Winter 2024

IAF ASTRODYNAMICS TECHNICAL COMMITTEE

Introduction

The IAF Astrodynamics Committee was established more than four decades ago and currently includes 32 members. The Astrodynamics Symposium, coordinated by the Committee and conducted annually at IAC, is an international forum for recent advancements in the areas of guidance, navigation and control, mission design, optimization and operations, orbital and attitude dynamics.

Summary

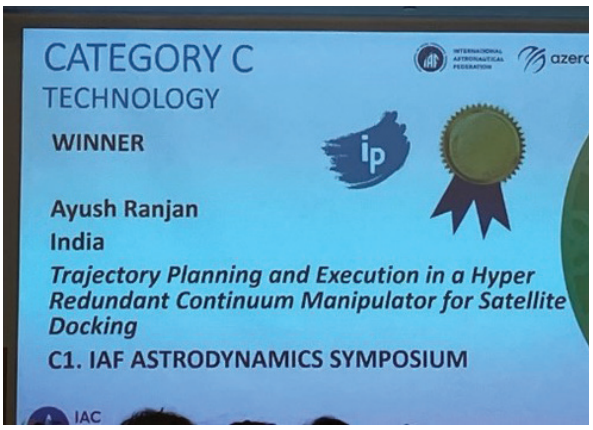
In the context of orbital dynamics, works presented at IAC 23 propose classical as well as emerging techniques to deal with perturbed environments around the Earth and in cislunar space. Orbit resonances in multi-moon systems are exploited to design cyclers. Low-energy trajectories involving different aspects of libration point regimes and photo-gravitational effect are the focus of current transfer design methodologies. As for semi-analytical methods, new approaches have emerged for the determination of reachable domains, the probabilistic analysis of capture around minor bodies and complex computations in non-autonomous systems. Machine learning principles find extensive application in all areas.

The Astrodynamics Symposium at IAC 23 has also reflected the general interest in small satellites (including Cubesats and micro-satellites) primarily through the development of low-thrust techniques with wide implementation of modern mathematical methods for guidance and control. Mathematics guides interplanetary mission design via invariant manifolds and the restricted four-body problem, whereas formation flying has been extended to missions in the vicinity of libration points in the circular restricted three-body problem. The miniaturization of electrical propulsion pushes the development of motion control algorithms for satellite formation maintenance.

The ion-propelled Psyche probe, NASA's first mission designed to study a metal-rich asteroid, was launched on Oct. 13, 2023.

The John V. Breakwell Memorial Lecture at IAC 23 – Prof. Mikhail Ovchinnikov (Keldysh Institute of Applied Mathematics – Moscow, Russian Federation)

Prof. Mikhail Ovchinnikov from the Keldysh Institute of Applied Mathematics, Moscow, Russian Federation (in the photo with Prof. Kathleen Howell and Prof. Daniel Scheeres) received the Breakwell Award from the International Astronautical Federation (IAF) in recognition of his outstanding contributions in the field of Astrodynamics, in particular in Attitude Control of Small Satellites and Formation Flying.



The work by Mr. Ayush Ranjan titled Trajectory Planning and Execution in a Hyper Redundant Continuum Manipulator for Satellite Docking presented within the Astrodynamics Symposium during IAC 23 in Baku was selected as best Interactive Presentation of Category C (Technology).

Highlights

Current astrodynamics research is highly focused on the design of missions to the moon and cislunar space, small bodies in the solar system, and planetary satellites. Small body mission applications include the influential impact of asteroid Dimorphos by the DART mission, achieved using correction maneuvers and uncertainty quantification for trajectory optimization and navigation, as well as the successful sample return from asteroid Bennu as OSIRIS REx (now OSIRIS APEX) carries on with an extended mission to fly by Apophis. Similarly, preparations continue for Europa Clipper and for an orbiter and a lander for a mission to Enceladus. Low-thrust techniques are used to minimize fuel consumption and/or transfer time. In this context, an important breakthrough is the first rigorous formulation and solution of the minimum-time Earth-to-Moon transfer problem without any approximation. In the context of lander missions to asteroids, noticeable progress has been made in autonomous guidance also with the employment neural networks. These trends are also reflected in recent missions to the moon, namely the ispace MK1 landing attempt and the successful landing of IRSO's Chandrayaan-3 mission. The first scientific results of the latter were presented in a highlight lecture at IAC-23. Further topical keynote presentations included the Artemis cooperation as well as the ispace lunar landing attempt experience.

Future Outlook

The trends identified during this year's IAC clearly indicate that missions to lunar and cislunar space as well as minor bodies (asteroids, comets, and planetary moons) will drive the development of astrodynamics techniques in the near future. A more and more extended use of machine learning and artificial intelligence for trajectory & attitude planning, navigation and control can be foreseen.

The ever-increasing number of missions to the moon has also triggered the study of infrastructure systems to ease access and boost the performance of single missions by providing communication and navigation services. This requires establishing satellite constellations around the moon (and Mars) as e.g. envisioned by JAXA's LNSS, ESA Moonlight and NASA's LCRNS programs.

To avoid Earth's space debris problem in the lunar environment ESA has introduced a new version of the ESA Space Debris Mitigation Requirements, which can have a significant impact on the lunar mission and trajectory design with the goal of avoiding any debris problem emerging in lunar space.

Committee activities

The IAF Astrodynamics Committee is organizing the 12th edition of the International Workshop on Satellite Constellations and Formation Flying (IWSCFF 2024). The conference will be held by the Taiwan Space Agency in the last quarter of 2024 and the call for papers will be announced soon. This specialist workshop gathers experts and researchers from science, mathematics and engineering to discuss recent advances in the field of Astrodynamics applied to Satellite Constellations, Formation Flying and Proximity Operations. Starting in 1997, all the editions of this event have been organized by the IAF Astrodynamics Committee.