

IAF ASTRODYNAMICS TECHNICAL COMMITTEE

1. Introduction

The IAF Astrodynamics Committee promotes advances in orbital mechanics, attitude dynamics, guidance, navigation and control of single or multi-spacecraft systems as well as space robotics. The IAF Astrodynamics Committee was established more than four decades ago and currently includes about 30 experts from academic and research institutions, industries and space agencies. The IAF Astrodynamics Symposium is coordinated by the IAF Astrodynamics Committee and conducted annually during the International Astronautical Congress (IAC).

2. Latest developments

This year's trends in mission design and optimization concern Earth missions (multi-layered satellite constellations, debris removal, on-orbit refueling techniques and closed-form solutions for low-thrust trajectory optimization) as well as lunar missions (indirect optimization of low-thrust orbit transfers from LEO to low lunar orbit, orbit transfers between libration point orbits and extended perilune rendezvous for the Lunar Gateway), interplanetary missions (Europa Clipper, missions to Venus and Mars, Enceladus probes) and design of asteroid missions (using dynamical structures, low-thrust propulsion or multiple planetary flybys).

In the context of orbital dynamics, state-of-the-art analytical developments provide new theoretical support in perturbation theory, averaged dynamics and estimation of probability capture. These developments often include new vectorial propagations and jet transport cutting-edge techniques. The latest advances extend to computational techniques for invariant objects, lobe dynamics and applications to libration point orbits and nonlinear rectilinear halo orbits in different scenarios.

The application of machine learning and neural networks to all areas of Astrodynamics is a confirmed trend.

3. Breakthroughs

- Artemis 1, including NASA's Orion capsule and ESA's service module, successfully completed its mission to a Distant Retrograde Orbit (DRO) around the Moon. The 25-day round-trip test flight included 6 days, or approximately half a revolution, in the DRO. This DRO is a member of a family of stable periodic orbits around the Moon.
- Three spacecraft successfully flew Ballistic Lunar Transfer (BLT) trajectories to the Moon. These low-energy transfers employ solar gravity to significantly reduce orbit insertion costs at the Moon compared to faster direct transfers.
 - The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) arrived in a Near Rectilinear Halo Orbit (NRHO) on 13 November 2022. CAPSTONE is a technology demonstration mission performing relative navigation with the Lunar Reconnaissance Orbiter (LRO) and a pathfinder for NASA's Gateway testing the dynamical environment of the NRHO.
 - The Korea Pathfinder Lunar Orbiter (KPLO), also called Danuri, was inserted into a polar low lunar orbit on 16 December 2022. Danuri is a lunar exploration mission developed by the Korea Aerospace Research Institute (KARI) to demonstrate technology and perform scientific research, including studying permanently shadowed regions near the poles.
 - Hakuto-R, a commercial lunar lander developed by the Japanese company ispace, entered an elliptical low lunar orbit on 21 March 2023 and was scheduled to land on 25 April 2023.

It carried several payloads, including a rover developed at the Mohammed bin Rashid Space Center in the United Arab Emirates. After a historic landing attempt on 25 April 2023, communication with the probe was lost. Hakuto-R has been the first commercial spacecraft to perform a ballistic low-energy three-month trek to the moon.

- ESA's Jupiter Icy Moons Explorer (JUICE) (Fig. 1) was successfully launched on April 14 on the second to last Ariane 5. The spacecraft is expected to reach Jupiter in July 2031 after four gravity assists and eight years of travel. This interplanetary mission phase is followed by a moon tour that includes another 35 fly-bys. The mission is planned to study Ganymede, Callisto, and Europa, three of Jupiter's Galilean moons. During the commissioning phase, a problem with the deployment of the 16-metre-long Radar for Icy Moons Exploration (RIME) antenna occurred. The operations teams are currently troubleshooting the issue.

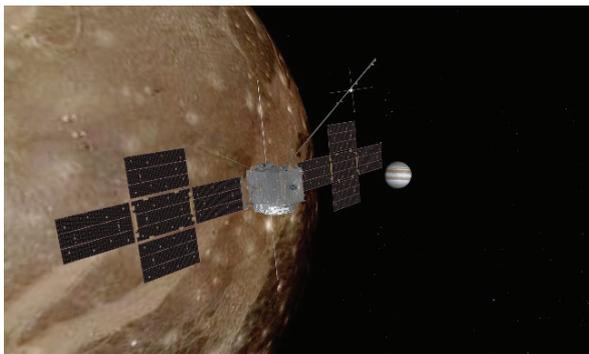


Figure 1: ESA's JUICE mission.

- The launch of ESA's Euclid mission to the Sun-Earth Lagrange point L2 (SEL2) is planned for July 2023 (Fig. 2). Euclid will be directly injected into a large amplitude quasi-Halo orbit about SEL2, not requiring a deterministic injection maneuver. Euclid is designed to explore the evolution of the dark Universe. It will draw a 3D-map of the Universe by observing billions of galaxies out to 10 billion light-years, across more than a third of the sky. The mission will be launched on a SpaceX Falcon 9 from Cape Canaveral after the originally planned Soyuz-Fregat launcher from Kourou became unavailable. This change in the launch vehicle was achieved in a remarkably short period of time.

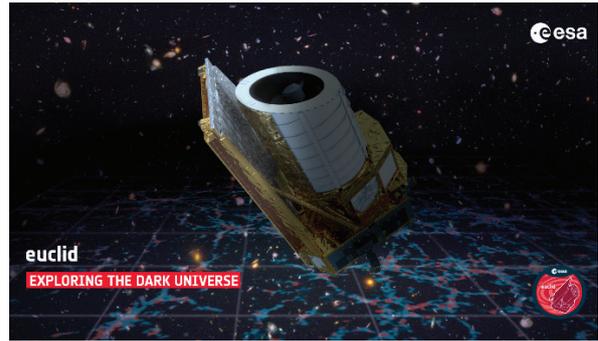


Figure 2: ESA's Euclid mission.

4. Action plan for the year

- The 2023 edition of the John Breakwell Memorial Lecture will be hosted within the Astrodynamics Symposium of the 74th International Astronautical Congress in Baku and will be given by Dr. Mikhail Ovchinnikov of the Keldysh Institute of Applied Mathematics. This prestigious Lecture was initiated by the late Prof. V.J. Modi of University of British Columbia in 1991 as a tribute to the late Prof. John V. Breakwell (1917–1991) of Stanford University, who is regarded as an outstanding astrodynamist of the last century.

5. Announcements

- In 2024 the Taiwan Space Agency plans to host the 12th International Workshop on Satellite Constellations & Formation Flight (IWSCFF) in Taipei. The event will gather experts in science, mathematics and engineering from research institutions, universities and industries to discuss recent advances in the field of astrodynamics applied to satellite constellations, formation flight and proximity operations. Details about the event will be released in the next edition of the IAF Committee Highlights.