

IAF ASTRODYNAMICS COMMITTEE

1. Introduction

The IAF Astrodynamics Committee was established more than four decades ago and is currently made up of about 30 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 & control, mission design, optimization and operations, orbital and attitude dynamics.

2. Summary

The trend toward applying artificial intelligence and machine learning techniques in all areas of Astrodynamics is persistent. Innovative paradigms such as reinforcement learning, neuro-fuzzy system and neural networks are frequently applied in new investigations and designs. Trajectory optimization under uncertainty is another highly researched topic. The circular restricted three-body problem is the context of many new developments in orbital dynamics and mission design, operations & optimization.

As far as the applications are concerned, Mars and lunar missions (including transportation and communication hubs in lunar orbit) are in the spotlight, and this reflects also in the growing number of studies in all areas of Astrodynamics in support of the exploration of the Moon and Mars and the construction of infrastructure in lunar orbit. Precise formation flight techniques are being developed for fractionated spacecraft, such as the space gravitational wave telescope B-DECIGO, and in preparation for the realization of a GPS constellation near the Moon. Autonomous optical navigation and trajectory optimization for autonomous asteroid rendezvous for small spacecraft and CubeSats constitute a new trend.

In the area of attitude dynamics, the impact of the fast-developing sector of deep-space missions shows in the

control requirements set by the implementation of large antennas and solar arrays and in the operation of solar sails. As a result, accurate and reliable control of flexible appendages and complex structures is in high demand, and a growing number of studies on the topic are appearing.



The John V. Breakwell Memorial Lecture at IAC-22— Jesús Peláez (Technical University of Madrid - UPM, Madrid, Spain)

Jesús Peláez from the Technical University of Madrid, Madrid, Spain (in the photo) received the Breakwell Award from the International Astronautical Federation for his dedication and outstanding research on Space Dynamics, Tethers and Orbit Propagation. Peláez delivered a keynote speech on Electrodynamics Tethers and Orbit Propagation.

3. Highlights

During this year, Astrodynamics techniques have enhanced a significant number of missions beyond Earth orbit

- The Double Asteroid Redirection Test (DART) has been humanity's first test of planetary defense. Launched in November 2021, the NASA spacecraft intentionally crashed into Dimorphos, the minor-planet moon of the near-Earth asteroid Didymos on September 26, 2022. DART has been the first-ever mission dedicated to investigating and

demonstrating one method of asteroid deflection by changing an asteroid's motion in space through kinetic impact. In a collaborating project, the European Space Agency is developing Hera, a spacecraft that will be launched to Didymos in 2024 and arrive in 2027 to do a detailed reconnaissance and assessment of the object.



- The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) was launched to the Moon on June 28, 2022. CAPSTONE is the first spacecraft to test the Near Rectilinear Halo Orbit (NRHO) around the Moon, the same orbit intended for NASA's Gateway mission, a multi-purpose orbiting platform that will provide support for long-term lunar missions within the Artemis program. The main objectives of CAPSTONE are to verify the orbital stability of a lunar NRHO and demonstrate relative navigation at the Moon. CAPSTONE is scheduled to arrive in the NRHO on November 13, 2022.



- Korea Pathfinder Lunar Orbiter (KPLO also known as Danuri), the first Korean mission to the Moon, was launched in August 2022 on a ballistic lunar transfer to a polar low lunar orbit. Its objectives include the identification of potential landing sites for future lunar missions.
- Launched on December 25, 2021, the NASA/ESA/CSA James Webb Space Telescope successfully entered into a halo orbit around the Earth-Sun L2 Lagrange point on January 24, 2022.
- On September 29, 2022, NASA's JUNO spacecraft performed the closest flyby of Europa since Galileo's passing 22 years ago. The flyby reduced the spacecraft's orbital period and provided detailed photographs of the moon's surface in preparation for the upcoming Europa Clipper mission, scheduled to launch in 2024.
- ESA's and JAXA's BepiColombo Spacecraft is well on its way to Mercury, having performed the second

Mercury fly-by in June 2022 with final arrival planned for late 2025.

- ESA's Solar Orbiter S/C has reduced its perihelion distance to less than 1/3 AU allowing an unprecedented view of our mother star.

4. Future outlook

New missions enabled by state-of-the-art Astrodynamics methods:

- The Artemis 1 mission will carry several CubeSat payloads of interest, including NASA's LunaH-Map and Lunar Ice Cube missions, which will use ion propulsion to achieve Lunar orbit by low-energy trajectory; NASA's NEA Scout mission, which will use solar sail to an asteroid; JAXA's OMOTENASHI mission, which will test landing technologies at the Moon; JAXA's EQUULEUS mission, which will use low-energy-orbit techniques to enter into an orbit around the Earth-Moon L2 Lagrange point.
- Other lunar missions of note include NASA's IM-1 launch of the Commercial Lunar Payload Services (CLPS) lunar lander, which will carry out navigation demonstration technologies; the Russian Space Agency's Luna 25 (lunar lander) mission; NASA's Prime 1 (Polar Resources Ice Mining Experiment-1) and Peregrine Mission 1 lunar landers; JAXA's Smart Lander for Investigating Moon (SLIM) lunar lander.
- Psyche, NASA's first mission designed to study a metal-rich asteroid, will launch in 2023 and will use ion propulsion to reach its namesake asteroid. A secondary payload on the same launch is the twin Janus smallsats which will reach and investigate binary asteroids and their dynamics.
- ESA's JUperiter ICy moons Explorer (JUICE) will launch and begin its interplanetary journey to the Jovian system in 2023.

2022-2023 events:

- The 2nd International Stardust Conference will take place at ESA/ESTEC from 7 to 11 November, 2022, and the focus will be on NEOs and space environment management and space sustainability (<http://www.stardust-network.eu/starcon2/>). Two special collections are associated with this event: one on advanced space technologies for the exploration of asteroids (Nature Scientific Reports, <https://www.nature.com/collections/gdfcdaefb/how-to-submit>), the other on machine learning applications (Celestial Mechanics and Dynamical Astronomy, <https://www.springer.com/journal/10569/updates/23270936>).
- The joint 3rd IAA Latin American Symposium on Small Satellites and the 5th IAA Latin American CubeSat Workshop will take place between 7 and

10 November, 2022 in Brasilia (Brazil) (<https://iaaspace.org/event/joint-3rd-iaa-latin-american-symposium-on-small-satellites-and-5th-iaa-latin-american-cubesat-workshop/>).

- The 2023 COSPAR Symposium on Space Science with Small Satellites will be held in Singapore from 16 to 21 April, 2023 (www.cospar2023.org).
- From 7 to 11 May 2023, Berlin (Germany) will host the 14th IAA Symposium on Small Satellites for Earth Observation (<https://iaaspace.org/event/14th-iaa-symposium-on-small-satellites-for-earth-observation-2023/>).

5. Committee activities

- The Politecnico di Milano (Milan, Italy) has hosted the 11th International Workshop on Satellite Constellations & Formation Flight (IWSCFF, June 7-10, 2022, <https://iwscff-2022.polimi.it/>). The event has gathered experts from 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. The conference covered the following topics:

- new mission concepts and services for users: the SMEs perspective
- nanosats as an opportunity for fractionation and flexibilityground segment tuning for new space paradigms
- future planetary constellations and formation flying
- challenges in proximity navigation and control
- agency perspectives for new technologies: needs and development plans.

The event was a great success with 80 oral technical papers, 35 of which were from students. The registered participants came from 18 universities, 3 research centers, 4 space agencies and 18 companies.

- The honorary Breakwell Lecture will be held during the Astrodynamics Symposium of the 74th International Astronautical Congress (Baku, 2023). The speaker will be announced in the coming months.