European Commission

Business Innovation Observatory

Space tech and services

Electric Propulsion

Case study 65

Internal Market, Industry, Entrepreneurship and SMEs

Space tech and services

Electric Propulsion

Business Innovation Observatory
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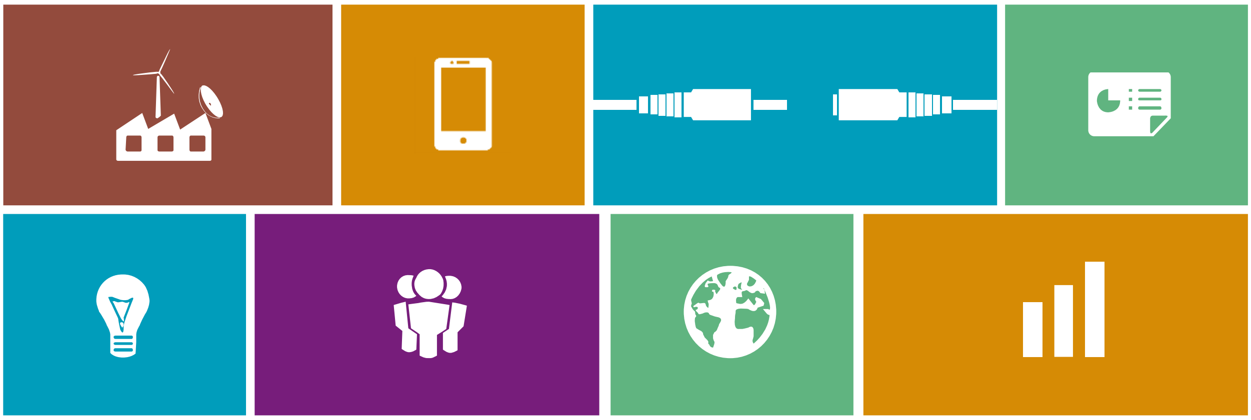
Table of Contents



1. Executive summary

Space propulsion is a method used to accelerate spacecraft or artificial satellites. Currently space propulsion systems include two main solutions. Electric Propulsion (EP) uses electric power (provided by solar panels or a nuclear source) to accelerate ionised propellant. And Chemical Propulsion (CP) uses the propellant itself as source of energy for the propulsion.

Recent developments in the field of EP have brought this technology to the forefront of the space scene. Today, EP systems offer new business models and a real economic paradigm shift in the telecommunication-by-satellite sector. This commercial sector represents almost half of the revenues of the European satellite manufacturing industry revenue and is therefore of the utmost importance.

The commercial success of the European industry is not the only driver behind the development of EP. Today EP is also considered as a revolutionary technology that will contribute substantially to the performance of future scientific and operational space missions. EP could potentially allow new missions, by expanding the limits of reachable space. Subsequently EP will impact scientific progress and boost growth in areas such as space telecommunications, navigation, and Earth observation.

EP is an important technology for the EUR 310 billion global space industry, being a EUR 28 billion sector itself. Its importance in Europe relates both to the European space capability and the competitiveness of a strategic industry. Today, the satellite propulsion market is still experiencing a transition phase from CP to EP. And Europe needs to urgently catch up with American and Russian competitors in order to maintain its good position on the global scene.

Developing a competitive EP system requires a considerable investment. For this reason a public support to R&D is crucial. Innovation is at the heart of the competitiveness of this industry. To win the global race, the emergence of disruptive solutions that will provide a substantial competitive advantage to Europe is essential. In this context, it is the SMEs that are the best placed to innovate and conduct early and high-risk research. And active contribution of commercial customers would allow for more market driven developments.

The European Commission and Space agencies in Europe have invested heavily in R&D programmes to support the development of European EP systems.

To be fully effective, the R&D support should cover the complete range of successive activities, up to In-Orbit Demonstration. This approach would create heritage, a key success factor for any space product, by acting as a springboard for market uptake. Focusing on large programmes rather than small R&D activities would contribute to mitigating development risks and provide more visibility on the market, erasing important barriers to private investment. To stimulate innovation, facilitating access to R&D funding to companies, especially SMEs, is a prerequisite.

2. Electric Propulsion

The trend "Space technologies and services" covers the latest developments in the space industry through four case studies. Each of them focuses on innovations related to space technologies and services fostered by the European Space Policy to tackle some of the most pressing challenges today. This paper explores the technology trend related to Electric Propulsion.

2.1. Trend presentation

Space is a strategic sector mostly driven by public institutions. In Europe, the European Commission (EC), the European Space Agency (ESA), National Space agencies and other public entities account for 54 per cent of turnover in the industry.

With 24 per cent of revenues originating from export and 20 per cent from European commercial markets[1], Europe is highly exposed to the inherent volatility of foreign and profit-oriented markets. Among these markets, telecommunication-by-satellites is the most significant and mature one. It is a core market for both satellite (around 50 per cent of satellite industry turnover[2]) and launcher (87 per cent of Ariane 5 launches[3]) industries in Europe.

For a few years now the satellite industry has been exposed to a new trend, the emergence of Electric Propulsion for new applications. This trend is mostly driven by the Telecommunication-by-satellite market and is therefore of major importance for the satellite industry at large. According to ESA, *"EP is currently considered by all space actors as a key and revolutionary technology for the new generations of commercial and scientific satellites. Initiatives in this field all over the world are aimed at the development of competitive new generations of Electric Propulsion Systems".*[4]

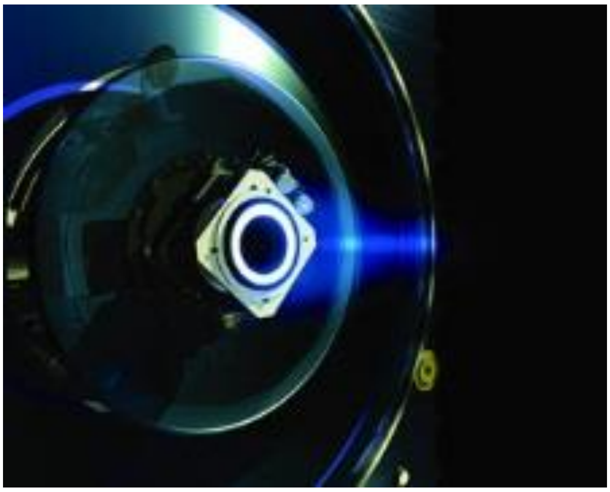
*"The competitiveness of propulsion systems is driven by four criteria: reliability (heritage and quality), flexibility, performance and cost. Recent results suggest a clear advantage for EP for a wide range of applications. EP may also very likely enable new missions" – **Elwing***

Two solutions exist to provide propulsion to a satellite in space: Electric Propulsion (EP) and Chemical Propulsion (CP). Both systems consist in expelling propellant to provide acceleration to the satellite; the main difference actually lies in the origin of the energy. CP uses the propellant itself as source of energy for the propulsion while EP uses electric power (provided by solar panels or a nuclear source) to accelerate ionised propellant.

EP is not a new technology; it was actually conceptualised before the beginning of the conquest of space and first in-orbit tests had already been performed in the 1960s. In fact CP and EP, as any solution, have pros and cons and a trade-off is performed when engineering a Space system (satellite, probe, rover, etc.) to select which solution is the most suitable for the mission profile. Until recently CP was the best solution for a vast majority of applications and became the main propulsion system used on-board satellites.

This is still the case today, however, recent developments in EP technologies and emergence of new business models have reshuffled the cards and put back EP on the level playing field for key applications such as **Telecommunications** (Orbit transfer and Attitude control), **Space exploration** (Deep-Space and long duration), **Human flight, Science, Earth Observation or Navigation**.

Figure 1: SMART-1 was the first European satellite to use electric primary propulsion in space



Source: European Space Agency[5]

According to ESA, *"the advantages of EP with respect to CP is the high specific impulse that implies a significant saving in propellant mass, and the capability of a very good controllability due to the possibility of generating a very low thrust and very small impulse bit. On the other hand, to obtain such high specific impulses, the EP system needs a high power-to-thrust ratio, meaning in some cases power systems capable to generate several kWs."* [6]

Figure 2: Eutelsat 172b, manufactured by Airbus Defence & Space will be the first full-electric European satellite to demonstrate EP for orbit raising

Source: Airbus Defence & Space[7]

EP has enabled new business models in the Telecommunications sector where new Geostationary Full-Electric Satellites offer a real paradigm shift: at the cost of a much longer orbit transfer phase, the propellant mass is significantly reduced. From a market perspective, this translates into: at the cost of a longer time-to-market, the initial investment can be significantly reduced. Indeed, the launch still represents a significant share of an operational Space system costs (other elements include the satellite itself, the ground segment and Maintenance in Operational Conditions costs). Yet, propellant for orbit transfer can represent up to 40 per cent of a GEO satellite mass. Given that launch costs are almost directly proportional to the satellite mass, EP can help drastically reduce the overall cost of the Space system.

The **emergence of a new launch service provider**, namely SpaceX, is also pointed out to explain the sudden success of EP for GEO Telecommunication satellites. This new American actor has cut launch prices thanks to institutional supports (mainly US Department of Defense and NASA) and to an optimised supply chain. As a consequence Falcon 9, SpaceX launcher, has become an economically attractive medium-lift launcher particularly suitable to launch lighter GEO satellites that contributes to making EP solution even more appealing.

Pushed by new attractive business models, recent developments have raised EP as an essential technology and a key challenge for the competitiveness of the European Space industry. This is particularly true for Telecommunications but also for other Space missions for which mature EP systems allow innovative applications.

2.2. Overview of the companies

Table 1: Overview of the company cases referred to in this case study

Company	Location	Business innovation	Signals of success
Elwing	Luxembourg	The Elwing Company designs and commercialises EP systems for satellites and spacecraft based on an innovative electrodeless plasma thruster technology.	- Elwing already owns several patented technological breakthrough - Elwing innovative EP system is at an early stage of development but has already demonstrated high performance results - Despite its small size Elwing built a large network in Europe and in the United States
LuxSpace	Luxembourg	LuxSpace offers innovative and economical space services, maintaining state-of-the-art technology in Luxembourg.	- LuxSpace built satellites Vesselsat 1 & 2 that have successfully completed their mission and even overperformed - LuxSpace has built a strong heritage on a wide range of space products and services
Mars Space	UK	Mars Space is a fast growing innovation-focused SME providing services and consultancy on space propulsion and plasma engineering and science.	- Business expectations are high and Mars Space foresees to triple its turnover in the next 5 years

Problem 1 – Electric Propulsion system performance is at the heart of satellite industry competitiveness and a key to enable new missions.

Innovative solution 1 – The disruptive E-IMPAcT satellite EP technology (Electrodeless-Ionization Magnetized-Ponderomotive Acceleration Thruster) developed by Elwing offers outstanding performance levels with comparison to already existing EP technologies.

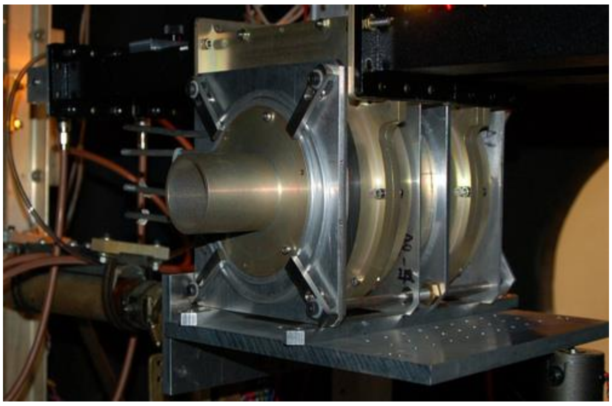
Elwing E-IMPAcT technology compared to other EP technologies show strong arguments

	Hall Effect Thruster	ELWING	Ion Thruster	Arcjet
Mass Saving	***	*****	*****	*
Reliability	***	*****	***	***
IP Status	***	*****	***	*
Benefit/Cost	*	*****	*	***
Thrust	***	*****	*	*****
Development	***	*	*****	*****
R&D funding	***	*	***	*
OVERALL	***	******	***	*

Source: The Elwing Company[8]

The technology holds the potential for fast orbit raising, increased orbital agility and repositioning capacity. It also allows reducing propellant mass by as much as 70 per cent.

Elwing E-IMPAcT thruster prototype was tested in various laboratories in the United States and in Europe



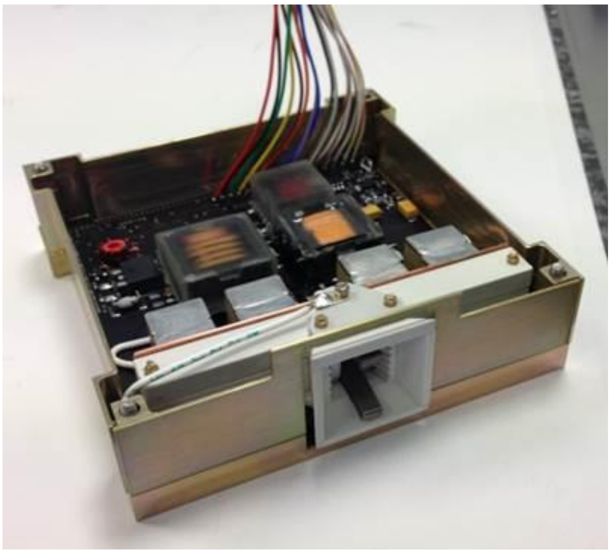
Source: The Elwing Company[9]

This innovative technology can operate without an auxiliary power source or the implementation of non-mechanical thrust vectoring or oxidising propellants. It has been tested and proven at the Electric Propulsion and Plasma Dynamics Laboratory at Princeton University (EPPDyL), and has undergone further testing at NASA's Propulsion R&D Laboratory. More recently, in early 2014, the technology underwent initial testing at the ESA.

Problem 2 – Recent small satellite constellations counting with a hundred cubesats fly in very low orbits and deorbit in a few months. For this reason a costly continuous replenishment is required to maintain the constellation operational.

Innovative solution 2 – Mars Space is currently developing and qualifying a series of innovative propulsion concepts to increase the capabilities and commercial value of cubesat and pico, nano and microsatellite by providing them with flexible and affordable propulsion systems to fit their needs.

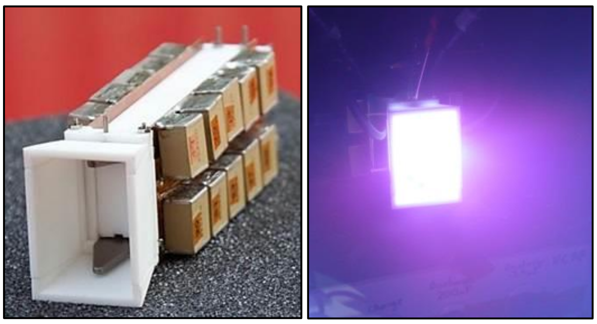
Mars Space PPTCUP is suitable for a range of missions including drag compensation, orbit keeping, formation flying and small orbit transfer



Source: Mars Space[10]

Mars Space innovation is based on Pulsed Plasma Thrusters (PPTs). This thrusters technology is long-standing, space-qualified and of proven reliability, relatively simple and low-cost. Compactness, robustness and scalability of these thrusters are particularly relevant for small satellites, a growing segment of the space sector. Mars Space added-value consists in adapting this well-established technology to small satellites: it is the Pulsed Plasma Thruster for CubeSat Propulsion (PPTCUP) technology. Today the Engineering Model (EM) has successfully completed its lifetime campaign and a full flight qualification program has started.

Mars Space Micro-PPT is adapted to nano satellite class



Source: Mars Space[11]

Mars Space also took advantage of the scalability offered by this technology to develop solutions for larger satellites up to 100 kilograms. First test results show that, in average, Mars Space system could double the lifetime of satellites. In addition Mars Space EP system can contribute to risk mitigation by allowing small satellites, often launched as piggy back payloads on rockets, to correct slightly their orbit in case of wrong orbit injection. Finally, for satellites in higher orbits this EP system can be used to comply with space laws requiring deorbitation within 25 years.

Problem 3 – Small satellites are usually launched as piggy back of larger satellites and are therefore injected on the same orbit. An efficient, light and powerful propulsion system is required to reach another orbit.

Innovative solution 3 – LuxSpace innovative product is a scalable EP subsystem that is optimised for microsatellites (between 40 kilograms and 400 kilograms wet mass). Orbit and attitude control can be performed with low thrust ion thrusters without requiring reaction wheels or magnetorquers. It can be used in a wide range of missions, from Low Earth Orbit (LEO), Middle Earth Orbit (MEO), High Earth Orbit (HEO), and Geostationary Earth Orbit (GEO) to interplanetary missions. Such system also allows a satellite to reach high orbits even if it was injected in a low altitude orbit.

"Being the first in a rising market is essential. In existing markets, gaining visibility is a driver. Export regulations also play an important role, from this standpoint US manufacturers are disadvantaged" – ***LuxSpace***

The platform being developed in the frame of the SmallGEO project will use Electric Propulsion

Source: LuxSpace[12]

The solution that is being developed is optimised for satellites in the range of 40 kilograms but the technology is highly scalable and could be adapted for satellites up to 400 kilograms.

The first objective is to develop a solution for LuxSpace platforms and projects such as SmallGEO but a commercialisation of the EP system alone for other microsatellites could be envisaged in the future.

3. Impact of the trend

The Space manufacturing industry is a niche sector accounting for EUR 7.25 billion of final sales and representing 38,000 highly qualified jobs.[13] Despite its small size, the Space sector enables a wide array of services and applications and is highly strategic for governments and businesses. For this reason, *"supporting the global competitiveness of the European Union (EU) space industry"* and *"developing a competitive, solid, efficient, and balanced industrial base in Europe"* are key priorities of the EU.[14]

In Europe this industrial sector is highly dependent on commercial markets and more particularly on the Space telecommunications one. To be sustainable the European Space industry must remain competitive on these open international markets. In this high-tech sector, remaining on the level playing field requires European Space systems to continuously improve cost-efficiency, performance and quality and to constantly adapt to market evolutions.

Recent developments in EP technologies in other countries (US and Russia) have overtaken on the European Space industry. Indeed, the US is a major competitor of Europe on the commercial Space market. These developments have enabled new competitive offers that are becoming increasingly interesting for customers.

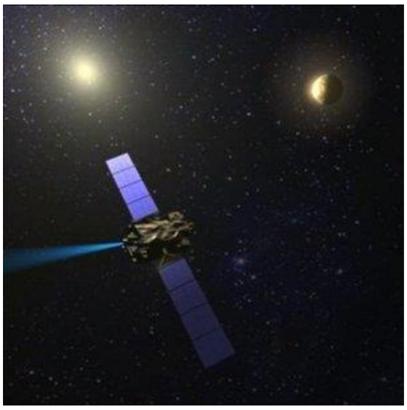
3.1. The market potential of the trend

The number of satellites launched worldwide every year is low: under a hundred spacecraft per year (excluding the numerous and trendy microsatellites that represent only a small fraction of the Space business). Each satellite is worth tens or even hundreds of million euros. The largest and most advanced ones reach a few billion euros. In 2014 the Space Foundation estimated that the global satellite market was worth around EUR 30 billion[15] and that the total Space economy, including Space enabled services midstream and downstream revenues was worth EUR 330 billion.

Despite the market growth trend EP only concerns a small fraction of the satellite market today. Even on the core target market, **Geostationary Telecommunications Satellites (GEO satcom)**, customers have not yet fully engaged in this new solution. Space is a specific industrial sector where product reliability remains the main criterion for customers. From their perspective, system reliability is assessed on the basis of flight heritage (number of similar systems having successfully been operated in Space) and product/quality assurance processes implemented within the supply chain. For this reason, and despite substantial price and performance arguments, customers remain reluctant to switching to full electric satellites too fast. They keep considering positively hybrid (electric/chemical propulsion) or even full chemical platforms. In a recent interview, Airbus Defense & Space estimated that *"about half the bid requests received today include at least an option for electric propulsion*". Their estimate of electrical propulsion market uptake is that ***"eventually at least 50 percent of the market will use electric in one way or another".***[16]

Although it is the core market today, GEO satcom is not the only segment where EP could reveal useful. Another major potential application refers to **deep-space exploration**. In addition to current robotic exploration missions, EP could also support future Human exploration such as Moon or Mars missions. The market is limited to a few missions per year worldwide but requires even superior quality profiles leading to more substantial selling prices.

Figure 3: Solar-electric propulsion can open the door to a whole new era of space exploration



Source: European Space Agency[17]

The maturation of EP systems has also raised some interest for other missions including **Earth Observation, meteorology and science**. Flexible and sizeable technical solutions could expand EP reach to an important share of the overall satellite market.

"With regards to propulsion, the space sector is currently experiencing a transition period. Today, satellite operators are cautious and are not ready to fully engage in EP yet. This being said, first results suggest that EP will very likely and very quickly replace chemical propulsion for a wide range of applications, GEO satcom being the first one" – ***Elwing***

The satellite propulsion market is experiencing a transition phase and the first results indicate that EP systems have strong arguments to become the next generation propulsion systems for a wide range of missions. Unlike the rest of the sector, EP market seems to be quite open internationally and highly competitive. The development of European solutions is of the utmost importance for four key reasons:

- Maintain the European Space industry competitiveness on the level playing field
- Enable new applications for the benefits of European institutions, businesses and citizens
- Ensure European technology non-dependence to other countries
- Position European products on a growing commercial market

3.2. The social potential of the trend

According to the European Commission, *"the space industry [...] drives scientific progress and boosts growth in areas such as telecommunications, navigation, and Earth observation"*[18]. Space technologies also help *"to address major societal challenges including climate change, scare resources, health, and an ageing population"*[19].

Because of its importance for the sustainability of the European Space sector at large, EP directly contributes to these impacts.

In addition to being of a strategic importance for the EU, EP is at the cutting edge of technology and involves **highly qualified jobs**. The European space manufacturing industry is strong of 38 thousand highly qualified jobs. In addition to the upstream sector, midstream and downstream sectors (related to satellite exploitation and services) account for 21 thousand jobs. Including jobs impacted indirectly as well, it is a total of 326 000 jobs that are dependant on space activities[20] in Europe.

"EP involves highly qualified jobs. Today we are looking for at least three new engineers. This would almost double our team but the required set of skills is rare." – ***Mars Space***

R&D achieved in the frame of the development of Space EP have spin-off applications to other major scientific challenges.

4. Drivers and obstacles

4.1. Developing competitive EP systems requires big investment

The development of a complete competitive EP system is a technical challenge. It requires long-term, risky and significant investments that cannot be supported by private funds alone.

R&D for a complete and competitive EP system includes numerous expensive activities: basic and applied researches in science and engineering, system design, prototyping, product development and tests. R&D costs are further increased by stringent Product & Quality Assurance (P&QA) requirements applied to all Space systems.

European institutions have set up a series of programmes to support R&D activities in the Space sector: the European Commission through FP7 and then Horizon 2020, the European Space Agency through the Advanced Research in Telecommunications Systems (ARTES) programme and National Space Agencies through their own programmes. Public institutions already contribute substantially to R&D costs for EP systems. Nevertheless, this contribution could be optimised to yield more results.

4.2. Innovation is at the heart of competitiveness but is limited by sector conservatism

Today the Russian and American industries are already well positioned on the EP systems market. In these countries, complete EP systems, and even satellite platforms integrating them, have been developed and demonstrated in the frame of national satellite and R&D programmes. As a consequence European industry competitors already offer a wide range of solutions to customers. These solutions have already been flight proven and keep accumulating flight heritage (heritage is accumulated by a Space system for each successful mission having demonstrated the system capability to perform according to mission objectives).

The development of the European EP systems using similar technologies and offering similar performance to competitors is essential to keep Europe in the game. However, that would allow only to maintain and not improve the European position. In such mature market **disruptive innovation is crucial to increase market uptake** and should therefore be promoted. In the frame of EP, European competitiveness lies in differentiation with existing systems.

Yet, the Space sector is cautious and usually prefers building on proven technologies to mitigate risks. This conservatism is a strong barrier to innovation and usually relegates it to a position of second importance. As explained, promoting innovation is essential to make disruptive solutions offering significant performance improvements emerge.

4.3. The involvement of SMEs is essential in higher risk activities

SMEs and start-ups are particularly relevant to undertake early and innovative development because of their low structural costs and their ability to take more risk.

As part of the Horizon 2020 programme, the European Commission has set up an **SME Instrument to invest and support innovative businesses**. However, the assessment of financial strength performed by the European Commission tends to favour companies for which Space is a secondary activity rather than a core business. Secondly, a heavy administrative burden is required to apply for public grants. The effort is often not proportional to the size of the subsidy and can discourage SMEs applications for small projects. Last but not least, the significant effort required for indirect cost accounting is also a substantial obstacle. Altogether, these challenges constitute a strong barrier to SMEs participation to R&D activities for EP.

5. Policy recommendations

5.1. Support R&D activities up to In-Orbit Demonstration and Validation to boost market uptake

Recently, the European Commission, the ESA and National Space Agencies have invested heavily in R&D programmes to support the development of competitive European EP systems.

This support should of course be maintained in the next years. It is also important that subsidies cover the whole sequence of development activities. In particular, public programmes should allow the European industry to demonstrate technologies in the frame of In-Orbit Demonstration & Validation (IOD/IOV) projects.

In the Space sector a key market success criteria for a system is **flight heritage**. In addition to stringent P&QA specifications applied all along the project, customers place a lot of value on this parameter. To support market uptake **R&D activities should thus be completed with IOD/IOV projects**.

The launch of an EP system on-board of an institutional satellite would ensure a degree of heritage to meet the need of customers and would be a springboard for market penetration.

5.2. Focusing on large programmes to stimulate private investment by improving market visibility

Public support generally contributes only to a share of the total investment required for R&D activities. It is therefore of the utmost importance to **stimulate private capital expenditure** (CAPEX) as well. From a private company perspective, the decision to invest is based on a wide range of criteria. Among them, Return On Investment (ROI) and risk are usually the main ones. Yet, public programmes usually subsidise small R&D activities part of a larger plan based on long-duration technology roadmaps. From a company point of view this approach limits visibility on future potential markets resulting from the R&D activity and as a consequence on ROI and risks. **Larger programmes with a commitment on the complete development plan would further encourage companies to engage in these uncertain developments**.

5.3. Promoting innovation to allow disruptive solutions to emerge

To support the development of EP technologies, the European Commission has funded, as part of the Horizon 2020 Space Work Programme 2014, a Programme Support Activity (PSA) for the implementation of a Strategic Research Cluster (SRC) on “In-Space electrical propulsion and station keeping”.

The “Electric Propulsion Innovation & Competitiveness” (EPIC) is the PSA project for the Electric Propulsion SRC. EPIC project aims, between others, to provide a clear integrated roadmap of activities and a master plan for its coordination and implementation through the Strategic Research Cluster (SRC) on “In-space Electrical Propulsion and Station-Keeping”.

SRC has the goal of enabling major advances in Electric Propulsion for in-space operations and transportation, in order to contribute to guarantee the leadership of European capabilities in electric propulsion at world level within the 2020-2030 timeframe.

5.4. Improve coordination between European institutions, industry and commercial customers

Engaging in **direct relations with commercial customers** and involving them in R&D programmes is a key success factor to ensure market uptake of European EP systems.

Coordination between European institutions subsidising R&D activities, industry undertaking these developments and commercial customers generating the market should be promoted. This is true for the whole sequence of development activities, from identification of promising technologies to demonstration in orbit.

6. Appendix

6.1. Interviews

Company	Interviewee	Position
Elwing	Grégory EMSELLEM	Chief Executive Officer
Luxspace	Hubert MOSER Farzin ARZPAYMA	System Engineer Senior Telecom Engineer
Mars Space	Michele COLETTI	Co-founder

6.2. Websites

Company	Web address
Elwing	http://www.elwingcorp.com/
LuxSpace	http://www.luxspace.lu/
Mars Space	http://www.mars-space.co.uk/

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