IAF ASTRODYNAMICS COMMITTEE

Introduction

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

Summary

This year's research in astrodynamics includes a continued focus on trajectory design and GNC to and around the Moon, employing both novel and classic techniques. Topics include low-energy and low-thrust trajectories, cislunar traffic management, autonomous navigation and rendezvous in cislunar space, and transfers between Near Rectilinear Halo Orbits and Low Lunar Orbits or Sun-Earth libration point orbits. Other areas of interest include trajectory design, attitude control, and GNC for on-orbit servicing missions, both in Earth orbit and in cislunar space, as well as GNC for rendezvous, proximity operations, docking, and imaging with cooperative and non-cooperative targets. In addition, the application of AI techniques is a primary focus. Topics include AI-aided algorithms for GNC and formation flight, reinforcement learning for design of multiple gravity assist trajectories, and automatic initialization of low-thrust trajectory optimization tools. Research also includes a focus on GNC and trajectory design for smallsats. Of particular interest is launch ridesharing for reduced-cost access to space for small missions, including piggy-back launches with LEO spacecraft for smallsats with beyond-Earth-orbit destinations. Dynamics and control of lunar constellations for communication, navigation, and remote sensing is another primary topic of study. Additional areas of focus include the transition of multibody trajectories into higher-fidelity models, as well as mission design to asteroids and comets.

Highlights

- The joint ESA and JAXA mission BepiColumbo successfully performed its sixth Mercury flyby on 8 January 2025, with a close approach altitude of 295 km. Mercury orbit insertion is planned in 2026.
- The commercial Hakuto-R mission (ispace) launched on a rideshare with the commercial Blue Ghost Mission 1 (Firefly Aerospace) on 15 January. Hakuto-R successfully completed a lunar flyby on 15 February that inserted the spacecraft onto a low-energy transfer to lunar orbit. Employing solar gravity to raise perigee, Hakuto-R achieved lunar orbit on 6 May. The attempted lunar landing resulted in impact on 5 June.
- After launching with Hakuto-R, Blue Ghost Mission 1 performed a 25-day set of Earth phasing orbits, followed by a 4-day direct transit to lunar orbit. After 16 days in lunar orbit, Blue Ghost successfully landed on 2 March and completed a 14-day lunar mission.
- The commercial IM-2 Mission (Intuitive Machines) launched on 27 February and performed a direct transit to the Moon, successfully entering lunar orbit on 3 March. Its landing on 6 March resulted in an incorrect attitude on the Moon.
- ESA's Solar Orbiter performed its fourth Venus gravity assist on 18 February, increasing inclination from 7.7° to 17°. The spacecraft will perform its fifth Venus gravity assist on 24 December, further increasing inclination to 24°. The inclination increases are designed to enable views of the Sun's polar regions.
- NASA's Europa Clipper launched on the opening

day of IAC-2024 on 14 October 2024. It successfully performed a Mars flyby on 1 March 2025, setting up a future Earth gravity assist to aid in reaching Europa in 2030.

- ESA's HERA mission successfully performed a Mars flyby on 12 March, including a 300 km altitude flyby of Deimos, setting up its arrival at the asteroid Didymos scheduled in December 2026.
- NASA's Lucy spacecraft performed a flyby of asteroid 52246 Donaldjohanson on 20 April at an altitude of 922 km, the second of eight planned asteroid flybys during its twelve-year primary mission.
- NASA's Parker Solar Probe completed its 23rd, 24th, and 25th perihelion passages on 22 March, 19 June, and 15 September respectively, reaching a speed of 191 km/s relative to the Sun at an altitude of 6.1 million km. It will perform its 26th perihelion passage on 24 December.
- ESA's Juice mission successfully performed a gravity assist at Venus on 31 August, with a flyby altitude of 5088 km. The Juice spacecraft will perform a pair of Earth flybys in 2026 and 2029, arriving at Jupiter in 2029.
- In future plans, the Emirates Mission to the Asteroid Belt (EMA) will launch in 2028 and perform a Venus gravity assist to set up a flyby of 7 asteroids in the main belt using electric propulsion. A lander will be released from the spacecraft to impact Justitia, the last asteroid of the tour.

Future Outlook

Looking ahead, increased computational capabilities will enhance autonomy of spaceflight operations. In particular, autonomous operations in constellations, including navigation, collision avoidance, and reconfiguration, will be important, and autonomous operations in cislunar space, including navigation and rendezvous/docking will continue to be of interest. The miniaturization of spacecrafts with cubesats and smallsats can lead to lower costs for development and launch of satellites, though often GNC and trajectory design are more, not less, challenging for smaller spacecraft. An increased pace of investigation into AI-aided algorithms for GNC, formation flight, and low-thrust trajectory design and optimization is expected.

Committee activities

The John V. Breakwell Memorial Lecture at IAC25 was delivered by Prof. Josep Masdemont (Universitat Politecnica de Catalunya – Spain) during the Mission Design, Operations & Optimization (1) session of the Astrodynamics Symposium. Prof. Masdemont is a pioneer of libration point orbit dynamics, including the use of invariant manifolds for low-energy trajectory design. The title of his Breakwell Memorial Lecture was "Libration Point Orbits: A Brief Journey Through Fundamental Dynamics and Applications."

Upcoming conferences include the following events:

- Spacecraft Mission Operations SMOPS 2026 to be held in Bangalore India on 8-10 April 2026
- International Symposium on Spaceflight Dynamics (ISSFD) to be held in Toulouse in May/June 2026
- The 2nd IAA Latin America Conference will be held in Salta, Argentina on 1-6 June, 2026.
- The COSPAR conference to be held in Florence, Italy in July 2026 will include a special session (A0.1) on open scientific problems regarding the tropics; Earth observation challenges can be addressed with smallsats. The call for abstracts opens in November 2025.