November 2021

IAF SPACE PROPULSION TECHNICAL COMMITTEE

1. 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; air-breathing rocket propulsion; innovative 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 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.

2. Summary - Space Propulsion Highlights in 2021

In the **United States**, SpaceX is continuing the development of its Starship launch system, powered by a cluster of **Raptor** engines (LOX-methane, full-flow staged combustion, 2 MN thrust). In May, a Starship prototype powered by three Raptor engines achieved an apogee altitude of 10 km and successfully performed a rocket-powered landing maneuver.

Other US large rocket engines under development include Blue Origin's **BE-4** engine (LOX-methane, 2.4 MN thrust) for the Vulcan and New Glenn launch vehicles, and Aerojet Rocketdyne's RS-25 (upgrade of the Space Shuttle Main Engine) for the Space Launch System program.

Raptor engine (court. Wikipedia)

In **Europe**, the development of the **Vulcain 2.1** engine for the first stage of the Ariane 6 launcher is being completed (LOX-LH2, gas generator, 1.3 MN thrust), in parallel with the upper-stage **Vinci** engine and the P120C solid rocket boosters (one-piece, composite case, 4 MN thrust).

Test of the Vulcain 2.1 engine (court. ESA)

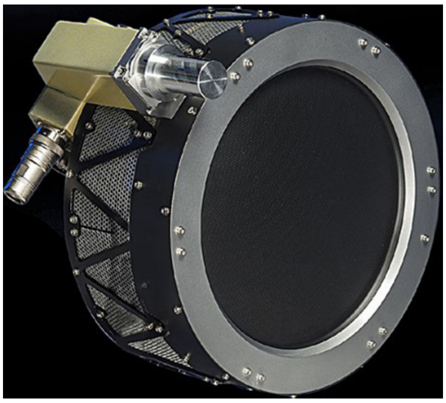
In the meanwhile, the 3 stage-solid rocket motors and liquid upper module launcher **Vega** has successfully completed its 20th launch, confirming its versatility for the launch of small orbital payloads.

In **Asia**, China has successfully started the manufacturing and component-level hot fire testing of a **5 MN-thrust class LOX/kerosene rocket engine** for a future heavy-lift launch vehicle, intended for deep space exploration and manned landing on the Moon. The engine is based on an oxidizer-rich staged combustion cycle system and after-pump gimbal configuration.

Japan is preparing for the maiden flight of its new H3 launch vehicle, based on the **LE-9** engine (LOX-LH2, expander bleed cycle, 1.4 MN thrust) and the **LE-5B-3** engine (LOX-LH2, new and updated version in the LE-5 family of upper-stage engines).

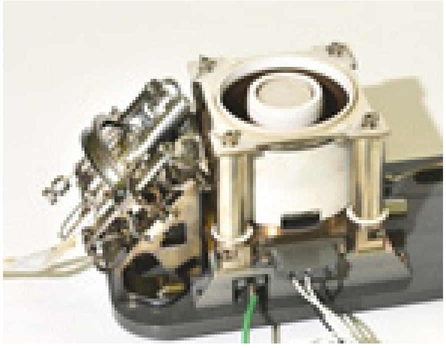
In the **Electric Propulsion** scenario, Maxar Technologies and Busek Co. have successfully completed in March an end-to-end hot fire test campaign for their 6 kW system **SEP** (Solar Electric Propulsion), featuring four Busek's **BHT-600** Hall Effect thrusters using Xenon propellant. The final goal is to develop a 50 kW electric propulsion system for the Power and Propulsion Element of the NASA Gateway, which will be the most powerful electric propulsion system ever flown in space.

Ariane Group is continuing the development of its RIT-2X series of radiofrequency ion thrusters (Xenon propellant, thrust ranging from 80 to 205 mN), intended to be used on the Earth Return Orbiter of the Mars Sample Return Program.



RIT-2X thruster (court. Ariane Group)

In 2021, using a RAFAEL developed propulsion system comprising two **IHET-300** thrusters, the Venµs satellite, a joint CNES-ISA mission, successfully completed a significant orbit transfer from 720 to 410 km, and is currently maneuvering back to a new 560 km orbit.



IHET-300 thruster (court. Rafael)

The **micro-propulsion** scenario has been very dynamic this year, with a number of innovative systems under development to meet the needs of ambitious deep space small satellite missions. Examples are: the 8-thrusters high performance mono-propellant system for the NASA CAPSTONE CubeSat and the 4-thrusters green mono-propellant for the NASA Lunar Flashlight CubeSat; the miniaturized ion thruster for the ESA M-ARGO CubeSat; and the AQUARIUS water micro-resistojet for the JAXA EQUULEUS CubeSat.

3. Future Outlook

This year, one of the most active rocket launcher sectors has been in the field of **micro-launchers**, with a multitude of start-ups and other companies currently developing their own launcher to address the 100-1000 kg payload market. The development and qualification of new, low-cost, reliable rocket engines in the 100 kN-thrust class or below will be crucial for the success of this category of micro-launchers.

Another very promising and fast developing sector for rocket propulsion is **Additive Layer Manufacturing**, a technology with enormous potential in terms of simplification and reduction of lead times. As an example, the team at NASA Marshall Space Flight Center has recently demonstrated a 90-days manufacturing cycle for a 5 ft diameter, 6 ft height metallic nozzle with fully integral cooling channels.

Significant developments are expected in the short-term for **air-breathing rocket engines**, where the recent successes of Reaction Engines Limited in the validation of the precooler technology for their SABRE engine are particularly remarkable. Several research groups are currently working at the development of engines based on **aerospike nozzles**, for which a significant milestone has recently been achieved by Pangea Aerospace, with the demonstration in a 2.5 min hot fire test of a 20 kN regeneratively cooled engine.

Finally, the continuous **Rotating Detonation Engine** is a concept that is receiving great attention in recent years, with a number of numerical and experimental activities that have allowed to greatly improve our understanding of the detonation process and its mechanisms. As an example, Nagoya University (Japan) and their team have successfully completed in August the world-first flight demonstration of a Rotating Detonation Engine.

4. Committee Activities

The new committee management structure (chair and vice chairs) for the period 2022-24 has been defined through elections involving all committee members. The new chairperson will be Angelo Cervone (Delft University of Technology, the Netherlands), supported by three vice chairs: Christophe Bonhomme (CNES, France), Elena Toson (T4I – Technology for Propulsion and Innovation, Italy), Riheng Zheng (China Aerospace Science and Industry Corporation).

The committee is currently made of 47 members, with good distribution among geographical areas and categories (industry, Academia, agencies). One of the main committee's goals for the period 2022-24 will be to significantly increase the percentage of female members (currently 8) and young professionals (currently 6). Another goal is to renew the committee area on the IAF website, including continuously updated information on the committee activities and on the recent developments in the field of space propulsion.

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.