2024

IAF SPACE PROPULSION COMMITTEE

Introduction

The Space Propulsion Committee addresses sub-orbital, Earth-to-orbit, and in-space propulsion. All types of propulsion are of interest to the committee: chemical and non-chemical/electric propulsion, but also advanced, unconventional, or air-breathing propulsion. The symposium sessions organized by the committee during the yearly International Astronautical Congress include: liquid systems (2 sessions); solid and hybrid systems (2 sessions); electric propulsion (2 sessions); small satellite propulsion; nuclear propulsion and power systems; propellantless propulsion; air-breathing rocket propulsion; disruptive propulsion systems enabling new/visionary space missions.

The committee deals with component technologies as well as complete propulsion systems and their implementation in missions and spacecraft, but also welcomes discussions on dedicated test facilities and diagnostics for space propulsion testing. Special attention is given to New Space developments, including miniaturized propulsion systems for small spacecraft/launchers, or how combined technologies, such as chemical and electric propulsion, can be optimized for extending the range of feasible space missions.

Summary - Space Propulsion Highlights

In the **United States**, SpaceX has achieved impressive results in the flight test campaign of the Super Heavy Booster for the Starship program. The rocket, powered in its first stage by 33 **Raptor engines** (LOX-Methane, full-flow staged combustion cycle) for a maximum nominal thrust of 69.9 MN, and by 6 additional Raptor engines on the Starship spacecraft (second stage), has undergone three successful launches in 2024, after the initial partial failures of the 2023 launches. Meanwhile, the U.S. Space Force has granted a contract to a national research team led by the University of Michigan to advance space propulsion systems, aiming to combine high-thrust chemical propulsion with advanced electric propulsion, such as high-power Hall thruster powered by a nuclear microreactor.

Another very active country for propulsion in Latin America is **Brazil**, also thanks to the activities connected to the **Alcantara Launch Center**, which has recently been opened to commercial activities and will host the first orbital launch ever from Brazilian soil next year, with the planned maiden launch of the HANBIT-nano hybrid rocket from the company Innospace (South Korea). R&D activities on chemical propulsion are carried out in Brazil at the University of Brasilia and DCTA (liquid, hybrid and ramjet engines), and at INPE (injectors and hybrid thrusters).

Starship launch in October 2024

In **Europe**, the Ariane 6 inaugural flight took place in July 2024 from the European Space Port in French Guiana, in the A62 configuration. With Ariane 6 now flying, Europe has closed the gap for access to space. The flight allowed for significant achievements in propulsion, such as: the first successful operation of two **P120C boosters** (4500 kN thrust) in lateral position around the liquid core stage; the first flight of the **Vulcain 2.1 engine** (LOX/LH2, 1370 kN thrust), derived from the Vulcain 2 heritage in Ariane 5; the first flight of the new **Vinci upper stage engine** (LOX/

LH2, 180 kN thrust, expander cycle). The first flight of the A64 version, equipped with four P120C boosters, is expected in 2025. The Ariane 6 Block2 with enlarged payload capability, coming from the P160 booster (10% more propellant than P120C) and Vinci thrust increased to 200 kN, will be introduced in 2026.

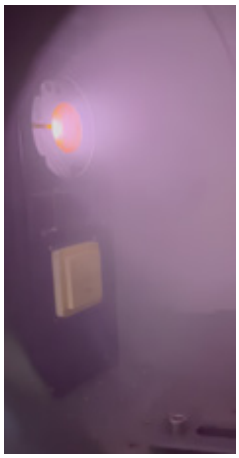
At the DLR Institute of Space Propulsion in Lampoldshausen, within the project **LUMEN** (Liquid Upper Stage Demonstrator Engine), a 25 kN breadboard engine running on liquid oxygen and liquid methane in an expander-bleed cycle is being developed, with a successful first hot fire test campaign in March 2024. LUMEN is the first turbopump-driven engine developed and tested in Germany in the last 50 years. The engine is designed to meet the specific needs of industrial customers and is now fully operational and ready to accelerate future space propulsion innovations.

Ariane 6 FM1 lift-off

In **Asia**, after a first failed attempt in 2023, three successful launches of the new Japanese rocket launcher H3 took place in 2024, in its H3-22S version. This version of the launcher features a new first stage including two **LE-9 engines** (LOX-LH2, 150-ton class), in parallel with two **SRB-3 boosters** (2.1 MN thrust).

Ariane 6 FM1 lift-off

In the field of **Electric Propulsion**, Advanced Propulsion Systems (Russia) completed the development of its electrodeless plasma thruster with magnetic thrust-vectoring **(MTVEPT)**, launched for an extensive flight campaign onboard the HORS 3 satellite in November 2024. This thruster is capable of generating propulsive forces in three directions by means of magnetic steering, and is a direct follow-up to the successfully completed flight test campaign of the Bi-directional Electrodeless Plasma Thruster (BDEPT) on the HORS 1 satellite. Ongoing developments include a thruster with a close-ring-shaped gas discharge chamber capable of generating propulsive forces in six directions, expected to be demonstrated on the HORS 5 satellite in 2025. Brazil is another very active country in electric propulsion, with ongoing activities at the Federal University of Santa Catarina (numerical modelling of plasmas with a special focus on the Discrete Unified Gas Kinetic Scheme, DUGKS, as an alternative to PIC for the development of new systems), at INPE (development and testing of new Pulsed Plasma Thruster concepts, such as the two-stage PPT, TS-PPT, and the Variable Specific Impulse PPT, VSI-PPT), and at the University of Brasília (experimental and numerical investigation of Hall-Effect thrusters using permanent magnets, Helicon-based Ambipolar thrusters, Pulsed Plasma Thrusters, Resistojets, Arcjets and Hollow Cathodes).



MTVEPT operation during integration phase into HORS 3

Space Propulsion Highlights from the IAC 2024 and Future Outlook

The **IAC 2024** congress in Milan (Italy) has been an unprecedented success, breaking all records in terms of participants and submitted abstracts. The main highlights from the Space Propulsion symposium of the IAC 2024 include:

» For **chemical propulsion**, Beihang University (China) presented the test results of a novel hydrogen peroxide electric pump for hybrid rocket engines, while the University of Naples Federico II (Italy) presented a number of numerical and experimental activities on innovative technologies for small-scale chemical propulsion for Cubesats, intended for future development and qualification of micro-

propulsion units within the framework of the ALCOR program coordinated by the Italian Space Agency and, in particular, in the RODiO mission, a formation-flying cluster of Earth-observation Cubesats capable of orbital manoeuvring.

» For **electric propulsion**, while conventional tech-nologies are used as a basis for the develop-ment of a new type of propulsion systems (such as the Hall Effect thruster with high-frequency electric field, presented by the University of Tokyo, the HT100 thruster successfully tested in a flight campaign by Sitael SpA, or the microwave thruster designed by DLR for use with different propellants), significant attention is also given to the development of unconventional systems, including: the gridded ion thruster prototype with corona discharge propellant ionization developed by students of the University of Alabama in Huntsville (US); the solar-powered electric propulsion system for an asteroid hopping mission, presented by the Technology Innovation Institute (UAE); the pulsed cathodic arc thruster, pre-qualified for flight by NeumannSpace (Australia).

» For **micro-propulsion**, a boom in flight testing is being experienced, providing valuable insights for the next development of new systems and encompassing the pathways of these developments. Some of the activities presented at the conference include: the work on electrospray thrusters from FOTEC (Austria), which reported the performance characterization of their ECLIPSE thruster, and from the MIT (US), which reported a study on the effects of micro-electrospray thruster operation on the electrical charging of a small satellite structure; an update on the micro-propulsion system based on Hall effect thrusters, under development at Berlin Space (Germany); an overview of the development process and experimental characterization of a multidirectional resistojet propulsion system for CubeSats, from Khalifa University (UAE); an overview on the cold gas propulsion system with thrust-vectoring capability for small satellites attitude control, under development at the Philippines Space Agency.

» For **space nuclear propulsion**, University of Alabama in Huntsville (US) presented a study on the Centrifugal Nuclear Thermal Rocket (CNTR), outlining strategies for developing a reference configuration and addressing the challenge of uranium vapour contaminating the propellant exhaust. If successfully implemented, with hydrogen as propellant, the CNTR propulsion system could achieve a specific impulse as high as 1800 s, enabling faster round-trip human missions to Mars. The CNRS (France) presented a detailed framework for designing Nuclear Electric Propulsion systems based on use cases proposed by the European Space Agency, aiming to meet requirements for medium- and long-term missions to Earth, Moon, and Mars orbits, as well as deep space exploration. The study evaluated the Heat Pipe Reactor for low-power applications and the Molten Salt Reactor for medium- to high-power scenarios.

Promising Achievements for Future Outlook

In November 2024, the world's first successful test of an **additively manufactured hydrogen peroxide/kerosene aerospike engine** has been performed by a team including TU Dresden, Łukasiewicz-ILOT, Fraunhofer IWS and ArianeGroup, within the ESA-funded project ASPIRER. The engine, designed for an operating pressure of 20 bar and a full-load thrust of 6 kN, has been demonstrated with multiple successful tests in both mono-propellant and bi-propellant modes.

In the field of **hybrid engines**, the ELS-R100 re-entry technology demonstration mission from Low Earth Orbit has been announced by Tohoku University, ElevationSpace Inc. and JAXA, and is scheduled for flight in 2026. The mission will employ a hybrid thruster for orbit transfer, based on a gaseous oxidizer and a multi-port solid fuel, which has demonstrated a significant number of stable firing tests during 2024, including vacuum firings. In July 2024 the Polish ILR-33 AMBER 2K suborbital rocket, using a main hybrid propulsion stage, was successfully launched from Andoya Space Center by **Łukasiewicz-Institute of Aviation**. It reached 101 km of altitude, demonstrating the capability of effective use of 98% hydrogen peroxide as oxidizer for space applications.

In the always dynamic field of **micro-launchers**, a particularly important achievement has been obtained by **HyImpulse**, a German company which successfully launched its SR75 rocket from the Koonibba Test Range in Southern Australia in May 2024, marking a significant milestone as the first privately developed commercial launch vehicle to achieve lift-off in Germany. The rocket is equipped with an innovative hybrid propulsion system using paraffin and liquid oxygen, and can carry payloads of up to 200 kilograms to an altitude of approximately 200 kilometers.

In November 2024, the Australian launch vehicle company **Gilmour Space** secured its orbital launch license. Its three-stage Eris vehicle uses hybrid rocket motors in its two first stages and is under preparation for its maiden flight.

At the DLR Institute of Space Propulsion in Lampoldshausen, a team of researchers in the Combustion Dynamics Group of the Rocket Propulsion Technology Department has successfully operated a **rotating detonation rocket combustor** for the first time in Germany. The small-scale, capacitively cooled, annular copper alloy combustion chamber, developed in cooperation with ONERA, has an outer diameter of 68 mm and runs on oxygen/hydrogen or oxygen/methane.

Another Rotating Detonation Engine project is undergoing in Japan, led by Nagoya University and JAXA. Within this project, a successful flight demonstration in space of a liquid propellant detonation engine has been conducted during the S-520-34 sounding rocket experiment in November 2024.

Committee Activities

The committee is currently made of 50 members from 16 countries, including 8 female members and 12 young professionals, with good distribution among geographical areas and categories (industry, Academia, agencies). In 2024, several new members have been welcomed in the committee: Masaki Adachi (Mitsubishi Heavy Industries, Japan), Lahib Balika (Thales Alenia Space, UK), Paolo Gessini (Brazilian Space Agency), Stefan Gregucci (Sitael, Italy), Justin Hardi (DLR, Germany), Stefano Mungiguerra (University of Naples Federico II, Italy).

The committee is not only active in the organization of the International Astronautical Congress, but also fosters synergies with other relevant space propulsion conferences, such as the EUCASS (European Conference for Aeronautical and Space Sciences) and the biennial 3AF/ESA Space Propulsion conference. The committee members are also active in knowledge dissemination to the space propulsion scientific community through the publication of papers and books.