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ELECTRIC PROPULSION, AN ENABLING TECHNOLOGY FOR IN-ORBIT SERVICES

18 Mayo 2023

Natalia Franco Rodríguez

Agenda

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- Electric Propulsion
  - Principles
  - Types
  - Electric Propulsion vs Chemical Propulsion
  - Applications & Opportunities
  - Missions
- In-orbit Services (IOS)
  - Missions/examples
- Electric Propulsion for IOS
- Wrap-up

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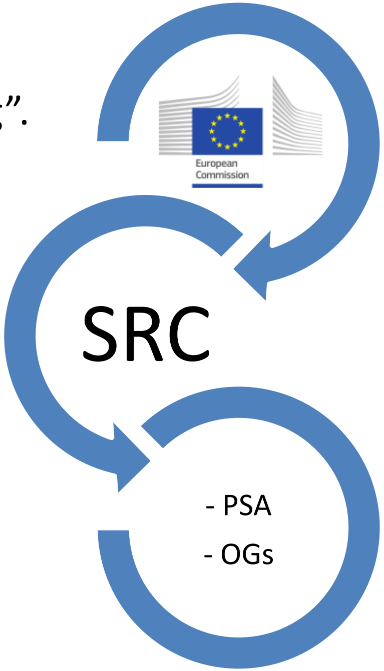
Introduction

Strategic Research Cluster “In space Electrical Propulsion and Station Keeping”.

Programme Support Activity →

Main PSA tasks:

- Roadmap creation
- Project monitoring
- Give support to the European Commission
- Dissemination and education.



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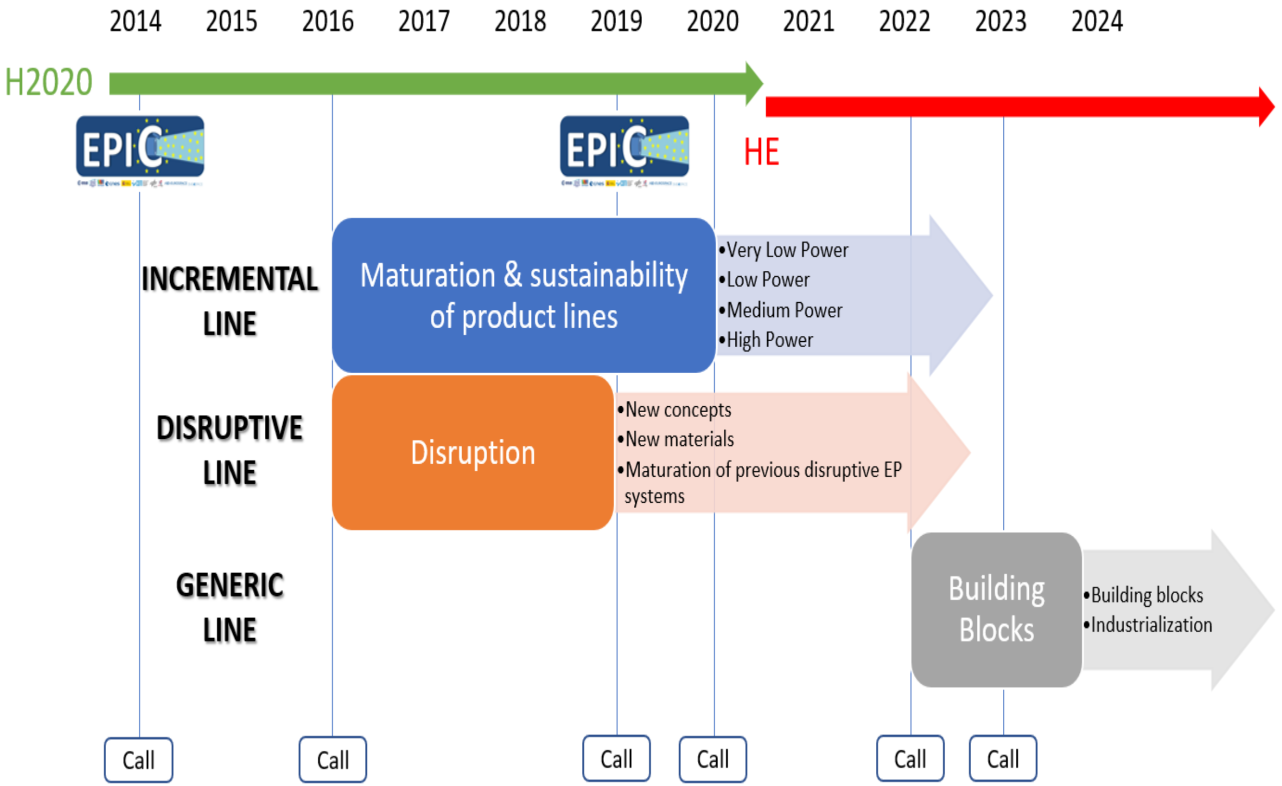
Introduction



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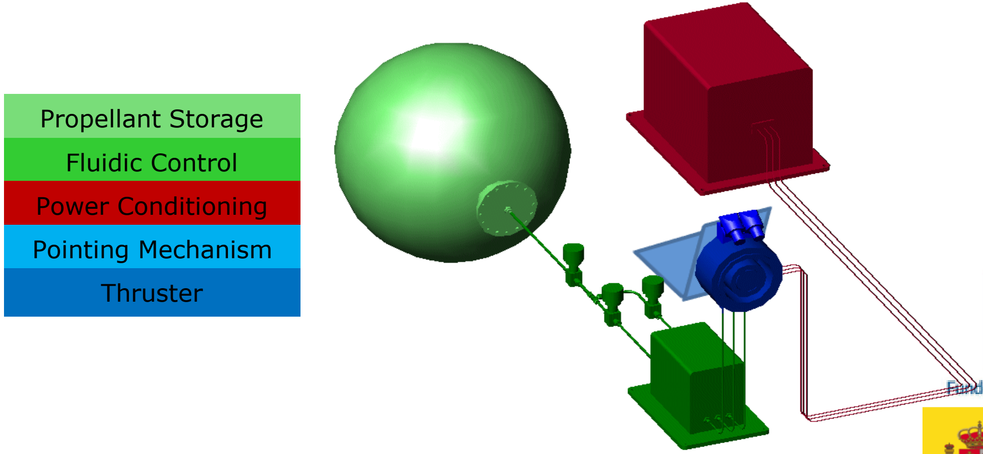
Electric Propulsion - Principles

- In general, Electric Propulsion (EP) encompasses any propulsion technology in which electricity is used to produce thrust.
- Electrical energy is used to ionize the propellant (gas, liquid, solid) and accelerate the resulting ions/plasma to very high exhaust velocities (10-40km/s).
- Electric Propulsion is very fuel efficient, but much lower thrust levels achievable than for chemical propulsion.



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Electric Propulsion - Types

- Depending on the process used to accelerate the propellant, electric propulsion thrusters fall into three main categories.

- Electrothermal
  - Resistojets*
  - Arcjets*
- Electrostatic
  - Gridded Ion Engines (GIE)*
  - Colloid
  - Field Emission Electric Propulsion (FEEP)
- Electromagnetic
  - Hall Effect Thruster (HET)*
  - High Efficiency Multistage Plasma Thruster (HEMPT)*
  - Pulsed Plasma Thrusters
  - Magneto Plasma Dynamic Thrusters

*Applicable for GEO satellite propulsion

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Electric Propulsion – EP vs CP

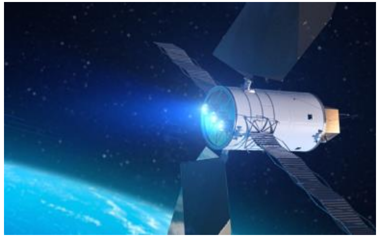

Table 2: Comparison of Chemical and Electrical Propulsion Systems' Physical Quantities

System Type	Propellant Type	Thrust (N)	Specific Impulse (s)	Thrust Time (h)	Propellant Consumed (kg)	Total Impulse
Chemical Propulsion: (Fregat Main Engine (S5.92M)	Nitrogen tetroxide / Unsymmetrical dimethyl hydrazine	1.96×10^4	320	0.24	5350	1.72×10^7
Electrical Propulsion (SMART-1 Hall Effect Thruster (PPS-1350))	Xenon	6.80×10^{-2}	1640	5000	80	1.2×10^6

Note: Reprinted form from EASA. (2019 September, 1) Electric Spacecraft Propulsion.

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Electric Propulsion – Applications & Opportunities

- 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.

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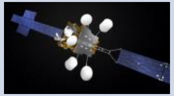
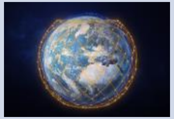
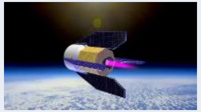
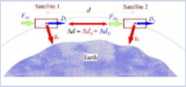
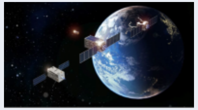
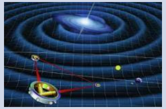
Electric Propulsion – Applications & Opportunities

Orbit		
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)	
MEO Navigation (Galileo 2G)	• Emerging market • 5kW xenon HET systems for EOR + Aux systems • non-dependence, medium-high production, medium lifetime (7.5MNs)	
LEO small (>150 kg) 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)	
VLEO	• Opportunity market • ABEP systems for drag compensation • Medium-long lifetime	

Electric Propulsion – Applications & Opportunities

Application		
Earth Observation	• SK, CAM and deorbiting • high-precision (GIE, FEEP) systems with long lifetime for drag free of gravity missions.	
Space Transportation – Space Logistics *(<u>last mile delivery</u>, in-orbit surveillance/assembly/<u>servicing</u>, life extension, debris monitoring/removal)*	• Low power, high precision (FEEP, GIE) systems for drag free and formation flying • high power/thrust/Isp GIE systems for interplanetary missions, • long lifetime.	
Science & Exploration	• Opportunity/emerging market • High thrust, moderate-high Isp • Medium-long lifetime • Propellants alternative to costly Xenon.	

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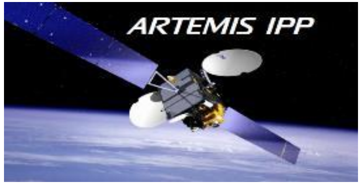
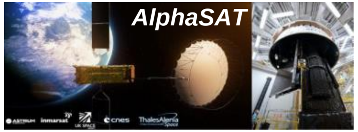
Electric Propulsion - Missions

Flight Telecom platforms with EP for SK and EOR



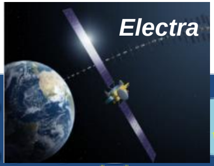
ESA **Artemis** satellite using **4 ion engines** (2 RIT and 2 UK-10) has paved the way for the use of electric propulsion in **telecommunication spacecraft**.

Astrium and Thales have demonstrated their capability to integrate this technology in GEO satellites. The ESA **Alphasat** spacecraft used PPS1350 for NSSK operations.



OHB with the ESA **Small GEO** satellite has **4 Hall Effect thrusters**, SPT-100.

ELECTRA will have EP for station keeping and orbit rising manoeuvres. **FULL EP SPACECRAFT** (PPS5000). Astrium and Thales will use the HET technology in Eurostar and Spacebus platforms.



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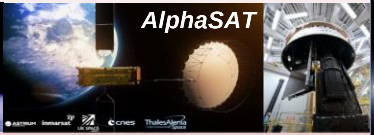
Electric Propulsion - Missions

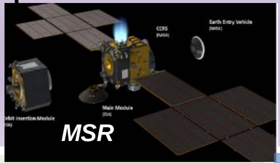
Flight Telecom platforms with EP for SK and EOR



Under development Telecom platforms with EP for SK and EOR

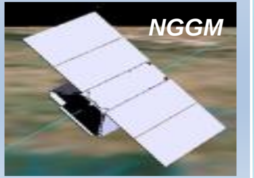
Completed/Ongoing Science & Exploration missions with EP for interplanetary transfers

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



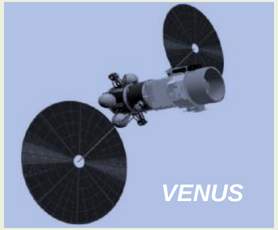
Completed Earth Observation missions with EP for drag free

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

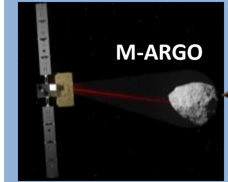


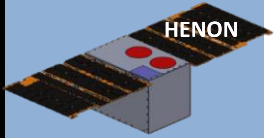
Under definition Space Navigation satellites with EP

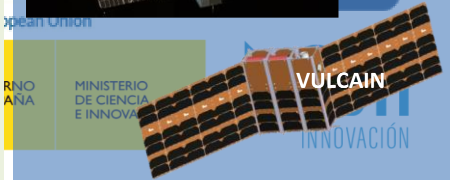
Under definition Space Transportation missions with EP



Cubesat missions with EP







In-Orbit Services

Some definitions:

- *“the robotic capability of maintaining and repairing satellites … by providing added operational flexibility through services such as refuelling, repair operations and orbital correction manoeuvres”*
- *the use of “robotic vehicles to physically inspect, assist, and modify on-orbit assets.”*
- *“a focused action, through a space tug in order to maintain, repair, upgrade, refuel or de-orbit a spacecraft while it is in orbit. These activities require the service spacecraft to approach, rendezvous and interoperate with the space asset to another State, Agency or private company”*

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In-Orbit Services

List of possible services in space:

- Live extension.
- **Maintenance**: Repair, Reconfiguration, Refuelling, etc.
- **Tugging and Towing**: Relocation, De-orbiting, Recycling, etc.
- Active debris removal.
- Assembly.
- Manufacturing.

New systems concepts will enable the evolution toward automated, flexible, sustainable space infrastructure maximizing business opportunities, based on modularity and easily maintainable spacecraft with compartmentalised functionalities that will allow re-configuration and re-use of spacecraft hardware and software for different mission purposes.

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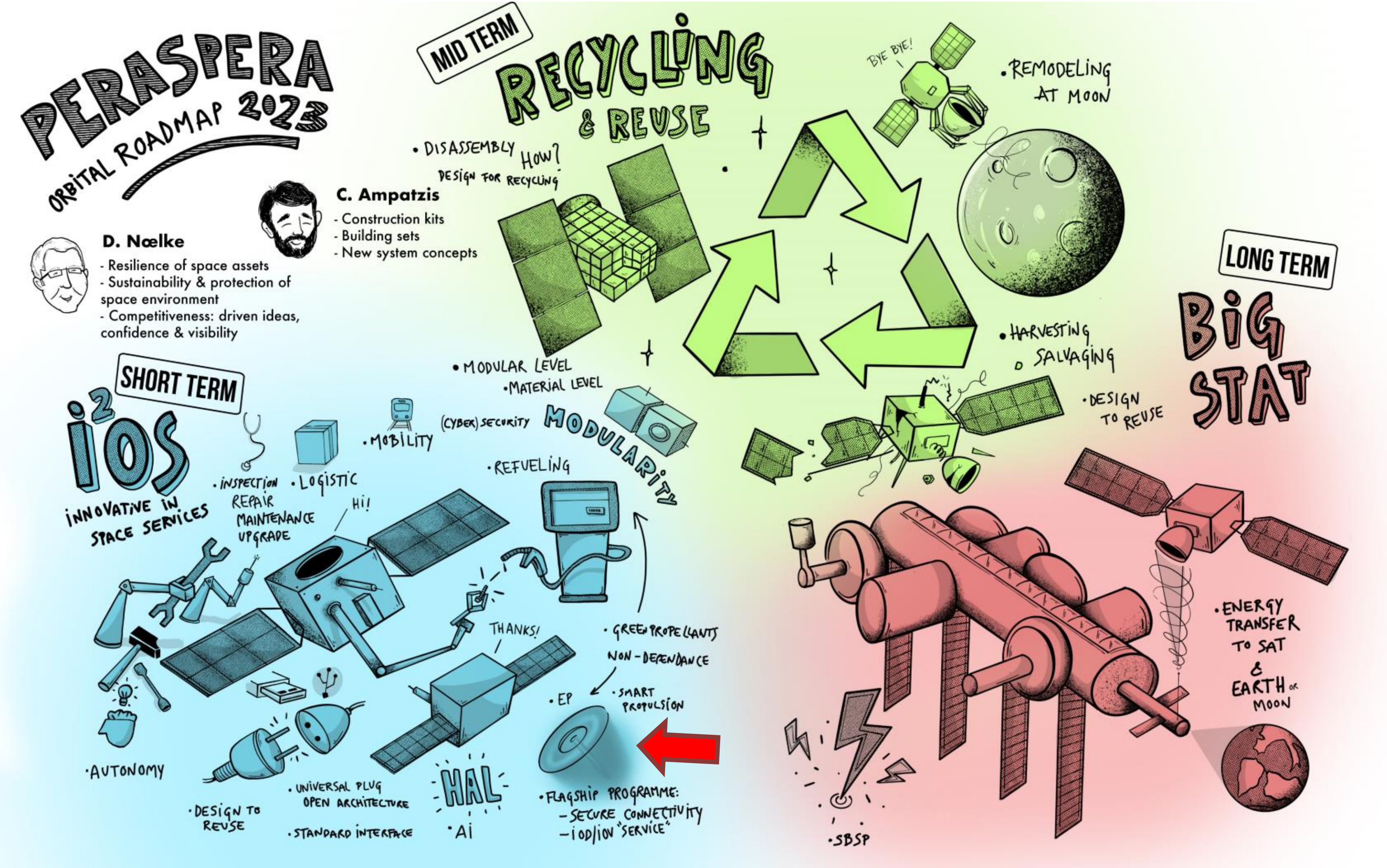
PERASPERA
ORBITAL ROADMAP 2023
C. Ampatzis
- Construction kits
- Building sets
- New system concepts
D. Nœlke
- Resilience of space assets
- Sustainability & protection of space environment
- Competitiveness: driven ideas, confidence & visibility
MID TERM
RECYCLING & REUSE
• DISASSEMBLY HOW?
DESIGN FOR RECYCLING
BYE BYE!
• REMODELING AT MOON
• HARVESTING
• SALVAGING
• DESIGN TO REUSE
LONG TERM
BIG STAT
• ENERGY TRANSFER TO SAT & EARTH OR MOON
• SBSP
SHORT TERM
i2OS
INNOVATIVE IN SPACE SERVICES
• INSPECTION
REPAIR
MAINTENANCE
UPGRADE
• LOGISTIC
• MOBILITY
(CYBER) SECURITY
• MODULAR LEVEL
• MATERIAL LEVEL
MODULARITY
• REFUELING
HI!
THANKS!
• GREEN PROPELLANTS
NON-DEPENDANCE
• EP
• SMART PROPULSION
• AUTONOMY
• DESIGN TO REUSE
• UNIVERSAL PLUG
OPEN ARCHITECTURE
• STANDARD INTERFACE
HAL
• AI
• FLAGSHIP PROGRAMME:
- SECURE CONNECTIVITY
- IOD/IOV "SERVICE"

Electric Propulsion for IOS

Electric propulsion can be used in the following services:

- In-orbit surveillance, assembly, life extension, refuelling, debris monitoring/removal.
- Last mile delivery, orbit changes, orbit maintenance, repositioning, collision avoidance and de-orbiting.

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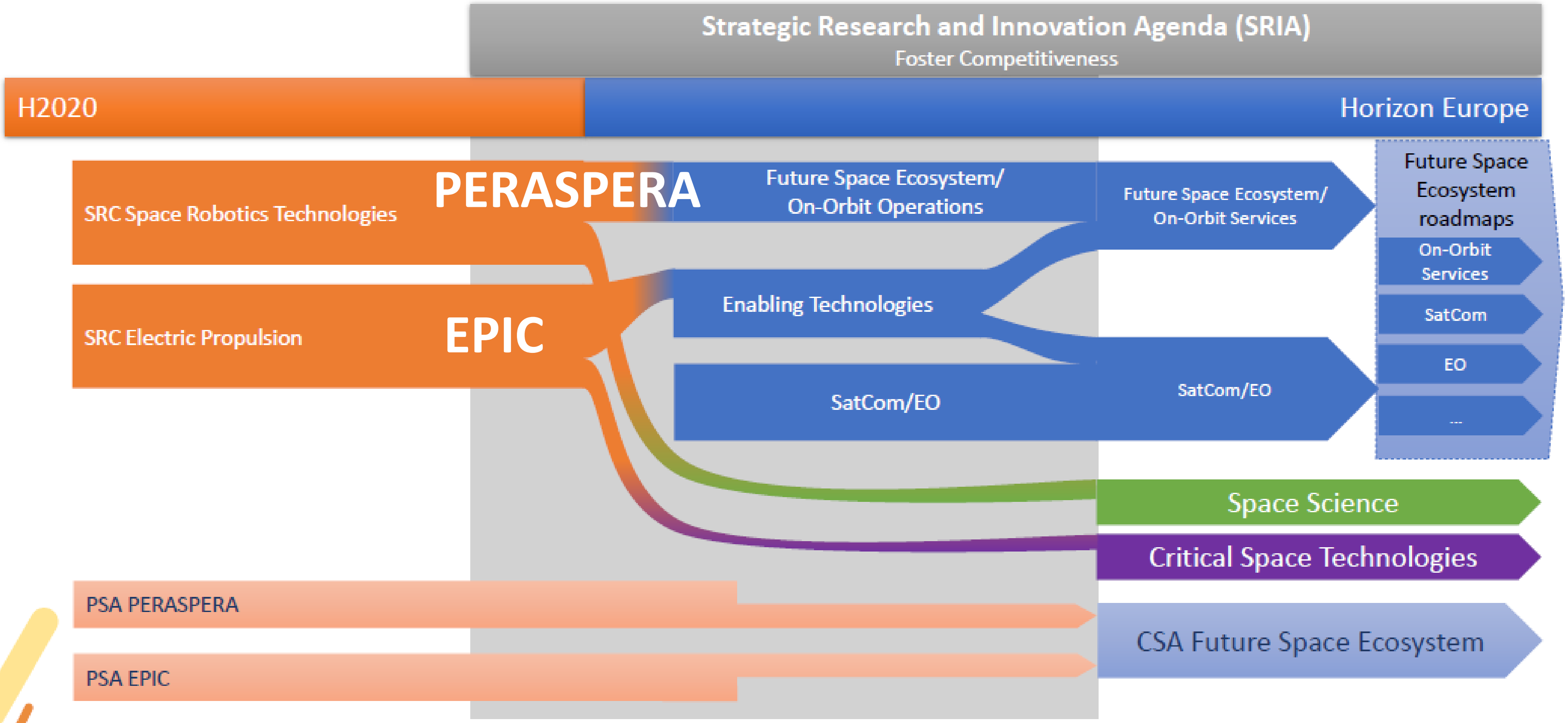
Electric Propulsion for IOS



Wrap-up

- EP has reached its maturation phase and is increasingly being used for different application.
- The relevance of IOS activities is growing and there are many market opportunities around this area of innovation.
- It is key to develop the needed technologies to reach a sustainable space ecosystem and competitive industrial capacities (robotic, electric propulsion, artificial intelligence, industry 4.0, digitalization, module “APPStore” SW and HW, etc.).

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