HEMPT – New EP Technology for SmallSats and LEO Constellations using Xenon, Krypton and Argon

1th Angelo Genovese
Electric Propulsion
Thales Deutschland
Ulm, Germany
angelo.genovese@thalesgroup.com

2nd Ralf Heidemann
Electric Propulsion
Thales Deutschland
Ulm, Germany
ralf.heidemann@thalesgroup.com

3rd Gabriel Suske
Electric Propulsion
Thales Deutschland
Ulm, Germany
gabriel.suske@thalesgroup.com

4st Heiko Stalzer
Electric Propulsion
Thales Deutschland
Ulm, Germany
heiko.stalzer@thalesgroup.com

5th Alexey Lazurenko
Electric Propulsion
Thales Deutschland
Ulm, Germany
alexey.lazurenko@thalesgroup.com

6th Joachim Daeubler
Electric Propulsion
Thales Deutschland
Ulm, Germany
joachim.daeubler@thalesgroup.com

7th Peter Holtmann
Electric Propulsion
Thales Deutschland
Ulm, Germany
peter.holtmann@thalesgroup.com

8th Guillaume Benner
PLM Space
Thales MIS
Velizy, France
guillaume.benner@thalesgroup.com

***Abstract*— THALES Deutschland develops innovative ion thrusters based on the HEMPT (High-Efficiency Multistage Plasma Thruster) technology. The first fully qualified thruster model, the 1.4kW-class HEMPT-3050, has been integrated on the German geostationary satellite H2Sat, launched in July 2023, and is successfully operating since then with nominal performance. As a further development Thales Germany is qualifying a 700W-class HEMPT thruster, the EV0. Thales Ulm has also started the development of a 1.5kW class thruster, the HEMPT 3050-C, both leveraging Thales in-orbit heritage and design for manufacturing approach. This paper will give an update on the status of the HEMPT product line at Thales, including recent results from development and qualification activities.**

Keywords— Ion, Propulsion, Constellation, Krypton, Argon

I. Introduction

Thales Deutschland, Ulm site, started the development of a new electric propulsion technology, the High Efficiency Multistage Plasma Thruster (HEMPT) at the end of the 90's. After having carried out several basic studies supported by DRL and ESA, Thales has qualified a complete electric propulsion system, the HEMPT thruster assembly (HTA), composed by the 1.4kW HEMPT-3050 ion thruster, its power/processing unit, the xenon gas flow controller, and other minor components. The HTA project was fully commissioned by the DLR's Space Administration.

Two HTA propulsion systems have been integrated on the German geostationary satellite H2Sat, launched in July 2023; both EP systems are performing the NSSK manoeuvres with nominal performance since early 2024 with more than 1000 firing hours already cumulated. This successful in-orbit demonstration is greatly increasing confidence in this innovative EP technology.

The number of satellites utilizing electric propulsion units is dramatically increasing, in particular thanks to the mega-constellations that require an extensive amount of propellant. This results in a strain on the availability of Xenon propellant in the context of a volatile noble gas market. due to its scarcity, associated with high production costs, and recent political influence, the price of Xenon has significantly risen. Utilizing alternative propellants has been recognized as a strategy to reduce the total propellant cost; Krypton is currently the most widely used alternative to Xenon as it is approximately 5 times less expensive. An even larger saving in propellant costs could be realized using Argon as propellant, as it is more than 50 times cheaper than Xenon. This is why SpaceX has decided to use high-power Argon ion thrusters on the Starlink satellites. However, low-power ion thrusters showed very low performance with Argon as of today.

Fig. 1. HTM-EV0

Thales is currently qualifying a new HEMPT model, the 700W-class EV0 thruster for LEO/MEO constellations and small GEO satellites. The HEMPT technology provides great benefits to the SmallSat and LEO constellation market due to its unique ability of using different propellants (Xenon, Krypton, Argon) without any design modification, its long lifetime thanks to a very limited thruster erosion, and its cost-effective design.

Furthermore, the HEMPT-EV0 thruster allows operation up to 700W with anode voltages ranging from 300V to 800V, enabling different operational modes suitable for orbit rising, for NSSK in the final orbit and for the EOL debris disposal.

The thruster can generate up to 33mN with Xenon and 27mN with Krypton in high-thrust mode (300V-700W). It can also be operated at higher voltages in high-Isp mode; it reaches an Isp of more than 2000s with 800V-700W. A recent test with Argon has shown very promising results with anode efficiencies similar to Krypton and significantly higher specific impulses.

Thales Ulm has also started the development of an enlarged version of the EV0 adapted for a higher power range, the HEMPT-3050C. The thruster uses the same module design as the EV0 and the same neutralizer, allowing a reuse of the processes already qualified for the EV0. The target maximal power of the EV0+ is 1.5 kW, with an expected total impulse of 1.5 MNs. This thruster can generate more than 75 mN with Xenon and 65 mN with Krypton in high-thrust mode (300V-1.5 kW). In high-Isp mode, it can reach an Isp of more than 2500 s with 800V-1.5 kW.

This paper will give an update on the HEMPT-EV0 qualification status. Furthermore, the first results with Argon will be reported and compared to the operation with Krypton and Xenon. The paper will include the development status of the high-power HEMPT-3050C thruster.

II. HEMPT-EV0 Qualification Status

A. *Design and performance*

Thales is currently finalizing the qualification of the low-power HEMPT-EV0 thruster module (which includes the new Thales neutralizer HCN-6500, see Fig. 1), suitable for LEO/MEO constellations and Small-GEO satellites [2]. It allows operation up to 700W with anode voltages ranging from 300V to 800V, enabling different operational modes suitable for orbit rising, NSSK in the final orbit and for the EOL debris disposal. The thruster can generate up to 32mN with Xenon and 27mN with Krypton in high-thrust mode (300V/700W). Operated at higher voltages in high-Isp mode, it reaches more than 2000s with 800V/700W.

The HEMPT-EV0 thruster module dissipates heat independently with its radiator, thus enables adiabatic mounting and minimizes thermal requirements towards spacecraft [3]; this relieves the thermal management of a satellite. The thruster comes with integrated harness and connectors that directly plug into the PPU. All these flexibility aspects are today key for mega-constellations driven by the low-cost aspect.

B. *Overview over performed tests*

- Performance and thermal vacuum testing have been completed with Xenon and Krypton.
- Successful mechanical testing on qualification level.
- Several successful coupling tests performed with different PPUs and FCUs.
- Endurance tests performed with both Xenon and Krypton, with very minor performance degradation.
- EMC test: A full electromagnetic compatibility characterization of the Thales HEMP-T Thruster Module was made. The electromagnetic emission from the thruster is characteristic and its spectrum is comparable to that of Hall thrusters

C. *Endurance Test with Xenon*

Thales has performed a Xenon endurance test with a HEMPT-EV0 Breadboard thruster cumulating 2000 firing hours (240 kNs total impulse) with very stable performance, see Fig. 2. The working point was 300V-700W and the average thrust was 32 mN. The thruster is still operational, the test was interrupted due to time schedule issues.

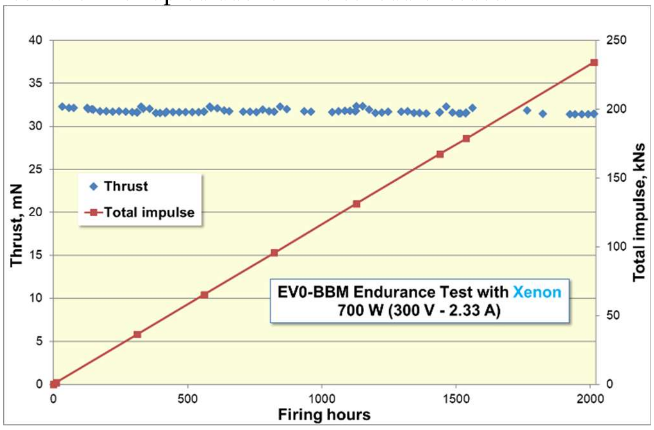

Fig. 2. 2000h endurance test with Xenon

D. *Endurance test with Krypton*

Thales has performed a Krypton endurance test with a HEMPT-EV0 Engineering Model (THR+NTR) cumulating > 4600 firing hours (> 360kNs total impulse) with very stable performance, see Fig. 3. The working point was 600V/700W and the average thrust was 22mN. The thruster module is still operational, the test was interrupted due to availability of test facility.

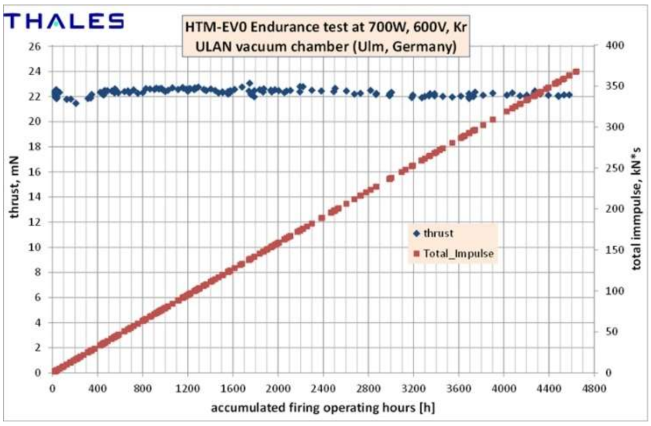

Fig. 3. 4600h endurance test with Krypton

III. HEMPT-EV0 Performance Characterization with Argon

Thales has performed a preliminary characterization with Argon without changing the EV0 thruster design. The test set-up was limited to a maximum Argon flow of 25 sccm, as can be seen in Fig. 5, which shows the measured thrust vs anode voltage for different anode power (from 100W to 700W). A thrust value of more than 20 mN can be expected at 700W for anode voltages lower than 500V.

Fig. 4. HTM-EV0 firing with Xenon, Krypton and Argon

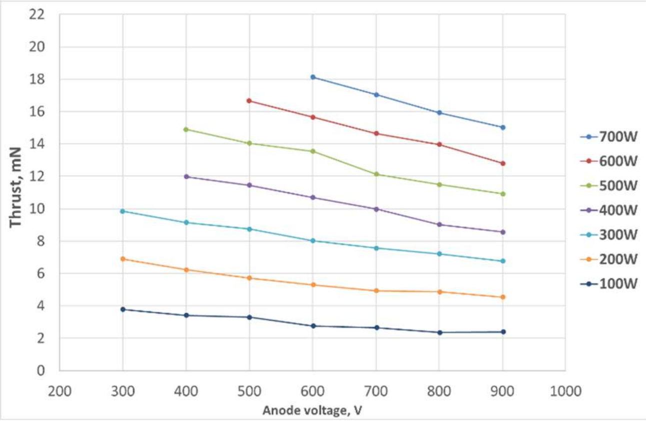

Fig. 5. EV0 thrust vs anode voltage from 100W to 700W

Fig. 6 shows a comparison between Argon and Krypton for the anode specific impulse ISP at 500W; Argon operation shows significantly higher values of ISP at anode voltages lower than 600V.

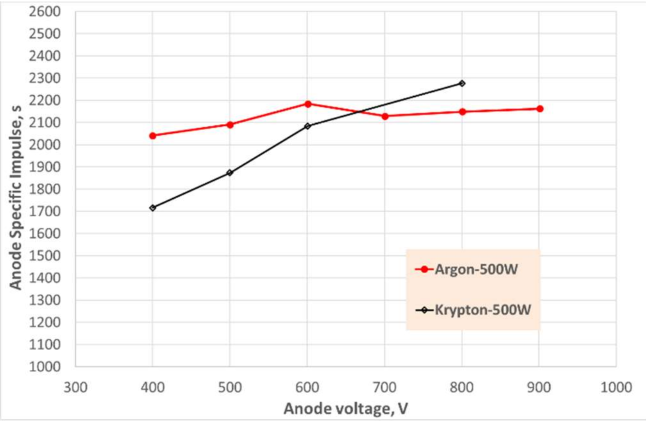

Fig. 6. Comparison between Krypton and Argon: anode specific impulse at 500W

Fig. 7 shows a comparison between Argon and Krypton for the anode efficiency at 500W; Argon operation shows efficiencies higher than 25% at anode voltages lower than 700V. This is a very promising result if compared with the Argon efficiencies for low-power Hall Effect Thrusters reported in the literature, which are well below 20% [4], [5].

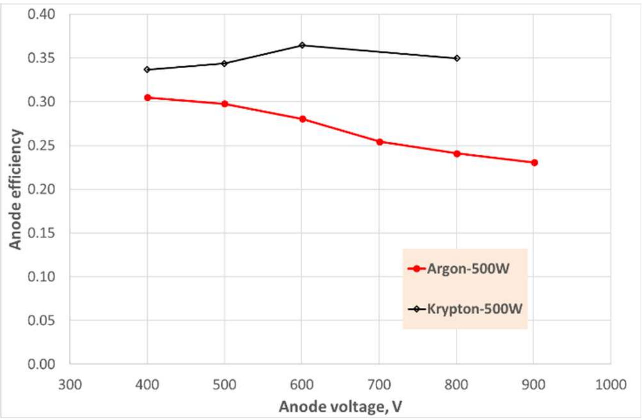

Fig. 7. Comparison between Krypton and Argon: anode efficiency at 500W

IV. Development of 1.5kW class thruster (HEMPT 3050-C)

A. Design

The thruster uses the same module architecture and anode design, and the same neutralizer as the EV0, allowing a reuse of the processes already qualified for the EV0. The thruster beam forming system, including discharge channel, is based on the HEMPT-3050 with the same magnet system and exit. By this, relevant areas for erosion are unchanged from HEMPT 3050 to leverage H2Sat in-orbit and lifetime qualification heritage. The monolithic radiator from the EV0 as central mechanical support structure will be scaled for being able to radiate the excess power into space for the maximum working point, while the fluidic interface is kept from the EV0. The neutralizer NTR6500 with its technology as used for the EV0 is currently under qualification. The heritage of the cathode is based on the 3050 in-orbit verification. Its position has to be optimized on module level. The target maximal power of the 3050-C is 1500W, with an expected thrust of 70mN, specific impulse (ISP) up to 2500s, and a total impulse of 1.5MNs. The main technical parameters are listed in the following. Thales Ulm will be therefore able to provide a robust design which is optimized for high volume manufacturing in an industrial environment with experience over several decades in the production of high technological and reliable space products.

- 700W – 1500W flexible power rating
- Thrust: up to 70mN
- Operating Voltage 400V – 1000V
- ISP: up to 2500s
- Total Impulse target: >1.5MNs
- Estimated mass: 4.0kg
- Dimensions: approx. 300x215x90 mm
- Possibility to mount with zero heat flux to spacecraft
- Designed for high radiation tolerance (option: additional shields for harness for improved radiation tolerance – up to 40 Grad with add on shields)

B. Expected performance

Typical expected thrust and ISP values based on 3050 measurements (BOL) are shown in Fig. 8.

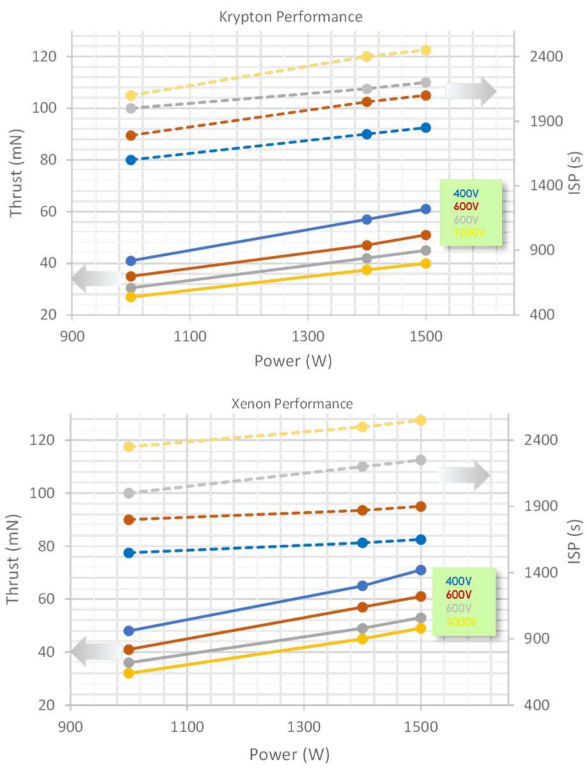

Fig. 8. Expected thrust and ISP values for HEMPT 3050-C

V. SUMMARY

Thales Deutschland, site Ulm, is finalizing the qualification of a new HEMPT thruster model, the 700W-class HEMPT-EV0 thruster module for LEO/MEO constellations and small GEO satellites. Performance, mechanical and thermal vacuum testing have been completed with both Xenon and Krypton. Extensive endurance tests have demonstrated very stable performance over time with both Xenon and Krypton. A recent test with Argon has shown very promising results with anode efficiencies similar to Krypton and significantly higher specific impulses.

Based on the EV0 and the 3050 design, which is nominally operating in orbit since end of 2023 on the technology demonstration satellite H2Sat, Thales is developing a new 1.5kW-class thruster, the HEMPT-3050C. This thruster is targeting near-future constellations with larger mass/power budgets as the new European constellation Iris[2].

The HEMPT technology provides great benefits to the SmallSat and LEO constellation market due to its unique ability of using different propellants (Xenon, Krypton, Argon) without any design modification, its long lifetime thanks to a very limited thruster erosion, and its cost-effective design.

REFERENCES

[1] A. Genovese et. al., “HEMPT – Electric Propulsion for LEO/MEO Constellations”, IAC-24-C4,IPB,7,x89116 in Proceedings of the 75th International Astronautical Congress (IAC), Milan, Italy, 14-18 October 2024

[2] A. Lazurenko et. al., “Qualification Testing of a 700W-class HEMP Thruster EV0”, IEPC-2024-777 in Proceedings of the 38th International Electric Propulsion Conference, Toulouse, France, June 23-28, 2024

[3] R. Heidemann et. al., “Development of low power HEMPT-EV0” paper IEPC-2019-A873 in Proceedings of the 36th International Electric Propulsion Conference , Vienna, Austria, September 15-20, 2019

[4] T.F. Munro-O’Brien et. al., “Performance of a low power Hall effect thruster with several gaseous propellants”, Acta Astronautica 206 (2023) 257-273

[5] V.G. Tirila, A. Demaire, C.N. Ryan, “Review of Alternative Propellants in Hall Thrusters” Acta Astronautica, 2023