investigated with this novel space mission design philosophy: from counteracting disturbances, to exploiting natural and artificial perturbations. To assess the risk of collision in Space against the many space debris objects, a mathematical model was built to represent the population of space debris and their evolution around the Earth, this model considers them a continuous fluid to know their distribution in space and time. Space is getting crowded also according to the recent announced plans on the deployment in orbit of large constellation of small satellites. We have performed the optimisation and design of satellite large constellations considering all the phases of their mission, from the orbit raising, till the mission end-of-life.

The natural forces acting on an Earth-orbiting satellites have been modelled with the Planetary Orbital Dynamics (PlanODyn)
suite. Through this tool, a new mean of spacecraft orbit control has been preliminary designed that progressively explores the phase space and, though the spacecraft parameters and propulsion manoeuvres, governs the effect of these perturbations to reach the desired orbit.

To enhance the interplanetary trajectory design and select the planets for fly-by manoeuvre a design strategy has been derived for “surfing” among planets. This, however, need to be compliant to planetary protection requirements, so that man-made objects do not contaminate other planets. We have devised new methods for verifying, through orbit propagation and uncertainty modelling, that these requirements are satisfied.

The COMPASS team has strengthen research collaborations with the European Space Agency and the Italian Space Agency.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

As space activities are boosting, it will be needed in the near future, to regulate the traffic in space. To this aim we are using the developed tools to devise a mean for “rating” satellites and missions based on their impact on the environment and the benefit they provide to human activities and life on Earth, to drive the development of space toward sustainability. This was represented also via a graphic interactive COMPASS game used for dissemination.

The devised techniques for orbit maneuvering through perturbations can be enhance the use for small satellites working in a constellation to achieve a unique mission goals. This will increase the services that spacecraft can offer to our daily lives, such as the monitoring of our planets, weather forecast, global positioning and navigation, global internet, telecommunications.