Evolution in maximised efficiency engines for space applications: from GIESEPP to GIESEPP MP

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As one of the EU´s major undertakings in electric space propulsion, the GIESEPP project concluded in 2021. GIESEPP-MP uninterruptedly follows it up to reach an almost-ready-to-flight product status.

GIESEPP MP

5kW-Electric Propulsion thruster fires

Starting point

All partners entered the start of the project with sound heritage and, on convening, understood the project's aim to be an incremental but solid development. It is founded on the following major targets:

a) Design solutions for three distinct applications (Figure 2):
   i. low Earth orbit platforms (LEO) with system power at ~ 500W
   ii. geostationary Earth orbit platforms (GEO) with nominal system power at 5kW
   iii. space exploration platforms with nominal system power at 20kW

b) Emphasise high competitivity to address the paradigm change in satellite market to move from single individual solutions to cost and time optimised industrial approaches

c.) Ensure a modular approach to prevent proprietary and single-source dependencies.

For each of the three distinct solutions, the need for two different sets of equipment was anticipated—one for low power for a nominal 500W and one for medium power for a nominal 5000W. The latter was to be aggregated to a redundant system to cover an available 20kW system power. GIESEPP MP uninterruptedly follows it up to reach an almost-ready-to-flight product status (see Figure 1).

Due to its very nature (significant less propellant need but typically slightly higher hardware mass), the gridded ion engine solutions best address the GEO and space exploration missions. Consequently, the perceived solution for LEO does explicitly not address the much-hyped mega-constellations. Still, it does instead target 'higher-value' platforms, typically above 150kg and with a 'more sophisticated mission profile' resulting in what is tracked as a 'higher ΔV'. Further, the LEO solution explicitly covers both xenon and krypton as propellant—the latter is less rare and thus much cheaper than Xe, and it offers an even further increased efficiency (but, of course, at a lower thrust level).

Commonalities

In all three solutions, a differential system approach was kept. The best commonality could be realised on the equipment level with the flow-control unit (FCU) and the electronic pressure regulator (EPR) being substantially equal on all configurations, eventually having minimised throttle discs exchanged to adapt to different pressure and/or mass flow requirements. Further, a sound level of commonality is expected with regard to harness and connectors—even though the more the paradigm between LEO and GEO are dividing, the less it gets relevant. Indeed, while the LEO missions require a deeply cost optimised product, the GEO (Figure 3) and deep space solutions are instead driven by the quest for superior performance and reliability. Nevertheless, at least concerning processes and proceedings, a sound commonality can still be followed.

On the other hand, two areas proved much less suitable to keep up a full commonality between the systems: thruster and power processing. For thrusters, the driving elements are the previously-mentioned paradigms. While the heritage thrusters fitted in well in a high-performance and high-reliability system, it became obvious that a cost minimised setup for LEO requires a very much simplified product design reducing both material and production cost to the detriment of a to-the-limit performance, thus only maintaining the basic product architecture between both worlds.

This got even more relevant when coming to the power processing unit (PPU). During an extensive engineering phase, the team had to convene that even cutting and shrinking the given heritage building blocks would not lead to the necessary mass and volume reduction request per LEO mission. The decision was taken to aim at a completely novel product design, putting low costs and as much minimised mass and volume in primary focus. An interim solution between this new design and the heritage-based GEO was set up to address short-term necessities.

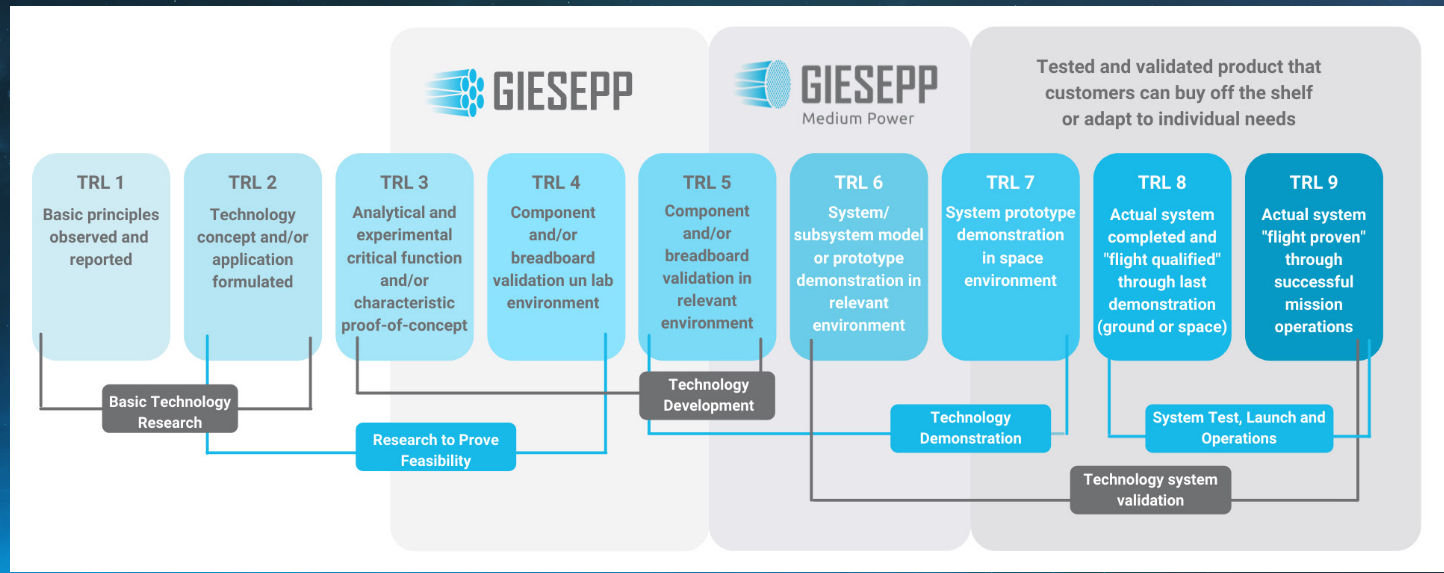

Figure 1: TRL evolution in GIESEPP/GIESEPP MP.

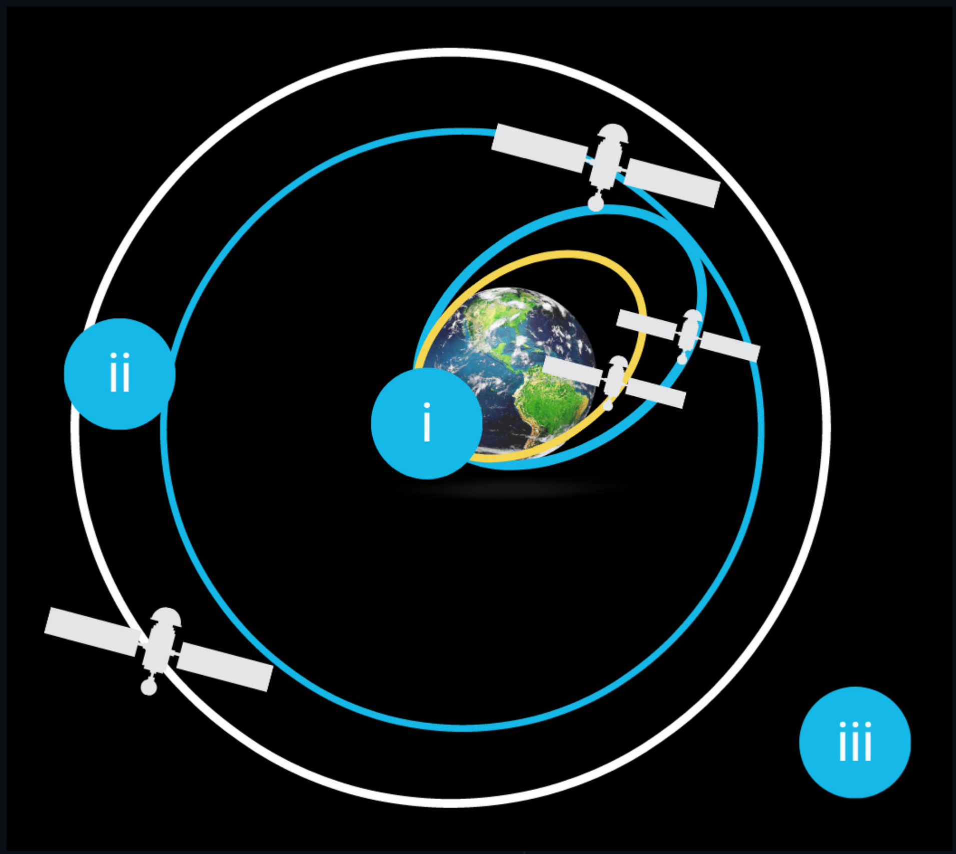

Figure 2: GIESEPP missions for LEO, GEO and deep space.

Achievements

The first phase saw a long and intense effort in defining the complete requirements between all project partners, starting from the basic mission requirements flown down to the system and then equipment requirements. The following design activities passed successful PDRs. The outcome was a complete set of equipment made available for evaluation under test. Indeed, beyond mere equipment level tests, the major target that was sought and reached was to bring all the equipment together for assessment under real-life conditions in a so-called coupled configuration. Within the last two years, four formal coupling tests took place in different coupling configurations for low and medium power solutions (see Figure 4). All partners agreed that a major success was the usually very sensitive equipment couplings proving successful in each of their configurations even though they all had to be orchestrated in a remote setup due to already brought-in COVID restriction. Also, some of the challenging operating points managed to be validated during these trials, while some are still pending revisitation. Overall the intended technology readiness level TRL 5 (technology validated in relevant environment) was well covered even though an interim PPU was used for the LEO system; thus, some follow-on activities have been retained.

Industrialisation

In parallel to the product development activities, first assessments regarding industrialisation have started. All approaches were driven by the satellite business's ongoing paradigm shift from the one-off projects to an industrial-scale product philosophy. An inspiration hereby was Elon Musk´s Tesla (rather than his Starlink, in consequence of the previously-mentioned positioning 'beyond' the mega-constellations): start from high-value and low quantity to less value and higher quantities.

In figures, this means the 5-kW-EPS (electric propulsion system) is conceived for quantities up to 50 / year (which is a tremendous number in the 'traditional' space business). This necessitates a throughput of one system per week and is planned to be delivered in much less than 12 months. For comparison, today, such a system would take two years to produce and would possibly hit less than 10 per year.

Of course, this does not happen overnight. A major hurdle is to overcome 'well founded' convictions of what is needed to produce space products. In the first instance, this is directed to three major streams:

a) re-assess production and integration, in particular with regard to product design, processes and equipment, in-production quality assurance activities;

b) re-think acceptance tests (that create a very substantial part of the current costs) in the context of their absolute necessity, their level of occurrence and their extent; and

c) re-visit the complete supply chain including warehousing whereby a particular challenge is currently given with all electronics (EEE) as those often announce lead times of more than 24 months for space rated variants.

Once this sound baseline is established for GEO, further progression is pushed for the LEO system. In its GIESEPP configuration, this is foreseen to enable an output of up to several hundred per year with a first delivery to come within six months after PO. Depending on the need dynamism, different ramp-up strategies would then be implemented. Those can vary from adding a few workplaces to the existing set up to a completely new production facility with its full infrastructure.

Way forward

With the completion of GIESEPP and a focus on the aforementioned strategy, the follow-up GIESEPP MP is now concentrating on getting the medium power system brought to a flight-ready maturity, notably a TRL 7 – system prototype demonstration in an operational environment.

To get there, the newly composed project team first re-assessed the whole set of requirements to ensure appropriate adjustment to the latest market needs. With this and considering the engineering and test outcomes of phase one, the final system design is currently being elaborated to allow the build of a qualification model (QM) of the complete system. This QM-EPS will then undergo an extensive set of qualification tests backed by substantial modelling and simulation activities in parallel (notably with the establishment of a so-called 'global model'). These actions are planned to take place both in 2022 and 2023, thus allowing a robust, validated solution to be at hand by the end of 2023. By then, the PPU shall have incorporated the last generation technology (in particular GaN-based). Also, the production facilities will experience a consecutive incremental (dozen-wise) ramp-up to ensure full-scale responsiveness to any market request by that time.

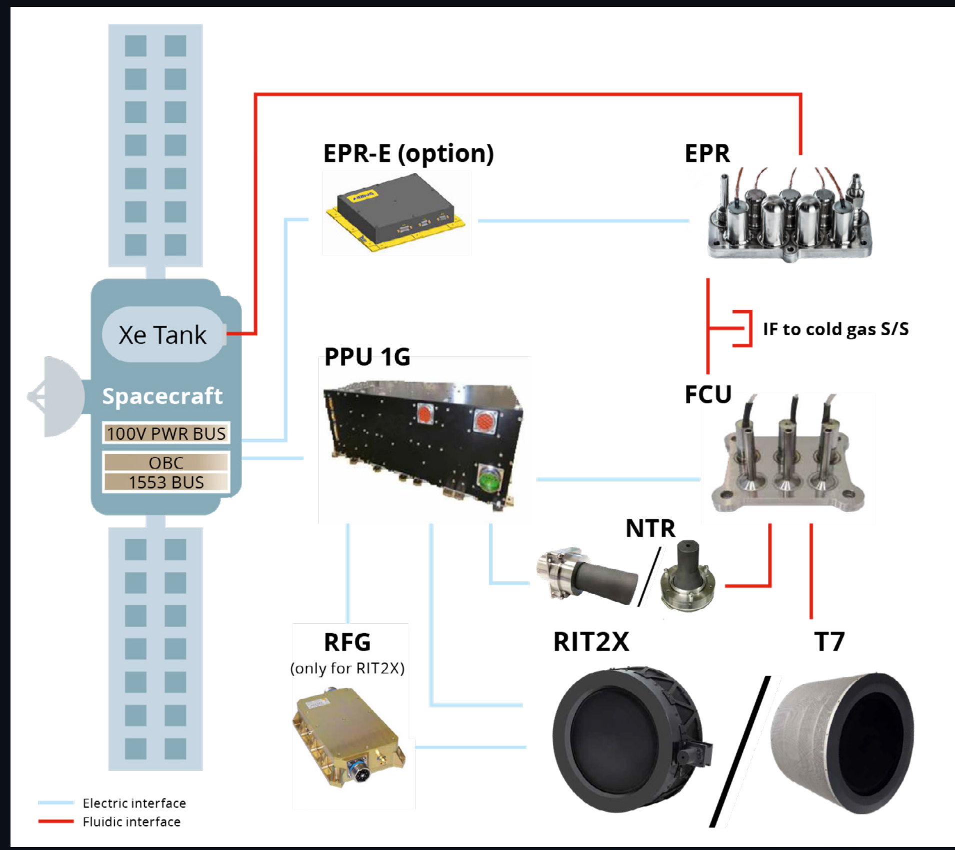

Figure 3: Baseline GIESEPP platform for medium power (1G/GIESEPP MP).

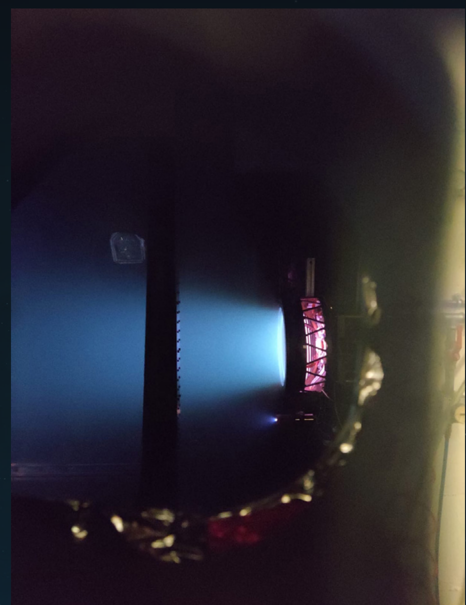

Figure 4: RIT-2X thruster under operation within coupling test.

GIESEPP – highest efficiency in every mission.

GIESEPP
Medium Power

PROJECT SUMMARY

The leading European companies for orbital space propulsion together with satellite integrators and in EP (electric propulsion) specialised companies, universities and research partners have joined efforts to boost the European electric space propulsion capabilities in the field of efficiency optimised gridded ion engine technology.

PROJECT PARTNERS

With ArianeGroup GmbH (D) as project lead, partners are OHB (D), Qinetiq (UK), CRISA (ES), Airbus DS GmbH (D), AST GmbH (D), Mars Space Ltd (UK), University of Southampton (UK) and Sensortechnik Sirnach (CH) in the first phase, while in GIESEPP-MP partners are Airbus Defence and Space SAS (F), CRISA (ES), Aerospazio (IT), Justus-Liebig-University Giessen (D) and WITBerry (LV).

PROJECT LEAD PROFILE

ArianeGroup GmbH, as the project consortium´s coordinator, holds a unique position within the domain of orbital propulsion as the provider in Europe to offer both electric and chemical propulsion solutions, ranging from single thruster or component to full system integration and hot-firing tests under vacuum.

ArianeGroup, a joint-venture between Airbus and Safran, employs ca. 9000 people in France and Germany.

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