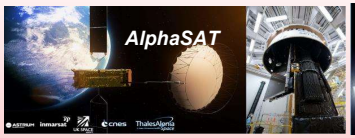
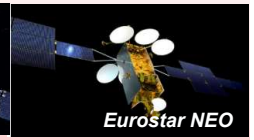
EPIC2 Workshop
Keynote on future EP system & THAG Roadmap

Davina Di Cara & THAG
EPIC Workshop 2023
Naples, Italy
davina.maria.di.cara@esa.int

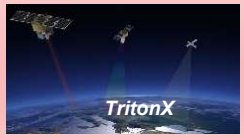
Electric Propulsion: completed & on-going ESA missions

Flight Telecom platforms with EP for SK and EOR

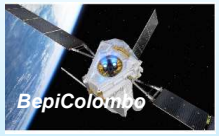




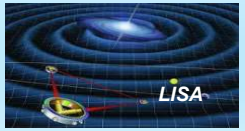
Under development Telecom platforms with EP for SK and EOR



Completed/Ongoing Science & Exploration missions with EP for interplanetary transfers



Ongoing Science & Exploration missions with EP for interplanetary and precise positioning



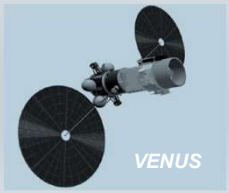
- EP has today reached its **maturation phase** and is increasingly being used for different application.
- Growing inclusion of EP on GEO communication satellites
- EP standards on LEO mega-constellations of small satellites
- Use of EP emerging on satellites for Navigation, Earth Observation, satellites in LEO/VLEO and on science and robotic exploration missions

Completed Earth Observation missions with EP for drag free

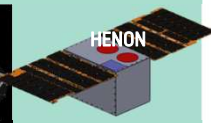
Under development missions with EP for orbit maintenance, drag free..

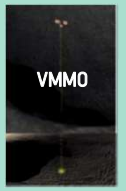
Under development Navigation satellites with EP


Under definition Space Transportation missions with EP



Cubesat missions with EP





ESA Technology Harmonisation: THAG

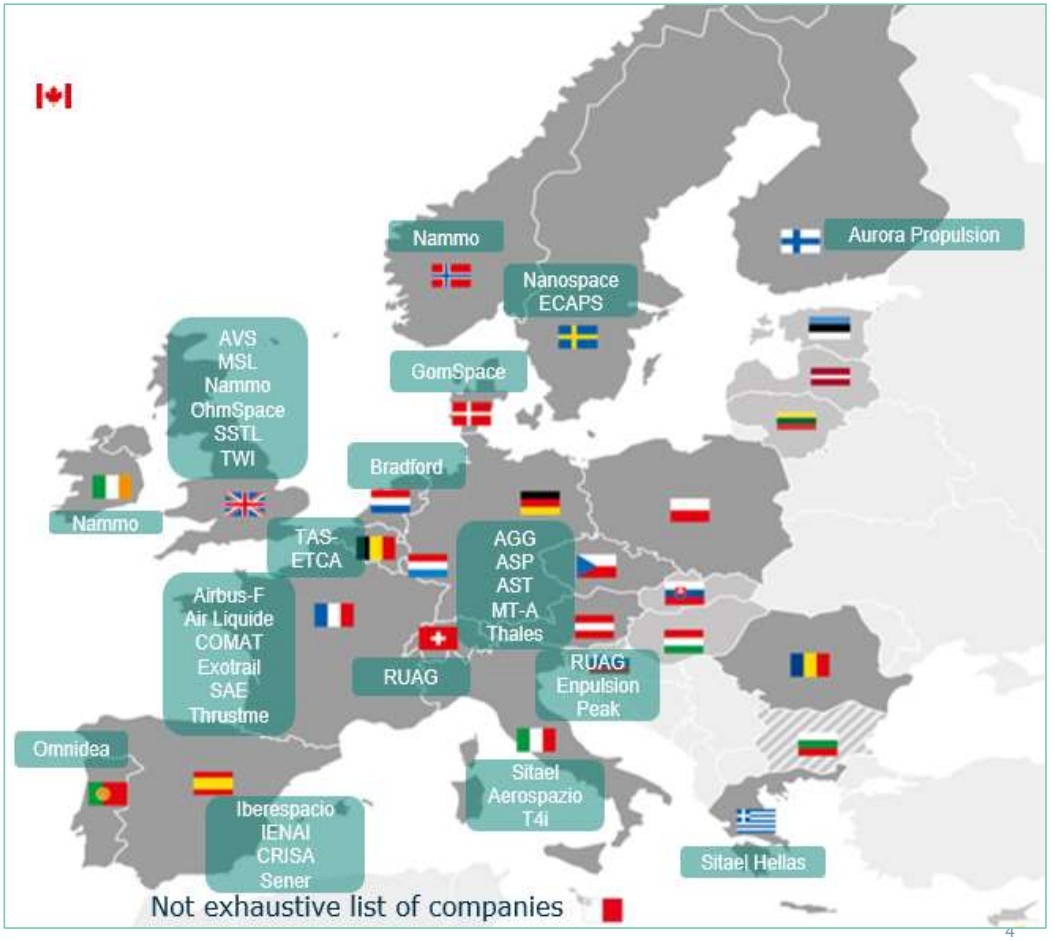
*Eurospace, SME4Space, ESRE, EARTO, etc..

Interested?

- seek involvement through Euroconsult (harmo@euroconsult-ec.com), which has been selected by ESA to support consultation for Harmonisation.
- You may also contact your national delegate (contact names can be found in the ESTMP: send an e-mail to ESTMP@esa.int).
- All European space sector stakeholders can request access to the Harmonisation Document Management System (HDMS/DCCM: https://tec-polaris.esa.int/eclipse) by sending an e-mail to harmo@esa.int providing business affiliation and position in the company.

State of Art of Electric Propulsion in Europe

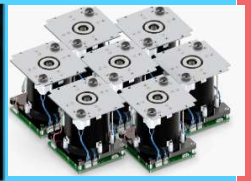
- EP technologies developments **supported by ESA, EC and National Agencies** over the last five decades
- Extensive **heritage** achieved through various missions success
- **Large capability** exist in ESA Member States covering Conventional and NewSpace
- **Good diversification** and **maturity readiness**
- **Established suppliers are well positioned** in worldwide landscape
- Advent of LEO mega-constellations demands new EP systems, offering **opportunities for new entries** (SME, start-up)



State of Art of European EP Technologies

EP Thrusters:



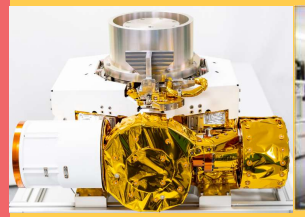
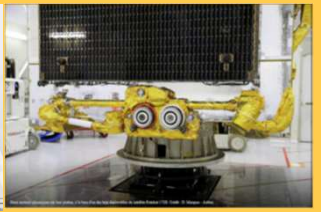


- **Established Suppliers:** Safran (FR) with over 200 PPS®5000 5kW-class HET thrusters ordered, over 70 delivered and 17 in orbit and Enpulsion/FOTEC (AT) with 167 FEEP systems in orbit are leader suppliers followed by AGG (DE) with RIT2X, Thales GmbH (DE) with HEMPTs, Sitael (IT) with various HETs.
- **Several new entries (SME, start-ups):** Exotrail (FR), ThrustME (FR), T4i (IT), URA (UK), COMAT (FR), MSL (UK), Airbus DS (DE), SENER (ES), Ienai (ES), Ion-X (FR), etc.
- Several research centres, academia!

EP PPUs:


- **Established Suppliers with extensive heritage:** Thales Alenia Space (BE) with over 140 PPUs for 1.5-5kW HETs ordered by 8 different customers and over 110 PPU delivered/in-orbit and Airbus DS – CRISA (FR, ES, DE) with over 600 PPUs for 300W HETs in-orbit, over 140 PPUs for 3-5kW HETs ordered and 82 delivered (40 units per year production rate) and 8 PPUs for 5kW GIEs delivered.
- Both working on next gen. PPUs for low-middle power HETs, GIEs and HEMPTs and to respond to market needs (low cost, high efficiency) with cutting edge technologies.
- **Several new entries:** Sitael (IT/GR), Safran (FR), ASP (DE), Beyond Gravity (AT) /Enpulsion (AT), Exotrail (FR), Ienai (ES), Ion-X (FR), etc.

EP Pointing Mechanisms:

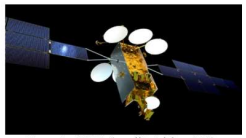

- The data examination shows that today European EPPMs have a definite **performance advantage in the global competition**.
- **Established suppliers:** BGA (AT), ADS (FR), EHP (BE), TAS (UK), MDA (CA)
- **Several new entries:** SENER (ES), AVS (UK), Exotrail (FR).

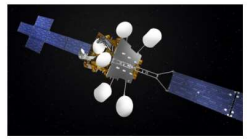
Electric Propulsion: recent achievements

- Some EP thrusters have completed their ground qualification (including life test demonstration) and have become commercially available:
  - **Safran 5kW-class HET PPS®5000**: ground qualification with 20,000 hours demonstrated, 17 thrusters in orbit
  - **Enpulsion/FOTEC IFM Nano/AR3/Micro FEEP**: ground qualification with 30,0000 hours demonstrated on emitter, 167 systems in orbit
  - **Thales GmbH HEMPT-3050**: ground qualification with 9,000 hours demonstrated, thrusters ready for launch in June 2023 on H2Sat
- Some EP thrusters have started their ground qualification, e.g. AGG RIT2X, Sitael HT100, Sitael HT5k;
- Several new companies (SME, start-ups) have started developing EP technologies and performed IODs;
- All European Primes are offering “all-electric” GEO telecommunication platforms with the 5 kW PPS5000 HET from SAE (FR), e.g. **Spacebus NEO** from Thales Alenia Space (FR), **Eurostar NEO** from Airbus DS (FR), **Electra** from OHB (D);
- Spacebus NEO and Eurostar NEO all-electric platforms have achieved flight heritage;
- Airbus DS (FR) and Thales Alenia Space (FR) have started the development of their new line of medium-size, reconfigurable platforms, named respectively **OneSat** and **Space Inspire**;
- The use of EP is the standard for LEO large/mega-constellations and thousands of low power (<1kW) hall thrusters are in operation on **Starlink** and on **OneWeb** small comsats.
- Thales Alenia Space has announced to have been selected by the operator Telesat to build constellation of small satellites using European EP thrusters named **Lightspeed**.

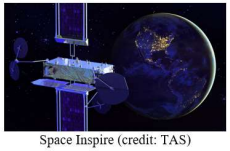

SAE PPS5000


Enpulsion FEEP


Eurostar NEO (credit: Airbus DS)


SpaceBus NEO (credit: TAS)

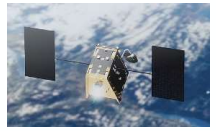

OneSat (credit: Airbus DS)


Space Inspire (credit: TAS)


SmallGEO (credit OHB)

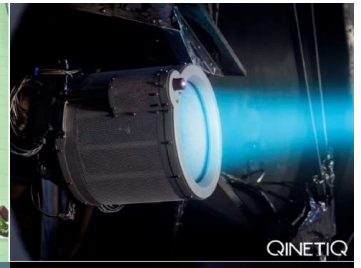

Electra (credit: OHB)

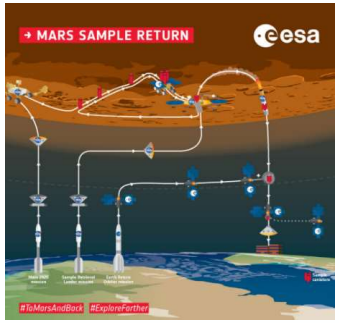

Starlink


OneWeb

Electric Propulsion: recent achievements

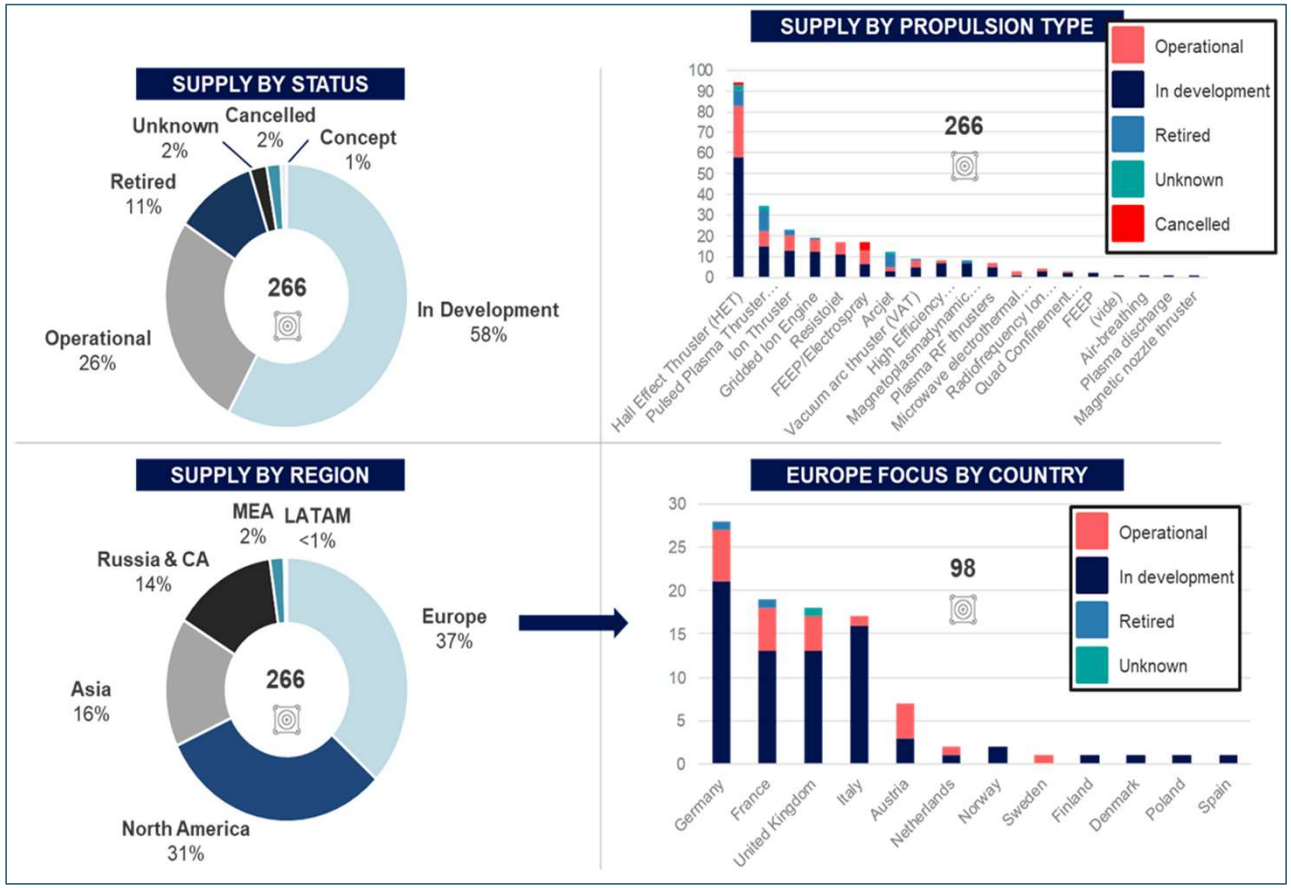
- ESA has launched **BepiColombo** mission which it is still on its way to Mercury propelled by the 5kW T6 Gridded Ion Engines from QinetiQ (UK);
- The **Galileo 2nd Generation** program has started the procurement phase of the first 12 satellites: six from Thales Alenia Space (IT) and six from Airbus Friedrichshafen (D). Both satellite manufacturers have chosen the 5kW PPS-5000 Hall Thruster from SAE (FR) for orbit raising to MEO in 180 days
- The **Mars Samples Return** - ERO mission has entered in its procurement phase choosing the RIT2X Gridded Ion Engines from ArianeGroup (D) to propel this satellite to and back from Mars;
- NASA **DART** mission with the 7kW NEXT-C GIEs;
- NASA **50kW EP system for the Lunar Gateway**;
- The European Commission has invested to date over **60M€ on developing Electric Propulsion technologies**, within the Horizon 2020 / HE **EPIC**

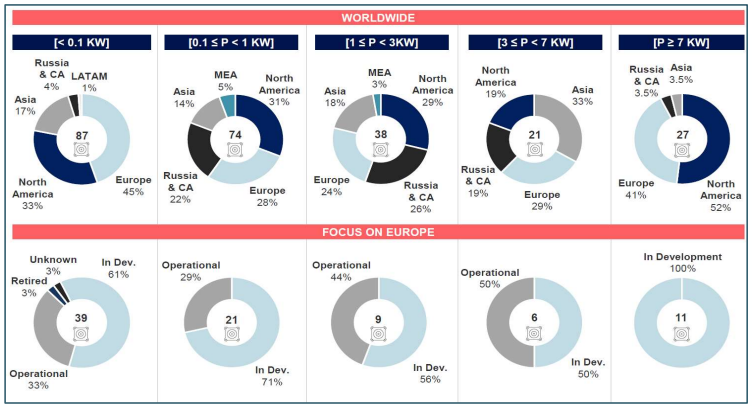



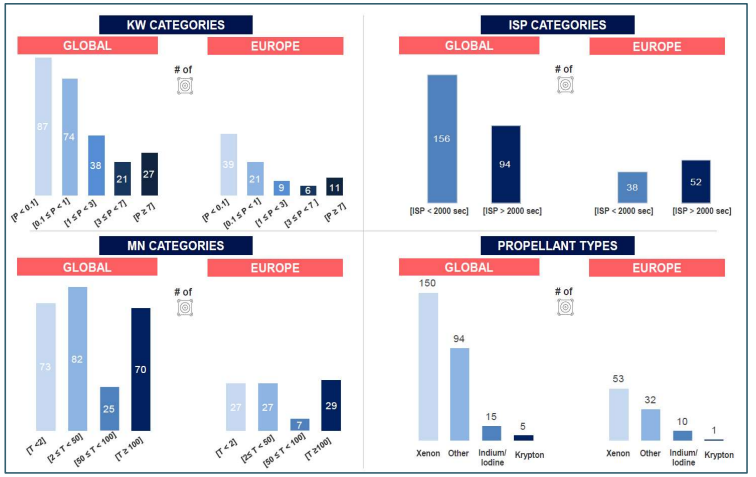


Competitiveness and Benchmarking – EP Thrusters

(credit: Euroconsult for THAG)



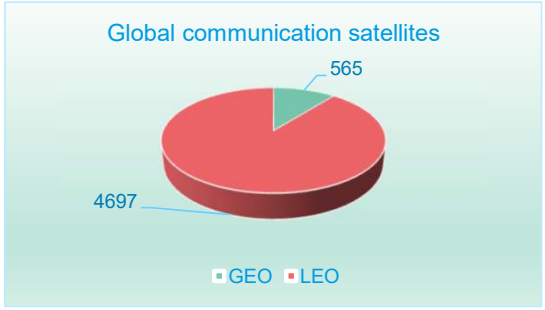


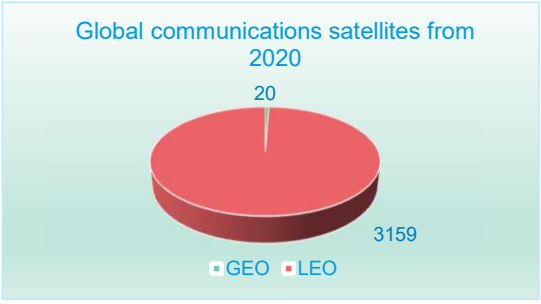


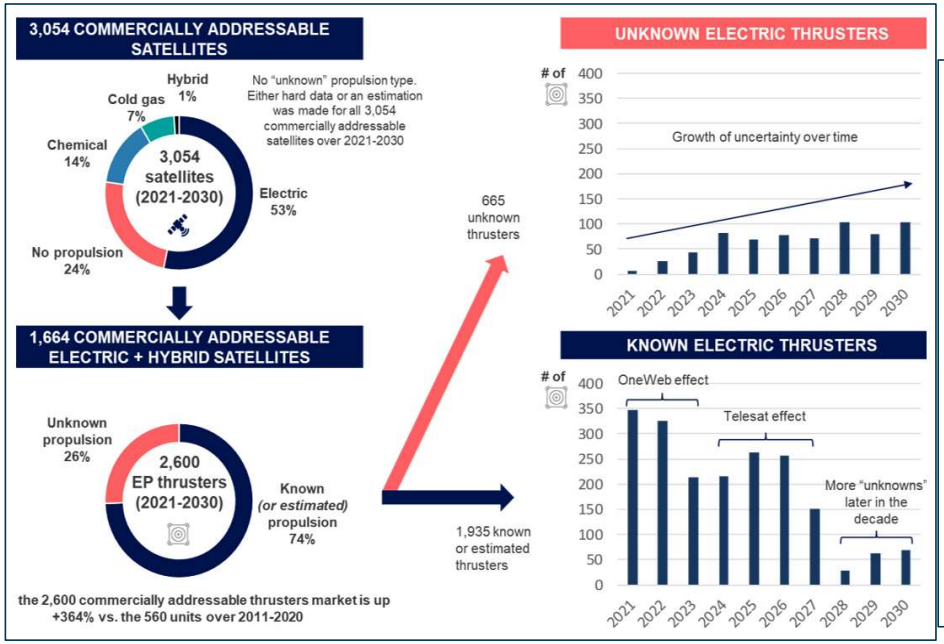
Market Analysis - EP Thrusters

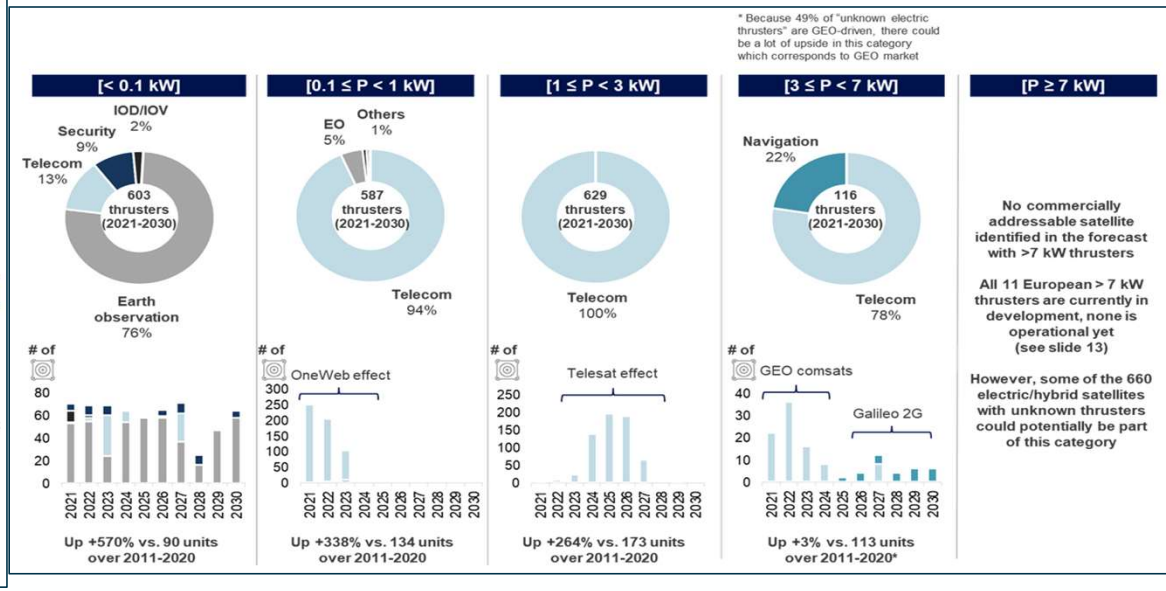
(credits: ucsusa.org @ April 22 & Euroconsult for THAG @ Nov 2022)

- Satcom remains main customer for EP thrusters
- Majority of satcom satellites are now on **LEO constellation**
- EP has become the **standard for LEO mega-constellations**









Electric Propulsion: a wide range of applications & opportunities

(credit: THAG)

GEO medium-large Telecom:

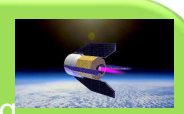
- Legacy/opportunity market
- 5-7kW xenon (HET, GIE) systems with high thrust for EOR & high ISP for SK, disposal + Aux systems
- Modularity, low cost, medium-high production, long lifetime (>15MNs)

Space Transportation - Space Logistics

(last mile delivery, in-orbit surveillance/assembly/servicing, life extension, debris monitoring/removal):

- Opportunity/emergency market
- High thrust, moderate-high ISP
- Medium-long lifetime
- Propellants alternative to costly xenon

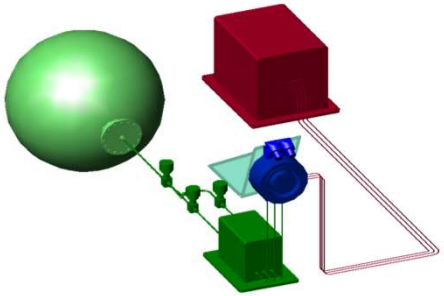
VLEO:



- Opportunity market
- ABEP systems for drag compensation
- Medium-long lifetime (5 years goal)

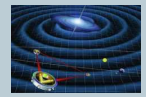
LEO small (>150kg) comsats medium/mega-constellations:

- Growing market
- <1kW EP systems, medium thrust for deployment, orbit changes, orbit maintenance, repositioning, collision avoidance and deorbiting,
- Alternative propellants to costly xenon: Kr, Ar, I2, H20, etc
- Low cost, large production, lead time, time-to-market, demisability, COTS in PPU and fluidics,
- Short lifetime (1MNs)

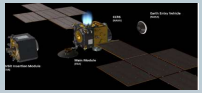


- Propellant Storage
- Fluidic Control
- Power Conditioning
- Pointing Mechanism
- Thruster

Science & Exploration:



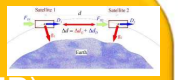
- Low power, high precision (FEEP, GIE) systems for drag free and formation flying
- high power/thrust/ISP GIE systems for interplanetary missions,
- long lifetime



MEO Navigation (Galileo 2G):

- Emerging market
- 5kW xenon HET systems for EOR + aux. xenon systems
- non-dependence, medium-high production, medium lifetime (7.5MNs)

Earth Observation:



- SK, CAM and deorbiting
- high-precision (GIE, FEEP) systems with long lifetime for drag free of gravity missions

Electric Propulsion: short term needs (3-5 years)

(credits: THAG)

- To complete ground **qualification** of:
  - **high power (5-7kW)** HET/GIE systems for GEO Telecom, Navigation, Space Transportation and Exploration missions;
  - **low-power (<1kW)** EP systems for LEO constellations of small Comsats and EO satellites.
- To **establish/secure leadership** and **boost commercialisation** with competitive price, short lead time, high production volume, high performance and high reliability:
  - Design to cost;
  - Lean Production;
  - COTS components in PPU, fluidics and pointing mechanisms;
  - Breakthrough technologies, e.g. planar transformers in PPUs, smart materials in pointing mechanisms, etc.;
  - Advanced manufacturing techniques;
  - Alternative propellants to costly xenon, e.g. Krypton, Argon, Iodine, Water, others,
  - Sustainable qualification & reduced flight acceptance tests;
  - Standardisation of test procedures, tools, diagnostics and optimisation/expansion of facilities and GSE for MAIT activities;
  - Automation of test activities and processes control.
- To **reduce dependence** in supply chain and **establish dual source** for critical/strategic technologies.
- To **accelerate maturation and qualification of ABEP** systems for drag compensation of **VLEO** (160-300km) comsats and EO satellites
- To **accelerate maturation and qualification of innovative/game-changing** technologies to expand existing / enable new markets.
- To **perform IODs** to complement, not to replace, on-ground qualification and **exploit flight data** for generation of lessons learned and models validation.
- To maintain, secure and expand **expertise.**

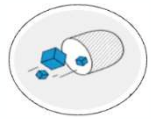
THAG Electric Propulsion Roadmap

Four targets driving ESA technologies development

30% Improvement of s/c development time by 2023

One order of magnitude improvement of cost efficiency with every generation

30% faster development & adoption of innovative technology

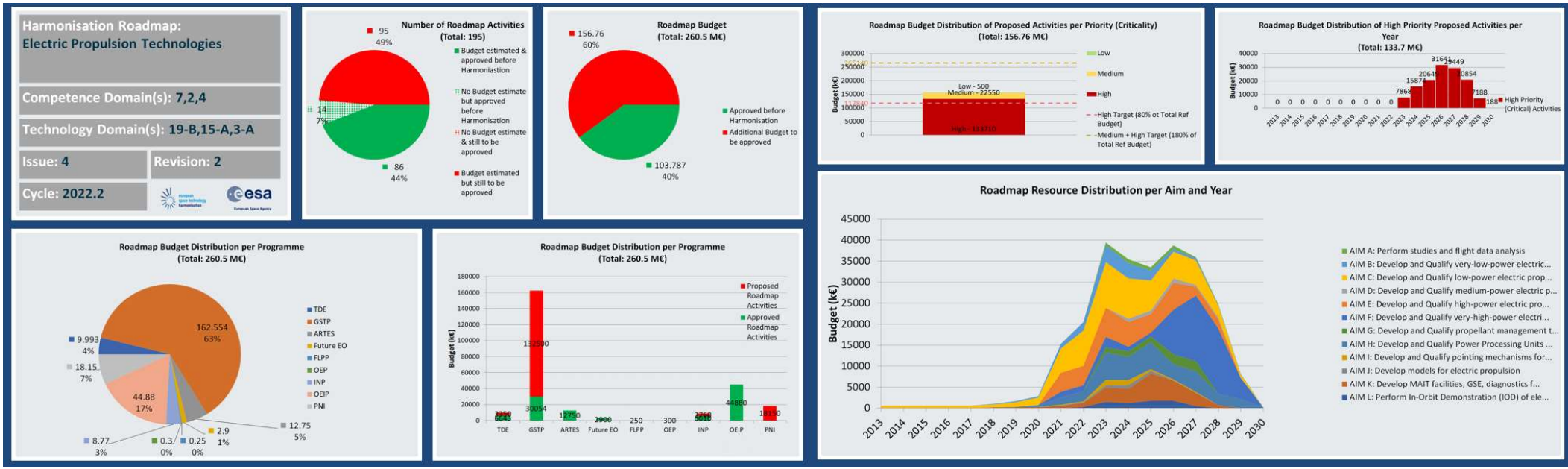


Inverting European contributions to space debris by 2030

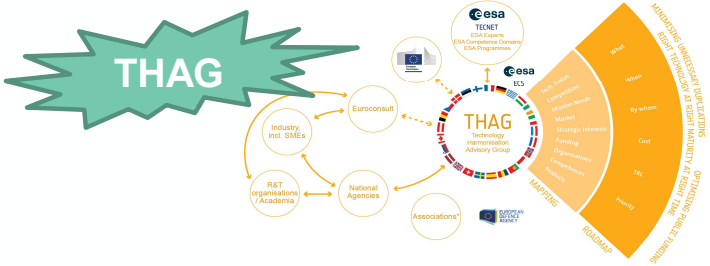
- AIM A: Perform studies and flight data analysis
- AIM B: Develop and Qualify very-low-power electric propulsion (P ≤ 100W)
- AIM C: Develop and Qualify low-power electric propulsion (P ≤ 1kW)
- AIM D: Develop and Qualify medium-power electric propulsion (1 < P ≤ 3kW)
- AIM E: Develop and Qualify high-power electric propulsion (3 < P ≤ 7kW)
- AIM F: Develop and Qualify very-high-power electric propulsion (P ≥ 7kW)
- AIM G: Develop and Qualify propellant management technologies for electric propulsion
- AIM H: Develop and Qualify Power Processing Units for electric propulsion
- AIM I: Develop and Qualify pointing mechanisms for electric propulsion
- AIM J: Develop models for electric propulsion
- AIM K: Develop MAIT facilities, GSE, diagnostics for on-ground and in-flight test of electric propulsion
- AIM L: Perform In-Orbit Demonstration (IOD) of electric propulsion

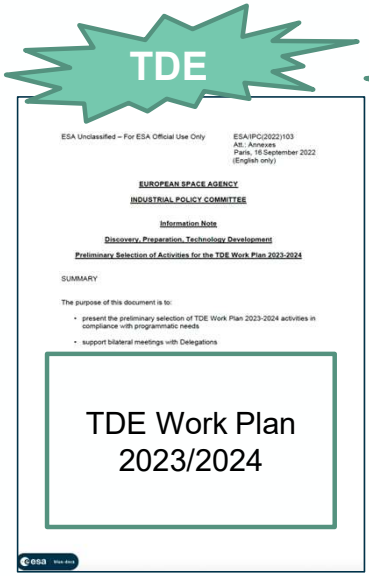
THAG Electric Propulsion Roadmap

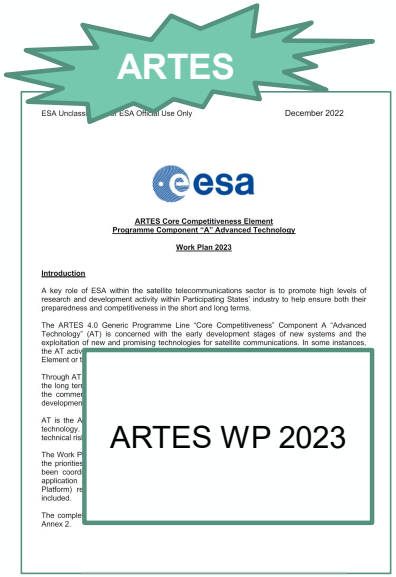
- A total of **124** ESA activities have been approved since 2017 for a budget of **147.3 M€**
- The 2022 THAG Roadmap requests a budget of about **156.76 M€ for 95 new activities** to be started within the next 5 years
- The requested budget is in addition to the 103.79 M€ of already approved activities
- Out of the total requested budget, 133.71 M€ are requested for 66 activities deemed to have high criticality



Implementation of THAG Electric Propulsion Roadmap: WP 2023-2024







- Short and mid term priorities are in TDE WP 2023-2024, GSTP Compendia, ARTES AT WP 2023.
- Complemented by ESA Projects-led developments, GSTP Element 1 (Develop) & Element 2 (Make) & Element 3 (Fly/IOD Cubesats), ARTES C&G & Pioneer, Incubed, HE/NAV WP 2023
- Complemented by IP-CCI white paper (under elaboration) => WS 28-30 June 2023

Major EP development activities to be implemented via TDE, GSTP, ARTES AT in 2023-2024

TDE WP 2023-2024	
T419-802MP	Low-power, high-thrust electric propulsion system for space transportation
T719-801MP	Disruptive propulsion technologies for CubeSat de-orbiting
T719-803MP	High-thrust, moderate-ISP, 6DOF electric propulsion system for CubeSats
T719-804MP	Demisable tank and fill & drain valve for CubeSat propulsion
T519-801MP	Isp Optimised EP system for Atmospheric Propellants
GSTP Element 1 2022	
GT17-650MP	Pressure regulator for electric, chemical and cold gas propulsion systems
GT17-651MP	High-pressure latching valve for electric propulsion
GT17-652MP	Miniaturised, high-pressure isolation valve for nanosatellite propulsion
GT17-653MP	Miniaturised pressure regulator for nanosatellite propulsion
ARTES AT WP 2023	
4B.170	Testbed for modular and scalable direct drive electric propulsion solutions
4B.171	High thrust, high specific impulse Xenon resistojet
4B.172	Cathode for oxygen-rich environment
4B.173	Cathodeless electric propulsion thruster
4B.174	Very low Earth orbit gas generator for air-breathing electric propulsion ground testing
4B.175	Mass production thruster testing technology
4B.176	Advanced manufacturing for electric propulsion components of low Earth orbit satcoms
4B.177	Demisable krypton tank

Electric Propulsion Technologies