Summer 2022

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 the United States, NASA has performed in April 2022 the first “wet dress rehearsal” of the Space Launch System for the Artemis I mission, which is currently planned for launch not earlier than August 2022. The rocket is powered by four RS-25D engines (LOX-LH2) and two solid rocket boosters, both adapted from the Space Shuttle propulsion system, plus a single RL10B-2 engine for the cryogenic upper stage (LOX-LH2), adapted from the Delta Cryogenic Second Stage used in the Delta III and Delta IV rockets.

RS-25 engine (court. Wikipedia)

In **Europe**, we expect to see in 2022 the maiden flights of the **Ariane 6** and **Vega-C** launchers. Ariane 6 is based on the Vulcain 2.1 engine for the first stage (LOX-LH2, gas generator, 1.3 MN thrust), the P120C solid rocket boosters (one-piece, composite case, 4 MN thrust), and the upper-stage Vinci engine. In preparation to the maiden flight, the upper-stage engine will undergo its firing tests in the P5.2 test bench in DLR Lampoldshausen, and the Lower Liquid Propulsion Module will be hot-fire tested during the combined tests in the Europe Space Port in Kourou. Meanwhile, Ariane Group has been notified by ESA to engage in the development of the ASTRIS kick stage of Ariane 6, based on the **BERTA** engine.

Vega-C will rely on the **P120-C** too for its new first stage, and on one **Zefiro 40** solid rocket motor for the second stage. In the meanwhile the **M10** engine (LOX-LCH4, 98 kN thrust), intended for the Vega-E upper stage, has successfully completed its first hot-firing test run. The **Prometheus** engine (LOX-LCH4, 980 kN thrust) will undergo its first firing test in June 2022 in Vernon.

In *Asia*, Japan is actively 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).

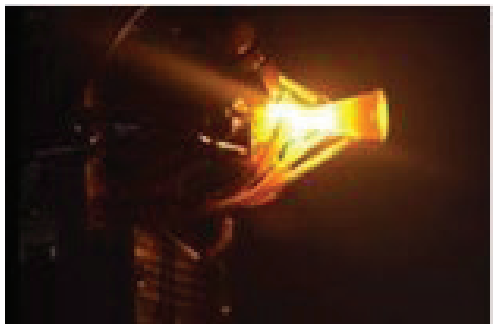
South Korea will make on June 15 a second attempt to lift off the Nuri space launcher rocket, after solving the technical issues that caused the failure of the previous flight attempt. In this launch, Nuri will carry a 200 kg satellite and a 1.3 ton dummy payload. The first stage of this launcher is powered by four **KRE-075** SL engines (LOX-Kerosene, 2.9 MN thrust), with the vacuum version of the same engine being used for the upper stage.

Test of the 500-ton Chinese solid rocket motor

China launched in March 2022 its first **Long March 6A** rocket with 4 solid boosters and two **YF-100** LOX-kerosene engines on the first stage, successfully sending two satellites into sun-synchronous orbits. Two tests of a 25-ton thrust expander cycle LOX-LH2 engine have been successfully conducted in December 2021, confirming its viability for the next-generation super-heavy-lift Long March 9. In October 2021, a 500-ton thrust solid motor has been successfully tested, marking a significant advance for China's space programme ambitions, such as manned Moon landings and deep space exploration. The technologies tested on the 500-ton motor are also expected to be applied on a larger 1000-ton motor.

In the **Electric Propulsion** scenario, the qualification programme of the RIT-2X Gridded Ion Thruster from ArianeGroup is continuing w.r.t. the MSR-ERO spacecraft (Mars Sample Return – Earth Return Orbiter). The main achievement in first quarter 2022 has been the performance characterization of the thruster in the complete operational domain. In parallel to this scientific exploration mission, the RIT-2X is currently also being adapted for commercial GEO satellites missions.

The **micro-propulsion** scenario continues to be very active and dynamic. Some examples: Aurora Propulsion Technologies (Finland) has recently launched their first satellite, AuroraSat-1, mainly intended for in-orbit demonstration technologies including a reaction control system based on water resistojets; Dawn Aerospace (Netherlands) has launched to space, during the whole year, a total of 14 units of their bi-propellant micro-propulsion system based on green propellants; ThrustMe (France) has been the first company to demonstrate in space an ion micro-thruster based on iodine, the NPT30-I2.



Firing test of the water electrolysis propulsion system (court. ArianeGroup)

In the green micro-propulsion domain, ArianeGroup has successfully tested a propulsive system based on water propellant including a tank, an electrolyzer, hydrogen and oxygen gaseous storage tanks and a stoichiometric thruster.

3. Future Outlook

The **micro-launchers** sector continues to offer very exciting developments in the field of low-cost, reliable rocket engines in the 100 kN-thrust class or below. RFA (Germany) has fully assembled their 100 kN staged combustion engine (LOX-Kerosene), which will soon be tested in long duration hot fire tests. ISAR Aerospace (Germany) is continuing the development of their Aquila engine, intended for use in the Spectrum micro-launcher.

In the field of **Additive Layer Manufacturing** (ALM), the impressive development work conducted at NASA Marshall Space Flight Center has led to the production of several additively manufactured components that are now part of the Space Launch System for Artemis I, including a POGO accumulator and Z-baffle. In Europe, ArianeGroup has successfully brought to flight on the Ariane 5 launcher some additively manufactured liquid propulsion components, including cardan cross and check valves. They also qualified some ALM critical items to be used on the Ariane 6, such as gas generator injection elements and a rotating impeller. The next generation liquid rocket engine currently under development, Prometheus, will consist of more than 70% ALM parts.

In the field of **Hybrid Rocket Propulsion**, international players are competing regarding the first use of hybrid technology to launch payloads to orbit. Gilmour Aerospace (Australia) demonstrated a 75-seconds firing of their 110 kN motor using LOX as oxidizer, with first orbital launch planned in the second half of 2022. HyImpulse (Germany) is planning to demonstrate their LOX-based hybrid motor on the SR75 suborbital vehicle in Q3 2022. INNOSPACE (South Korea) has planned the maiden suborbital flight of their LOX-based motor in December 2022 from Brazil. The suborbital launch of Hapith I of TiSpace (Taiwan) has been delayed, after some first attempts at the Australian Whalers Way Orbital Launch Complex in late 2021. This suborbital vehicle is based on nitrous oxide as oxidizer, while a mixture of nitrous oxide and gaseous oxygen is expected to be used in the orbital version. SpaceShipTwo, after its first fully-crewed flight using hybrid propulsion (approx. 2 MNs total impulse), has become the only vehicle that in recent years has demonstrated in-flight utilization of hybrid rocket motors. Two suborbital hybrid rockets from Poland have been successfully ground-tested with continuous burns of more than 40 seconds: the ILR-33 AMBER 2K (using 98% HTP) and the PERUN (using nitrous oxide). Finally, DeltaV (Turkey) has declared a hybrid propulsion flight demonstration on the suborbital SORS rocket in 2021 and a successful 50-seconds firing of the hybrid motor expected to be used in the country's first Moon mission in 2023.

Concerning **Air-breathing Rocket Propulsion**, development on the Synergetic Air-Breathing Rocket Engine (SABRE) continues by Reaction Engines (UK). Following the successful ground testing of the air precooler technology at Mach 5 Design point conditions, the current progress is focused on updating the overall engine cycle design and optimisation. Several R&D programmes are ongoing to mature the critical sub-systems, materials and manufacturing processes of the engine, and to explore the impact and sensitivity of launch vehicle operational capability and cost to key engine design parameters.

Nagoya University (Japan) has released more details on the first in-flight demonstrations of a continuous **Rotating Detonation Engine** (RDE) and a **Pulse Detonation Engine** (PDE), successfully completed in August 2021. Both concepts, working with methane as fuel and oxygen as oxidizer, were launched atop of a solid propellant S-520 suborbital rocket and were nominally operated in space: the RDE for 6 seconds at 500 N thrust, the PDE for 2 seconds x 3 times. A similar demonstration of a RDE was performed by the LRN Institute of Aviation (Poland), which successfully launched in September 2021 a small experimental rocket powered only by a liquid-fueled RDE. The small demonstrator used a regeneratively cooled engine based on liquid propellants (nitrous oxide and propane).

4. Committee Activities

The committee is currently made of 48 members, including 8 female members and 8 young professionals, with good distribution among geographical areas and categories (industry, academia and agencies). In the first half of 2022, three new members have been welcomed in the Committee: Vincent Guyon (Safran Aircraft Engines), Adam Okninski (Polish Academy of Sciences), Annafederica Urbano (ISAE Supaero).

The Committee area on the IAF website is currently under renovation/refreshment and will soon include continuously updated information on the committee activities and on the recent developments in the field of space propulsion.

One of our Committee Members, Ozan Kara, has received the prestigious 2022 Young Space Leader award from the IAF. The Committee congratulates Ozan for this great achievement.

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.