



2024

IAF ASTRODYNAMICS COMMITTEE

Introduction

The Astrodynamics Technical Committee (TC) of the International Astronautical Federation promotes advances in orbital mechanics, attitude dynamics, guidance, navigation and control of single or multispacecraft systems as well as space robotics. The Astrodynamics TC was established more than four decades ago and currently includes 32 experts from academic and research institutions, industries and space agencies. The Astrodynamics Symposium is coordinated by the TC and conducted annually during the International Astronautical Congress.

Summary

This year's research in astrodynamics focuses largely on cislunar space and missions to Gateway (rendezvous, docking, gravity gradient effects, optimal trajectories connecting LEO, Gateway and LLO) and the lunar surface. Important efforts are devoted to provide optimal trajectories and develop autonomous navigation algorithms for missions to asteroids, comets and giant planet moons, and even intercept and collect small debris, such as the ejecta of the Didymos asteroids following the DART mission. Near-Earth projects follow traditional approaches for attitude and orbital control while employing more effective sensors and actuators. Many investigations focus on contingency plans for failure of reaction wheels on extended deep space missions. As a result of the development and implementation of satellite constellations and formations, small satellites play an increasingly major role and so does the study of the impact of miniaturization on payload performance resolution, photovoltaics-battery effectiveness and onboard computer power. The trend towards miniaturization applies to interplanetary missions as well. This translates into the need for a larger involvement of higher-fidelity models (e.g., circular restricted three-body problem, circular restricted fourbody problem) in trajectory design.

Highlights

- NASA's Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) Cubesat completed its 100th revolution in a 9:2 lunar synodic resonant Near Rectilinear Halo Orbit (NRHO) on 4 September 2024. CAPSTONE is a technology demonstration mission orbiting in the NRHO planned for the Gateway mission. The 12U CubeSat is serving as a pathfinder mission for NASA's Artemis program.
- The Intuitive Machines IM-1 lunar lander launched on 15 February 2024 and landed near the lunar south pole a week later on 22 February 2022. Oriented 30^o from the horizontal, IM-1 operated for approximately 6 days on the lunar surface.
- The ESA/JAXA Bepi-Colombo mission completed its fourth flyby of Mercury on 4 September 2024, passing at an altitude of 165 km, returning photos of the south pole back to Earth. Two more flybys of Mercury are planned this winter. The mission is currently experiencing technical problems with the electric propulsion system. It can currently only operate at lower thrust levels. The trajectory was re-designed and the Mercury orbit insertion is now delayed to November 2026 to account for the lower thrust available.
- NASA's Parker Solar Probe executed a trajectory correction manoeuvre on 26 August 2024, aligning the spacecraft for a final Venus flyby planned on 6 November. This flyby will enable the minimum solar distance of 6.1 million km, with a perihelion at this unprecedented altitude scheduled in December 2024.
- ESA's Jupiter Icy Moons Explorer (Juice) has successfully completed a world-first lunarterrestrial flyby, using the gravity of Earth and Moon to send it Venus-bound. The closest approach to the Moon was at 23:15 CEST (21:15 UTC) on 19 August, guiding Juice towards the closest approach to Earth just over 24 hours later at 23:56 CEST (21:56 UTC)

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on 20 August. The inherently risky flyby required ultra-precise, real-time navigation, but is saving the mission around 100–150 kg of fuel. Since JUICE was coming so close to Earth, a conjunction assessment for collision avoidance with other spacecraft had been performed with teams on stand-by to execute an avoidance manoeuvre. The gravity assist flyby was flawless, using only a tiny fraction of the propellant reserved for this double assisted maneuver.

- JAXA's Smart Lander for Investigating Moon (SLIM) successfully made a pinpoint landing on the lunar surface on 19 January 2024 after completing a ballistic lunar transfer (BLT) to the Moon, landing within 10 m of its target. Despite a sideways landing, the spacecraft completed primary and secondary objectives, operating through April 2024, beyond its planned lifetime.
- Citizen scientists employed NASA Wide Field Infrared Explorer (WISE) telescope data, confirmed by ground-based telescope data, to identify a fastmoving object departing the Milky Way galaxy at about 2 million km/hour. The object is presumed to be a low-mass star or a brown dwarf. It may have reached its high velocity by an encounter with a binary black hole or by an explosion of a binary partner.
- In October ESA's HERA spacecraft will be launched on a SpaceX Falcon 9 to visit the binary asteroid Didymos – Dimorphos. The moonlet Dimorphos was impacted by NASA's DART mission on 26 September 2022 in a planetary defense demonstration. Hera will perform a detailed post-impact survey of the target asteroid. Demonstrating new technologies from autonomous navigation around an asteroid to low-gravity proximity operations, Hera will be humankind's first probe to rendezvous with a binary asteroid system.
- The Space Agency of the United Arab Emirates is developing an ambitious mission to explore the asteroid belt between the orbits of Mars and Jupiter. Known as the Emirates Mission to the Asteroids (EMA), the probe will fly past six asteroids at high relative speed, and in 2034 will release a lander on 269 Justitia.

Future Outlook

An ongoing NASA effort is exploring the architecture of a mission to the solar gravitational lens (SGL) focal region, targeting high-resolution imaging and spectroscopy of exoplanets. The mission envisions using solar sails and nanosatellite-class spacecraft to reach heliocentric distances of 650–900 AU, where a meter-class telescope could exploit the SGL's amplification to provide detailed multipixel images of exoplanets up to 100 light years away, allowing for the study of surface features and potential signs of habitability. This ambitious mission requires a Sun flyby using a controlled solar sail as well as the development of techniques for navigation and motion control in the focal region.

Committee activities



The John V. Breakwell Memorial Lecture at IAC-24 will be delivered by Prof. Amalia Ercoli Finzi (Politecnico di Milano – Italy) during the Orbital Dynamics (2) session of the Astrodynamics Symposium. Prof. Ercoli Finzi is one of the leading experts on space missions at a national and international level. She held countless roles of responsibility at Politecnico di Milano and was called to contribute to numerous technical and scientific committees of the Italian and the European Space Agencies. The title of her Breakwell Memorial Lecture is Unique Orbits for Unique Space Missions.



Starting in 1997, the IAF Astrodynamics Committee organized the International Workshop on Satellite Constellations and Formation Flying (IWSCFF). The next edition of the event (IWSCFF 2024) will be hosted at Kaohsiung by the Taiwan Space Agency from 2 to 4 December 2024. 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. Details can be found at <u>https://iwscff2024.conf.tw.</u>

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