

GUIDELINES FOR STRATEGIC RESEARCH CLUSTER ON IN-SPACE ELECTRICAL PROPULSION AND STATION KEEPING HORIZON 2020 SPACE CALL 2016

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1. INTRODUCTION

This paper presents specific guidelines for the applicants to topic COMPET-3-2016 (In-Space electrical propulsion and station keeping), to be implemented through a Strategic Research Cluster (SRC).¹

The distinct nature of these projects responds to the demand inserted in the Specific Programme for Horizon 2020 (Council Decision 2013/743/EU) that [The implementation will, where appropriate, be based on strategic research agendas developed in consultation with the Member States and National Space Agencies, ESA, stakeholders from European space industry (including SMEs), academia, technology institutes and the Space Advisory Group].

SRCs will be implemented through a **system of grants** connected among them and consisting of:

- 1) **“Programme Support Activity” (PSA):** The main role of this PSA is to elaborate a roadmap and implementation plan for the whole SRC (referred to hereafter as the **SRC roadmap**) and provide advice on the calls for operational grants. In 2014 interested consortia are invited to apply for one PSA **grant** for each of the identified SRCs: “In-space electrical propulsion and Station keeping” and “Space Robotics Technologies”. The PSA is also expected to contribute to the assessment of the evolution (and results) of operational grants.
- 2) **Operational grants:** In future work programmes (2016 and beyond), and on the basis of this **SRC roadmap and the PSA advice for the calls**, the Commission is expected to publish calls for **“operational grants”**. The work programmes will determine whether they will be considered research and innovation grants (100%) or innovation grants (70%). The operational grants will address different technological challenges identified in the roadmap. The objective of this system of grants is that the expected results of each individual grant would, when taken together, achieve the overall objective of the SRC.

Each individual grant within the SRC (either the PSA or operational grants) will follow the general principles of Horizon 2020 in terms of proposals, evaluation, selection process and legal obligations. However, to ensure the effectiveness of the SRC’s operation overall, some specific provisions are necessary.

2. OVERVIEW OF THE SRC ON IN-SPACE ELECTRICAL PROPULSION AND STATION KEEPING

EPIC stands for "Electric Propulsion Innovation & Competitiveness". EPIC is the PSA for the SRC on in-space electrical propulsion and station keeping. EPIC is a coordination and support action (grant number 640199).

2.1. Objectives of the document

This document, prepared with the technical contents supplied by the Programme Support Activity (PSA) EPIC, contains the high level description of work, in terms of goals and achievements, for the purpose of guiding potential applicants and evaluation experts.

¹ The work programme contains a reference to a set of specific guidelines for applicants which are those developed here. However, these guidelines are to be understood as guidance and do not supersede (or derogate from) the legal obligations contained in the work programme and basic legal texts for H2020.

Requirements and guidelines for each activity are given in terms of numbers and rationale, for each technology and for each application that shall be applicable to any proposal which will be submitted in response of COMPET-3-2016.

2.2. The roadmap of the SRC

The SRC on in-space electrical propulsion (EP) and station keeping follows a roadmap developed in EPIC, based on a critical review and gap analysis to match the identified requirements and the available/perspective electric propulsion systems (EPS) and EPS-related technologies.

Definition. An Electric Propulsion System is composed by four different building blocks:

- The thruster components, which includes the thruster itself (discharge chamber, anode, grids) and it(s) cathode(s) or neutraliser(s)
- The propellant components or fluidic management system, including the propellant tanks, valves, filters, pipes, pressure regulators, mass flow controllers
- The power components, which includes the PPU, thruster switching unit and other components such as electrical filter unit for an HET
- The pointing mechanisms (or thrust orientation mechanism), including the alignment mechanism and electronics, as an option on the EPS.

A schematic is presented in Figure 1. For the EPIC Roadmap and the objectives of COMPET-3-2016, the EPS does not include neither the thrust orientation mechanisms nor the tanks, and therefore is **composed of the thruster, propellant and other power components only**.

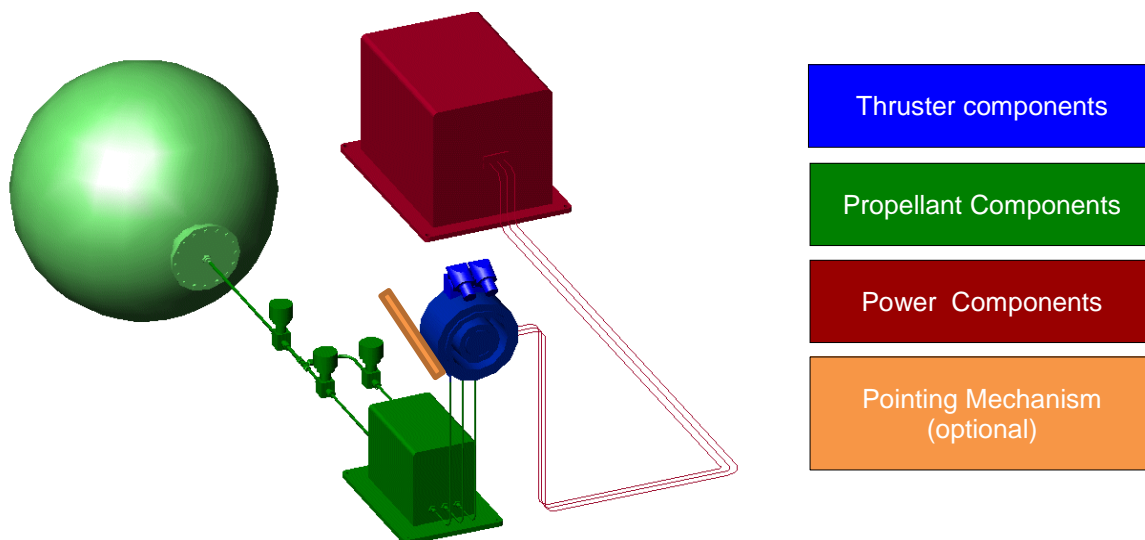


Figure 1: Electric Propulsion System Main components

The principal target of the EPIC roadmap is to increase the competitiveness of the EP systems developed in Europe. The expected competitive position in the European and non-European markets takes into consideration:

- future missions,

- valorisation of competencies/technologies already developed at European level in other national, European and/or international projects,
- performances gain achieved through disruptive technology advancement,
- potential spin-off initiatives for cross-related fields,
- integration capability within launch systems worldwide.

The EPIC roadmap is structured along two lines of developments: incremental and disruptive technologies. The roadmaps are developed taking into account two phases, a first one starting with the **2016 Call**, and a second one starting with a **second Call**.

2.2.1. Roadmap for incremental technologies

The challenge is enabling incremental advances in technologies already under development which require major advances in the development of the thruster itself and its equipment (including power processing unit, PPU, feeding systems, architectures, etc.), in order to increase substantially their TRL to enable them in-orbit in a short-to-medium timeframe.

The term "incremental" technologies refers to the most mature technologies, i.e. the ones with high TRL and possibly with flight heritage, with the physical principal well understood, and with established performances in all of the relevant parameters like thrust, specific impulse (*Isp*), power/thrust ratio, total impulse, and lifetime. The analysis performed focuses the incremental EPS in those based in three thruster types:

- Hall Effect Thruster (HET),
- Gridded Ion Engines (GIE), and
- High Efficiency Multistage Plasma Thrusters (HEMPT).

The three incremental technologies have individual strengths and weaknesses, which make them more competitive for certain applications and less competitive for others. The differences in performance between the three thruster technologies – practically as well as theoretically - are, however, by far not such that future versions of all three systems could not be (part of) a competitive European solution, which is intended to be developed by the SRC.

The advantage of having several mature technologies in the portfolio would be a particular strength of the European EP scene. This would allow a high flexibility to react to possible changes of the satellite market needs and unforeseen developments of the launcher market, giving to the European stakeholders a strategic position.

The roadmap developed by the EPIC consortium addresses all three technologies in the incremental line. It would allow the three types of thruster systems to be developed to higher TRL levels on a first stage (2016-2020), while complying with certain requirements to address the needs of a number of applications.

The main application domains targeted are:

- Telecom/MEO (including Navigation)
- Space Transportation
- LEO (including constellations)
- Exploration/Interplanetary/Science

Each thruster-based system shall address different gaps for different applications. A schematic view of the roadmap is presented in Figure 2: the layers represent different applications where each thruster-based system has to address its own gaps.

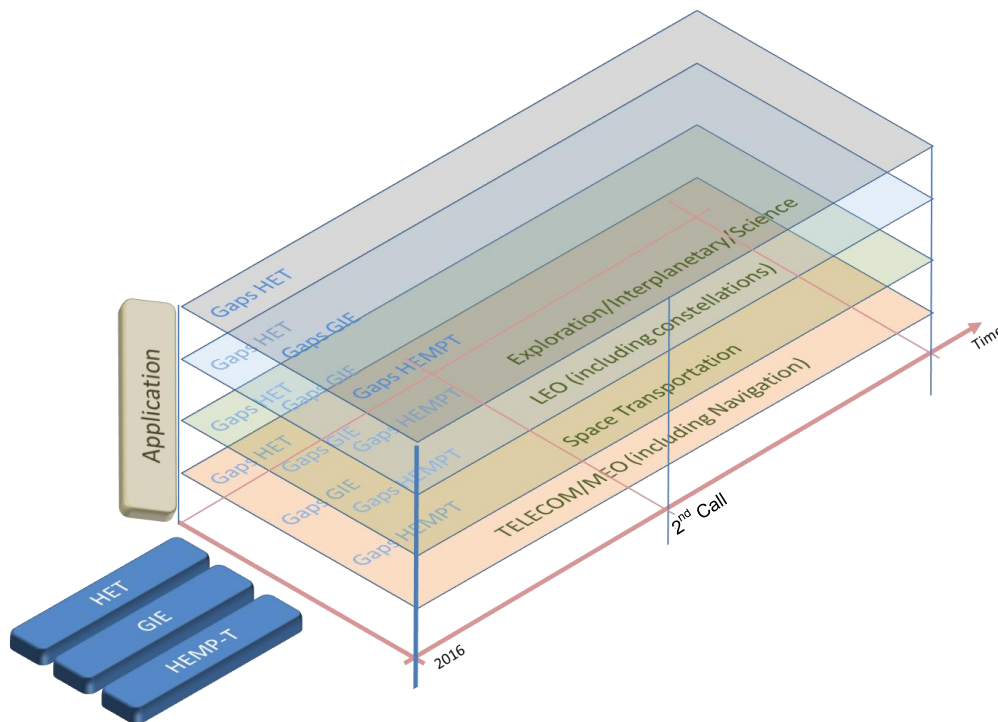


Figure 2: The Roadmap logic for the Incremental EP systems

The general roadmap is characterized by a technology/application approach whose layout presents two domains: the thruster domain and the application domain.

The technology line for the incremental line is characterized by the electric propulsion **system aspects**. For the incremental developments the complete EP system needs to be brought to the higher TRLs required for subsequent market introduction.

Each EP system, for the purpose of the roadmap and COMPET-3-2016, shall include the development of the thruster with the following sub-elements:

- Power Processing Unit (PPU)
- Fluidic Management System
- Cathode/Neutralizer.

Some common aspects to all thruster-based systems are the following:

- Alternative/non-conventional propellants
- High Power testing facilities and diagnostics
- EPS testing methods – Standardization of EP testing

During the first Call (2016) requirements definition, mission and system impacts should be considered to better address the EP system developments for the targeted applications.

Experience has shown that the **PPU** is a technically challenging and expensive part of each EP system (up to 50 % of the cost - indicative). Power performance beyond state-of-the-art, which is one of the tasks to be fulfilled for telecom applications (and even more for space transportation), may indeed be more challenging on the PPU side than for the thruster. Also for telecommunication applications dual mode EP systems are sought, which can switch between a high thrust - lower *Isp* mode for Electric Orbit Raising (EOR) and a high *Isp* – lower thrust mode for station keeping. The challenge for a dual mode PPU is to handle both high power at low voltage and high voltage. Also this requirement may make the dual mode PPU development more difficult than the dual mode thruster development. As telecommunication satellites are currently the most attractive application for electric propulsion systems and all of the three incremental technologies shall improve their competitiveness in this field, development of the adequate power supply system is part of the roadmap for all incremental technologies.

The **fluidic management system**, which provides the EP thrusters with the right amount of propellant, also needs to be improved. The aim is to simplify the fluidic architecture in order to reduce cost and complexity and also mass on the platform. Additionally, some fluidic systems presently produced together with European EP thrusters may contain parts, which are subject to export restrictions, such as pressure regulators.

Last but not least **cathodes/neutralisers** are required for all three incremental technologies. High current cathodes for thrusters with power performance beyond state-of-the-art do not yet exist in Europe or are not yet qualified. They need to be developed as part of the projects in all three technology lines.

The common aspects mentioned above are not meant to be addressed as separate projects. The topics mentioned are supposed to be investigated in parallel with the EP system development, as they are related to: alternative propellants, test facilities and common standards for testing. The standardisation of testing methods with reliable diagnostics tools is very important to compare results obtained at different facilities or with different technologies comparable among each other. All projects shall take these common topics into account and propose solutions.

First Call (2016). It is proposed through this call to start the development of a complete EP system, including cathodes, PPU and fluidic system management, up to TRL levels dependant on the targeted applications. The developments should foresee, amongst others, a definition of the requirements of the EPS intended to be developed for the chosen application(s); the impacts of this EPS on the system (platforms) and type of missions should also be studied.

Second Call. Completion of development of the complete EP system, including cathodes, PPU and fluidic system management, achieving the targeted higher TRLs. An assessment of the achievements in the first Call projects will be made for the second Call, and possible changes in the international competition, future missions, or new market requirements will be taken into consideration for the second call definition. Depending on the outcome of this analysis, the long-term goals may need to be redefined and the roadmap may need to be adjusted accordingly. The performance of the projects funded under Call 2016, together with the factors above and the available funding at the time, will have an important influence on the lines of the roadmap to be further funded and whether a down-selection should be made.

As mentioned in Figure 2, different applications for electric satellite propulsion have been considered for the incremental technologies developments.

The geostationary telecommunication satellite market is today the most attractive commercial application for electric propulsion and is considered to be of highest priority for the development of future EP systems. MEO, LEO, Space transportation, and exploration and science are the other applications considered and their relative importance is ranked to decrease in the given order. The three incremental EP technologies will have to focus on different technical parameters to be worked on and to be improved, such that EP systems based on each thruster technology can become competitive on the commercial market within a timeframe compatible with Horizon 2020.

The LEO constellation market (Space X, OneWeb, etc.) is opening new opportunities to EP systems which are capable to offer low cost and high performance solutions to the propulsion requirements of such missions involving hundreds or thousands of spacecraft.

As the technologies have individual strengths and individual weaknesses, they are expected to address and improve on different capabilities.

The expected TRL on system level for these developments as well as the main activities in each application field are depicted as well in further sections of this document. For instance, European Non-Dependence, competitiveness and the understanding of the interactions between the EP system and the spacecraft are goals to be achieved as much as possible across all application fields. Common goal for all three technologies with respect to the telecommunications application is a significant reduction of the EPS recurrent costs (30% on the overall system - indicative), and particularly for the PPUs. As a matter of importance with respect to costs, alternative propellants to replace Xenon could be investigated.

It should be noted that due to the different type and physical principle of the three technologies tackled under this incremental line, only the requirement on the power of the EPS is the same for the HET, GIE and HEMPT and is also dependant on the application targeted. Therefore, all the other performance parameters are technology specific.

2.2.2. Roadmap for disruptive technologies

This topic focuses on promoting the **Research, Technology and Development (RTD) of very promising and potentially disruptive concepts** in the field of Electric Propulsion (focusing on thrusters), in order to increase the currently low or very low TRL of potentially breakthrough concepts which in the long term could change the EP landscape.

Aside from the mature and well-established EP technologies within Europe (HET, GIE and HEMPT), tackled through the Incremental line, a number of alternative thruster concepts are emerging or have already gained some maturity, some of which could disrupt the propulsion sector if they are able to:

- provide a radical improvement in one or more performance attributes that are perceived as more valuable than those of more mature and well established thruster technology (HET/GIE/HEMPT), leading to them becoming a preferred technology for certain applications/markets; or,
- enable new markets or applications not possible with the existing technologies.

New and innovative concepts, which show disruptive potential although not yet fully explored, can be considered under this line. The alternative thruster concepts and related technologies (such as innovative PPU architecture, direct drive concepts, new testing techniques, new modelling tools, etc.) identified within the frame of “disruptive technologies” shall show some potential cost reduction and/or produce a radical impact in electric propulsion system performances, applications and efficiency.

Disruptive EP technologies span a huge range, from fairly simple and inexpensive devices to highly complicated ones. Similarly, the TRL of disruptive technology thrusters can differ greatly ($TRL \leq 4$). Some thruster types may still be in a concept state.

The three thruster technologies (HET/GIE/HEMPT) are classified as incremental, all the others are considered to be disruptive, discarding the electrothermal thrusters. As a result of this classification thruster models or planned developments with very low TRL, like μ N-GIE and μ N-HEMPT or their high-power counterparts like 10 kW HET thrusters are taken as incremental, whereas FEED or MPD thrusters fall into the disruptive technology class. This is a logical consequence of the definition of disruptive technologies. In the case of HET, GIE, and HEMP-T the physical processes are well understood and their scalability should not lead to unexpected adverse effects.

The **application fields**, for which disruptive thruster technologies shall be developed, are, in principle but not only,: Telecommunications, Space Transportation, LEO, MEO, Exploration, Interplanetary and Science. Due to the lower maturity and development status of these disruptive technologies no attempt has been made to relate individual technologies to specific applications, as it has been done for the incremental technologies. Moreover the technologies shall all be invited to propose their development lines and assign the expected results to the application field(s) where they fit best and where the disruption could be provoked. Applications for the technology should not be limited to looking at the same applications as the incremental technologies. The aim of further developing disruptive technologies is to find thruster and other EP-related concepts which can enable new applications, which are not technically feasible today, which can open new markets or shape the market in the medium to long term by offering Europe with new capabilities and allowing strategic positions.

For disruptive thruster technologies, where the development potential is not yet fully explored, the projects shall concentrate on the thruster technology (and respective cathode, if applicable). The aim is, with the help of a prototype or bread board model, to better understand the active physical principles, to improve the thruster performance, to look for alternative propellants to Xenon or non-conventional propellants, and to analyse the impact on the whole EP system. At least for the first phase, the 2016 Call proposals, a high TRL on system level is not expected.

Another aspect of disruptive technologies is the possibility for other elements in the EP system, rather than the thruster, to provoke a radical disruption. The PPU is the most evident example of such a subsystem with an enormous influence on cost and performance of the EP system. A radical break-through in PPU architecture or power sources including the direct drive concept could enable EP systems with performance parameters and recurring cost, which would make these very competitive on the market or even open up or shape new markets. These and other possible elements, not specifically mentioned here, are referred to as Transversal EP Concepts, and proposals for such concepts or elements shall be encouraged in the disruptive technologies line. This line could also include new testing techniques or modelling tools, which would bring a much better understanding of the phenomena than with what is available today.

The roadmap for disruptive technologies is based on currently known low TRL concepts such as HPT, ECR, QCT, PPT, and MPD, **but other thruster types are by no means excluded from it**. A specific topic to be addressed also by disruptive technologies could also be micro-propulsion for scientific applications.

Additional to thruster technologies, projects dealing with **transversal technologies** are welcomed. A transversal technology development could address elements which could be common to several thrusters. These are, for example concepts such as:

- direct drive,
- radical innovations in PPU,
- new equipments,
- innovative power source architectures,
- R&D studies (including modelling and testing) on advanced combination of materials for new PPUs,
- new electrical system architecture for EP,
- hybrid solution to drive different types of EP thrusters, or
- any other promising and potentially disruptive concept not specifically mentioned here.

The disruptive projects shall start in the 2016 Call timeframe, and continue with a **second Call**. In the first call, the disruptive technologies projects are not expected to develop a full EP system. Their task will be to demonstrate the potential of the technology to achieve the ambitious goals of this line in the medium-to-long term. These projects shall also include modelling and testing.

For the **second Call** the results achieved so far in the running disruptive projects from the first call will be evaluated and checked against possible international competition. Possible changes in the priorities of the commercial/institutional markets, future missions and/or new requirements will be taken into account, additionally. For the continuation of these projects through the second Call period, the same modalities apply as for incremental technologies. The number of technologies to be funded will be defined in due time for the second Call. Not all technology developments developed in the first phase might continue, and/or new ones might start on the second phase.

2.2.3. *SRC roadmap evolution*

The roadmaps prepared by EPIC for the incremental and disruptive technologies for electric propulsion foresee two subsequent phases, one starting with the 2016 Call, and the other one starting with a second call:

- Phase 1 = Horizon 2020 Space Work Programme 2016 and the SRC Operational Grants (OGs) funded through the COMPET-3-2016 call topic.
- Phase 2 = Horizon 2020 Space next Work Programmes with future SRC OGs funded through it.

Figure 3 provides an overview of the high-level SRC Roadmap evolution. In Phase 1, the basis will be laid for achieving the final aim of the SRC “In-Space Electrical propulsion”: European technical leadership and economic competitiveness on Electric Propulsion at world level. To that extend, the most promising technologies shall be supported and

enabled to reach higher levels of maturity, while proving their suitability for mid to long term identified or new applications needs.

2016 Call will focus on the challenge of enabling major advances in Electric Propulsion for in-space operations and transportation, in order to contribute to guarantee the leadership through competitiveness and non-dependence of European capabilities in electric propulsion at world level within the 2020-2030 timeframe, always in coherence with the existing and planned developments at national, commercial and ESA level.

Phase 2 foresees the continuation of the two lines of developments (incremental and disruptive technologies). Aspects as the number of projects, continuation or establishment of new projects, expected funding, etc. will remain open until the future Work Programmes are adopted, etc. The objective for this second phase is to support the more promising technologies developed in Phase 1 towards higher TRLs, in order, at the end of the Phase 2 projects, to achieve the SRC expectations and, potentially, be ready to prepare the chosen EP system(s) for a potential IOD/IOV.

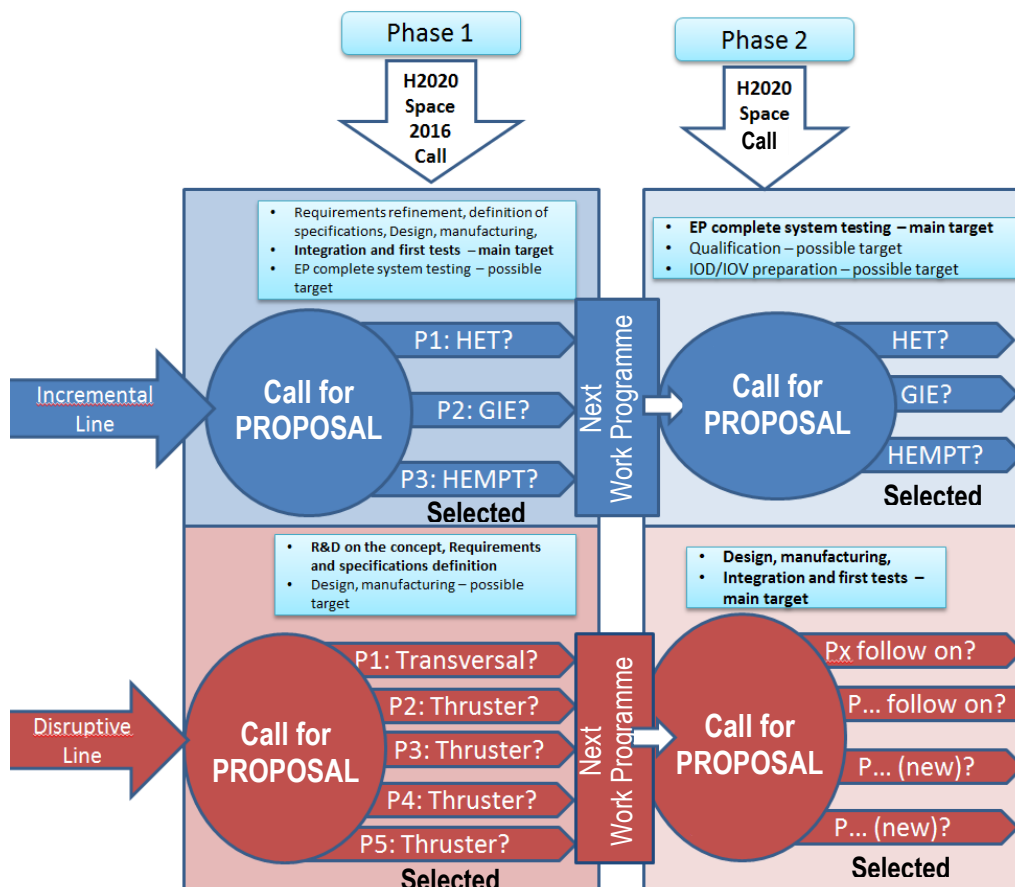


Figure 3: High-level SRC Roadmap evolution

2.2.4. Conclusion

The advantage of having several mature technologies in the portfolio of incremental technologies is a particular strength of the European EP scene. This allows much higher flexibility to react to possible changes of the satellite market needs and unforeseen developments of the launcher market (e.g. more payload capability in GTO, lower launch cost, direct injection, etc.), giving the European stakeholders a strategic position. System aspects, PPU, fluidic systems, cathodes and neutralizers are addressed with different

levels of expected improvements for the three technologies, thus resulting as relevant parameters in the technology/application roadmap for the incremental lines.

The aim of further developing disruptive technologies is to find thruster concepts (and respective cathode, if applicable) and other EP system concepts which can enable new applications which are not technically feasible today, which can open new markets, or to shape the markets in the medium to long term by offering Europe new or improved capabilities (better performances, lower cost, high industrialisation efficiency, etc.) and strategic positions.

Technical Annex

A - INCREMENTAL LINE

This section provides additional information in order to clarify what is expected from the proposals to be submitted in response to COMPET-3-2016: SRC – In-Space electrical propulsion and station keeping a) Incremental Technologies.

The projects to be funded under *COMPET-3-2016 a) Incremental Technologies* are meant to substantially advance the TRL of the EPS based in either:

- 1) HET technology,
- 2) GIE technology,
- 3) HEMPT technology,

in order to enable a number of application areas such as, Telecommunication / Navigation, LEO, Exploration, etc. in the mid-term, as described in the COMPET-3-2016 call text.

In practical terms, and in order to achieve the “Expected Impact” on this line, including the above mentioned goal, the proposals shall cover a number of topic areas and their assigned requirements, to which it is referred from now on as “**activities**”. Each “activity” is targeted to a specific application.

This section, focused on the Incremental Technologies line, is composed of several tables, which provides specifications for the activities to be pursued within the projects to be funded. The first table (Table 0) is applicable to and common to all the proposals focused on Incremental Technologies (HET/GIE/HEMPT), independently of the targeted application.

The remaining tables in this section (Tables 1.1 to 1.3, 2.1 to 2.4 and 3.1 to 3.4) identify specific challenges and considerations for each of the technology-based EPS and for each application. These tables shall be applicable to each thruster technology (HET/GIE/HEMPT) for each targeted application.

In summary, the proposals are invited to focus on the following activities, depending on the thrusters technology (HET/GIE/HEMPT) they are based on:

Proposals based on sub-line	Application activities the proposals shall address	Application activities the proposals can choose to address	Applicable Tables
HET	<ul style="list-style-type: none"> • Telecommunications / Navigation • LEO • Space Transportation / Exploration / Interplanetary 		0 1.1 1.2 1.3
GIE	<ul style="list-style-type: none"> • Telecommunications / Navigation • LEO 	<ul style="list-style-type: none"> • Space Transportation / Exploration / Interplanetary • Science 	0, 2.1, 2.2, 2.3 (optional), 2.4 (optional)
HEMPT	<ul style="list-style-type: none"> • Telecommunications / Navigation • LEO 	<ul style="list-style-type: none"> • Space Transportation / Exploration / Interplanetary • Science 	0, 3.1, 3.2, 3.3 (optional), 3.4 (optional)

It is important to note that the thrust orientation mechanism(s), the tanks and the SC power generation and distribution subsystem are not within the targets of these activities. Therefore the projects are meant to cover the following aspects of the EPS: thruster, cathode, PPU and fluidic management system.

Incremental technologies tables identify specific challenges for each application because each of the three EPS Incremental technologies (HET/GIE/HEMPT) is based on different physics phenomena and different concept architecture. The requirements set in these tables have been selected in order to request equivalent efforts beyond the actual state of the art for each technology.

Due to the different type and physical principle of the three technologies tackled under this incremental line, only the requirement on the power of the EPS is the same for the HET, GIE and HEMPT and is also dependant on the application targeted. Therefore, all other performance parameters targeted are technology specific.

Table 0 All incremental technologies (HET/GIE/HEMPT) activities	
Description and needed Action	<p>The Electric Propulsion Systems (EPS) based on (HET/GIE/HEMPT) are considered mature enough at the moment to allow for incremental steps through this SRC aiming at enabling capabilities like operating at dual mode, higher/lower power, Electric Orbit Raising (EOR)/Station Keeping (SK), etc., required by a number of applications and markets, which the current systems, some of them qualified and others with flight heritage, are not able to provide.</p> <p>The main action needed is to improve the current state of the art performances specified and reduce the cost of the EPS, in order to satisfy the medium and future needs of different markets.</p> <p>The projects shall cover the development, validation (including testing) of the EPS. The EPS development and validation (including testing) shall be done following the relevant ECSS Standards, and testing shall be performed in a relevant environment.</p>
Reference(s)	<ul style="list-style-type: none"> • Relevant ECSS Standards (www.ecss.nl) for the different elements of the EPS (i.e.: ECSS-E-ST-35C-Rev.1 – Propulsion general requirements, ECSS-E-ST-35-01C - Liquid and electric propulsion for spacecraft, , ECSS-E-ST-10-03C - Testing) and for the relevant milestone documentation (ECSS-E-ST-10C) • Proposers are invited to consult other EPIC public documentation available under www.epic-src.eu (EPIC website)
Proposals indicative content	<ul style="list-style-type: none"> • Proposals shall present an adequate approach addressing the relevant applications to be covered in a balanced way including all aspects and equipment of the EPS (thruster, cathode, PPU and fluidic management system). • Proposed developments shall include modelling/simulation and testing of each equipment in the subsystem as well as of the EPS. • Proposals shall include an initial work package dedicated to the requirements derivation based on the targeted application, as well as an analysis of the different classes of missions and EP system impacts on the satellite and the potential missions. The derivation of EPS specific requirements from the targeted application needs shall be included, taking into account the considerations described in the tables for each technology and application. Regarding the system impacts, thermal dissipation, plasma effects, electromagnetic interaction or any other effects shall be taken into account including considerations on integration of the EP system into the SC. • Proposals shall go beyond the present state of the art and, preferably, the expected state of the art at the time of completion if alternative technologies are being developed outside Europe. • Proposals shall demonstrate the readiness and interest to carry the developments further on through future calls of this SRC, by including a long-term plan for the developments to reach the TRL targeted in the EPIC

	<p>roadmap at the end of the SRC (2023-2024) and, whenever possible, in-orbit validation/demonstration, and a business plan on how to access the selected market with a full range of competitive products. These plans should be analysed in depth through a dedicated work package within the project.</p> <ul style="list-style-type: none"> • In order to reduce the cost of the full EPS system for increasing competitiveness in the markets, proposals shall clarify the expected cost (indicative) reduction for the whole EPS and the specific subsystems together with a clear methodology. • Proposals shall seek synergies while avoiding duplications with already existing or planned developments by other entities in Europe, such as ESA, EU-FP, EU-H2020, National Space Programmes, and commercial initiatives. • Proposals shall clearly declare any background IPR from the proposers that will be used to perform the activities described.
Expected Deliverables	<p>At least the following Deliverables shall be produced:</p> <ul style="list-style-type: none"> • System Studies Report, • Business Plan including Market Analysis, • PDR, CDR data packages including Technical Specification, System Design, Detail Design Report including justifications, Design and Development Plan, Manufacturing Report, Test and Verification Plans, Test and Verification Reports, Qualification Plan including ROM Cost Assessment (recurrent and development), according to the relevant ECSS Standards (ECSS-E-ST-10C) • Risk Assessment and Contingency Analysis report (yearly), • KPIs report (yearly), • Dissemination and educational public material: Activity and results presentations, photos, posters, videos, professional communication and educational movies; and • Project website.

A1 - Hall-Effect Thruster-based EPS (HET): Project activities

Table 1.1 Hall Effect Thrusters (HET) EPS activities oriented to Telecommunication / Navigation applications	
Description and needed Action	<p>EP is one of the new revolutionary technologies at the moment in satellite markets. In the case of Telecommunications, this is the main short-term commercial market for EP, with chemical propulsion as main competitor, and a fierce international competition.</p> <p>Hall Effect Thrusters (HET) EPS are the preferred option for this market at the moment due to their flight heritage and the acceptable Electric Orbit Raising (EOR) time. Activities in this area shall aim at consolidating this position in the mid-term and at being one step ahead for the future needs of the Telecom market, by substantially improving EPS performances and reducing cost of the EPS. All HET proposals shall cover this activity and the requirements specified hereafter.</p>
Requirements	
<ul style="list-style-type: none"> Target TRL² at the end of the COMPET-3-2016 project 	5-6

² TRL defined as ISO Standard 16290. This TRL definition applies to all the TRL mentioned in this Annex. The differences between TRL ISO Standard 16290 and the TRL M95 reference are basically described in the following table:

	Mankins 95 reference		ISO 16290 standard
TRL 1	Basic principles observed and reported	Equivalent	Basic principles observed and reported
TRL 2	Technology concept and/or application formulated	Equivalent	Technology concept and/or application formulated
TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept	Equivalent	Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 4	Component and/or breadboard <u>validation</u> in laboratory environment	Equivalent	Component and/or breadboard <u>functional verification</u> in laboratory environment
TRL 5	Component and/or breadboard <u>validation</u> in relevant environment	Split	Component and/or breadboard <u>critical function verification</u> in a relevant environment
TRL 6	<u>System/subsystem</u> model <u>or prototype</u> demonstration in a relevant environment (<u>ground or space</u>)	Shifted	Model <u>demonstrating the critical functions of the element</u> in a relevant environment
TRL 7	<u>System prototype demonstration in a space</u> environment	Removed	<u>Model demonstrating the element performance for the operational</u> environment
TRL 8	Actual system completed and <u>"flight qualified" through test and demonstration (ground or space)</u>	Equivalent	Actual system completed and <u>accepted for flight ("flight qualified")</u>
TRL 9	Actual system "flight proven" through successful mission operations	Equivalent	Actual system "flight proven" through successful mission operations

<ul style="list-style-type: none"> Target TRL at the end of the SRC (2023/2024) if the project were to continue 	7-8	
<ul style="list-style-type: none"> Dual mode 	250-800 V	The EPS should be optimized to work in two different points for two different types of functions: EOR mode with high thrust to minimise the time to final orbit; and SK mode with high efficiency to minimize the propellant used during the in-orbit operations.
<ul style="list-style-type: none"> EPS Power 	> 5 kW for EOR mode > 3 kW for SK mode	The EPS should demonstrate power performances beyond the state of the art, justifying the specific power performance selected with an analysis of the medium to long term market needs.
<ul style="list-style-type: none"> P/T 	~ 14 W/mN for EOR mode ~ 19 W/mN for SK mode	The time to orbit is a critical requirement from satellite operators and is fully dependent on the P/T ratio.
<ul style="list-style-type: none"> Isp 	> 1500 s for EOR mode > 2000 s for SK mode	The EPS efficiency in orbit operations is a critical requirement from satellite operators to optimize the mass of the propellant. The higher the Isp the better, but this requirement is a trade-off of several performance parameters. The Isp should be increased from the current state of the art, in order to make HET systems more competitive for SK utilisations.
<ul style="list-style-type: none"> Innovative and cheaper PPU 	The EPS should propose innovative and cheaper PPUs (addressing complexity vs. indicative cost), covering: industrialisation (reduction of number of EEE components, simplification of HV design, etc.), high power (high voltage (HV) modules in parallel, thermal coupling, etc.), in-orbit reconfiguration and modularity, etc. An asset would be a complementary study of alternative simplified PPU concepts for general orbit transfer application using direct input from spacecraft solar power systems.	
<ul style="list-style-type: none"> Recurring Cost reduction 	30% of the present EPS cost (indicative)	

Table 1.2		
Hall Effect Thrusters (HET) EPS activities oriented to LEO applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. There are many developments in LEO systems and applications, and EP could play a significant role in this market.	
	Hall Effect Thrusters (HET) EPS have good prospects for use in LEO, due to their power-to-thrust ratio allowing higher thrusts for the power-limited satellites in LEO.	
	Projects in this area shall aim at improving EPS performances and reducing the recurrent indicative cost of the EPS.	
	All HET proposals shall cover this activity and the requirements specified hereafter.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	5-6	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	7-8	
• Cycles	TBD by proposers	Due to the eclipses, a large number of cycles is needed for operation in LEO. Thus, the design shall take into account the impact that it has on performances and lifetime of the EPS. This number of cycles shall be compliant with the lifetime requirement of the platforms (currently around 5 years)
• EPS Power	200-700 W	The EPS should demonstrate useful performances when operated at low to medium power levels.
• P/T	< 16 W/mN	Low P/T ratio is needed in order to obtain useful thrust when little power is available.
• Isp	> 1500 s	The EPS efficiency is important for the often mass-limited LEO missions. The higher the Isp the better, but this requirement is a trade-off of several performances.
• Innovative and cheaper PPU	Low cost and compact PPU	
• EPS Cost	< 200 k€ (indicative)	
Remarks	Compact, integrated and low mass system shall be considered.	

Table 1.3		
Hall Effect Thrusters (HET) EPS activities oriented to Transportation / Exploration / Interplanetary applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. The specific characteristics enable new types of missions and applications, in particular in Transportation, Exploration and Interplanetary Missions. Hall Effect Thrusters (HET) EPS are a good option for this market at the moment due to their high thrust capabilities, though the <i>Isp</i> is not the best for interplanetary missions. Activities in this area shall aim at consolidating this position in the mid-term and at being one step ahead for the future needs of this market, by substantially improving EPS performances and reducing cost. All HET proposals shall cover this activity and the requirements specified hereafter.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	4-5	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	6	
• Lifetime (Total Impulse)	TBD by proposers	The required large total impulse implies a very long period of thrust operation. Thus, the lifetime of the system must be analysed and improved where necessary, in order to ensure that the system can meet the mission needs.
• EPS Power	> 20 kW	High Power thruster are required, since high thrust levels will be required for these types of missions, and the systems are expected to be able to provide higher power to the EPS.
• <i>P/T</i>	< 20 W/mN	High thrust levels will be required in order to enable the missions with reasonable durations.
• <i>Isp</i>	2500 s	The EPS efficiency is a critical requirement to allow the use of an EP technology in these types of missions, as they usually require large delta-V, and there are severe mass constraints.
• PPU	High power PPU able to provide 20 kW to the thruster	
Remarks	Clustering of lower power EPS could be considered.	

A2 - Gridded Ion Engines-based EPS (GIE): Project activities

Table 2.1 Gridded Ion Engine (GIE) EPS activities oriented to Telecommunication / Navigation applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. For Telecommunications this is the main short-term commercial market for EP, with chemical propulsion as main competitor, and a fierce international competition. Gridded Ion Engines are one of the best options for this market at the moment due to their high <i>Isp</i> , which allows significant mass savings and allows lower launch costs. Projects in this area shall aim at improving this position in the mid-term and at being one step ahead for the future needs of the Telecom market, by substantially improving EPS performances and reducing cost of the EPS. All GIE proposals shall cover this activity and the requirements specified hereafter.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	5-6	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	7-8	
• Dual mode	TBD by proposers	The EPS should be optimized to work in two different points for two different types of functions: EOR with high thrust to minimise the time to final orbit; and SK with high efficiency to minimize the propellant used in the in-orbit operations. In the case of GIE, it is expected that the effort for dual mode will mainly aim to improve the thrust level for EOR at an adequate <i>P/T</i> ratio.
• EPS Power	> 5 kW for EOR mode > 3 kW for SK mode	The EPS should demonstrate power performances beyond the state of the art, justifying the specific power performance selected with an analysis of the medium to long term market needs.
• <i>P/T</i>	~ 21.5 W/mN for EOR mode ~ 30 W/mN for SK mode	The time to orbit is a critical requirement from satellite operators and is fully dependent on the <i>P/T</i> ratio.

<ul style="list-style-type: none"> <i>Isp</i> 	<p>> 3000 s for EOR mode</p> <p>> 4500 s for SK mode</p>	The EPS efficiency in orbit operations is a critical requirement from satellite operators to optimize the mass of the propellant. The higher <i>Isp</i> the better, but this requirement is a trade-off of several performances.
<ul style="list-style-type: none"> Innovative and cheaper PPU 	The EPS should propose Innovative and cheaper PPUs (addressing complexity vs. cost), covering: industrialisation, simplification of the design, modularity and in-orbit reconfiguration. An asset would be a complementary study of alternative simplified PPU concepts for general orbit transfer application using direct input from spacecraft solar power systems.	
<ul style="list-style-type: none"> Recurring Cost reduction 	30% of the present EPS cost (indicative)	

Table 2.2		
Gridded Ion Engine (GIE) EPS activities oriented to LEO applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. There are many developments in LEO systems and applications, and EP could play a significant role in this market. Gridded Ion Engines have good prospects for use in LEO, due to the mass savings they can offer due to their high <i>Isp</i> . They have already demonstrated good performances in some LEO applications, such as drag compensation. Projects in this area shall aim at improving EPS performances and reducing the recurrent cost of the EPS. All GIE proposals shall cover this activity and the requirements specified hereafter.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	4-5	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	6-7	
• Cycles	TBD by proposers	Due to the eclipses, a large number of cycles are needed for operation in LEO. Thus, the design shall take into account the impact that it has on performances and lifetime of the EPS. This number of cycles shall be compliant with the lifetime requirement of the platforms (currently around 5 years).
• Power	200-700W	The EPS should demonstrate useful performances when

		operated at low to medium power levels.
• P/T	~ 25 (W/mN)	Low P/T ratios are needed in order to obtain useful Thrust when little power is available.
• Isp	> 3500 (s)	The EPS efficiency may be less important for the often mass-limited LEO missions than a high Isp . The higher the Isp the better, but this requirement is a trade-off of several performance parameters.
• Innovative and cheaper PPU	Low complexity PPU	
• EPS Cost	< 200 k€ (indicative)	
Remarks	Compact and low mass integrated system	

Table 2.3		
Gridded Ion Engine (GIE) EPS activities oriented to Space Transportation / Exploration / Interplanetary applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. The specific characteristics enable new types of missions and applications, in particular in Transportation, Exploration and Interplanetary Missions. Gridded Ion Engines have already been used for Interplanetary missions, due to their good <i>Isp</i> and lifetime characteristics. In order to increase their competitiveness within interplanetary missions, and as well to extend its use for Space Transportation and Exploration missions, the performances of existing systems must be improved. This activity is optional for GIE proposals.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	4-5	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	6	
• Lifetime (Total Impulse)	TBD by proposers	The required large total impulse implies a very long period of thrust operation. Thus, the lifetime of the system must be analysed and improved where necessary, in order to ensure that the system can meet the mission needs.
• Power	> 20 kW	The EPS should demonstrate power performances beyond the state of the art, justifying the specific power performance

		selected with an analysis of the medium to long term market needs. High power will be needed to develop the high thrust needed for some of the applications.
• P/T	$< 35 \text{ W/mN}$	In order to reach the adequate thrust levels for these types of missions, the P/T must be low enough. The activities must be aimed at improving the P/T ratio.
• Isp	$> 6000 \text{ s}$	High Isp is needed to achieve the large delta-V needed for these missions with a propellant mass compatible with launcher performance. The higher the Isp the better, but this requirement is a trade-off of several performances. The Isp should be increased from the current state of the art.
• Innovative and cheaper PPU	High power PPU able to provide 20 kW to the thruster	
Remarks	Clustering of lower power EPS could be considered.	

Table 2.4		
Gridded Ion Engine (GIE) EPS activities oriented to Science applications		
Description and needed Action	Science missions can have very specific propulsion requirements. Clear examples are the missions requiring micropropulsion with high controllability, for formation flying and high-accuracy orbit control. These missions also require continuous operation for extended periods of time, so they have in addition high <i>Isp</i> and long lifetime requirements. This activity is optional for GIE proposals.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	4-5	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	6-7	
• Resolution	<1 μN	In low thrust range (<100 μN)
• EPS Power	< 50 W	Low power levels are expected for micro-propulsion operation.
Lifetime	> 6 years	Very long continuous operation
• <i>Isp</i>	> 1000 s	High <i>Isp</i> is needed, in order to support continuous operation for periods. The higher the <i>Isp</i> the better, but this requirement is a trade-off of several performance parameters.

• PPU	The PPU should be adapted to allow the large throttability voltage control needed to ensure high thrust resolution.
Remarks	Large throttability (1:50) Very low noise

A3 - Highly Efficient Multistage Plasma Thruster-based EPS (HEMPT): Project activities

Table 3.1		
Highly Efficient Multistage Plasma Thruster (HEMPT) EPS activities oriented to Telecommunication / Navigation applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. Telecommunications is the main short-term commercial market for EP, with chemical propulsion as main competitor, and a fierce international competition. Highly Efficient Multistage Plasma Thruster (HEMPT) represents a promising option for this market. Projects in this area shall aim at demonstrating improved performances in the mid-term and at being one step ahead for the future needs of the Telecom market, by substantially improving EPS performances and reducing cost of the EPS. All HEMPT proposals shall cover this activity and the requirements specified hereafter.	
Requirements:		
• Target TRL at the end of the COMPET-3-2016 project	5-6	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	7-8	
• Dual mode	400-1000 V	The EPS should be optimized to work at two different points for two different types of functions: EOR with high Thrust to minimise the time to final orbit; and SK with high efficiency to minimize the use of propellant in the in-orbit operations.
• EPS Power	> 5 kW for EOR mode > 3 kW for SK mode	The EPS should demonstrate power performances beyond the state of the art, justifying the specific power performance selected with an analysis of the medium to long term market needs.
• P/T	~ 16 W/mN for EOR mode ~ 28 W/mN for SK mode	The time to orbit is a critical requirement from satellite operators and mainly depends on the P/T ratio.
• Isp	> 1500 s for	The EPS efficiency in orbit operations is a critical

	EOR mode > 3000 s for SK mode	requirement from satellite operators to minimize the mass of the propellant. The higher the <i>Isp</i> the better, but this requirement is a trade-off of several performances.
<ul style="list-style-type: none"> Innovative and cheaper PPU 	The EPS should propose innovative and cheaper PPUs (addressing complexity vs. cost), covering: industrialisation (reduction of number of EEE components, simplification of HV design, etc.), high power (high voltage (HV) modules in parallel, thermal coupling, etc.), in-orbit reconfiguration and modularity, etc. An asset would be a complementary study of alternative simplified PPU concepts for general orbit transfer application using direct input from spacecraft solar power systems.	
<ul style="list-style-type: none"> Recurring Cost reduction 	30% of the present EPS cost (indicative)	

closely

Table 3.2		
Highly Efficient Multistage Plasma Thruster (HEMPT) EPS activities oriented to LEO applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. There are many developments in LEO systems and applications, and EP could play a significant role in this market. HEMPT represents a promising technology for this market, although the performances at the available power levels in LEO should be demonstrated. Projects in this area shall aim at improving EPS performances and reducing the recurrent cost of the EPS. All HEMPT proposals shall cover this activity and the requirements specified hereafter.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	4-5	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	6-7	
• Cycles	TBD by the proposers	Due to the eclipses, a large number of cycles are needed for operation in LEO. Thus, the design shall take into account the impact that it has on performances and lifetime of the EPS. This number of cycles shall be compliant with the lifetime requirement of the platforms (currently around 5 years)

• Power	200-700 W	The EPS should demonstrate useful performances when operated at low to medium power levels.
• P/T (for EOR)	< 20 W/mN	Low P/T ratios are needed in order to obtain useful Thrust when little power is available. The P/T ratio should be decreased from the current state of the art.
• Isp (for SK)	> 1600 s	The EPS efficiency may be less important for the often mass-limited LEO missions than high Isp . The higher the Isp the better, but this requirement is a trade-off of several performances.
• Innovative and cheaper PPU	Low cost and compact PPU	
• EPS Cost	< 200 k€ (indicative)	
Remarks	Compact and low mass integrated system	

Table 3.3		
Highly Efficient Multistage Plasma Thruster (HEMPT) EPS activities oriented to Space Transportation/Exploration/Interplanetary applications		
Description and needed Action	EP is one of the new revolutionary technologies at the moment in satellite markets. The specific characteristics of EP enable new types of missions and applications, in particular in Transportation, Exploration and Interplanetary Missions. In order to improve the competitiveness of HEMPT systems within Interplanetary, Space Transportation and Exploration missions, the performances of existing systems must be improved. This activity is optional for HEMPT proposals.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	4-5	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	6	
• Power	> 20 kW	The EPS should demonstrate power performances beyond the state of the art, justifying the specific power performance selected with an analysis of the medium to long term market needs. High power will be needed to develop the high thrust needed for some of the applications.
• <i>P/T</i> (for EOR)	< 26 (W/mN)	In order to reach the adequate Thrust levels for these types of missions, the <i>P/T</i> must be low enough. The activities must be aimed at improving the <i>P/T</i> ratio.

• <i>Isp</i> (for SK)	>3000 (s)	High <i>Isp</i> needed to achieve the large delta-V needed for these missions with a propellant mass compatible with launcher performance. The higher the <i>Isp</i> the better, but this requirement is a trade-off of several performance parameters. The <i>Isp</i> should be increased from the current state of the art.
• Innovative and cheaper PPU	High power PPU able to provide 20 kW to the thruster	
Remarks	Clustering of lower power EPS could be considered.	

Table 3.4		
Highly Efficient Multistage Plasma Thruster (HEMPT) EPS activities oriented to Science applications		
Description and needed Action	Science missions can have very specific propulsion requirements. Clear examples are the missions requiring micropropulsion with high controllability, for formation flying and high-accuracy orbit control. These missions also require continuous operation for extended periods of time, so they have in addition high <i>Isp</i> and long lifetime requirements. This activity is optional for HEMPT proposals.	
Requirements		
• Target TRL at the end of the COMPET-3-2016 project	4-5	
• Target TRL at the end of the SRC (2023/2024) if the project were to continue	6-7	
• Resolution	<1 μN	In low thrust range (<100 μN)
• Power	< 50 W	Low power levels are expected for micro-propulsion operation.
• Lifetime	> 6 years	Very long continuous operation
• <i>Isp</i>	> 1000 s	High <i>Isp</i> is needed, in order to support continuous operation for long periods. The higher the <i>Isp</i> the better, but this requirement is a trade-off of several performances.
• PPU	The PPU should be adapted to allow the large throttability voltage control needed to ensure high thrust resolution.	
Remarks	Large throttability (1:50) Very low noise	

B - DISRUPTIVE LINE

This section provides additional information in order to clarify what is expected from the proposals to be submitted in response to *COMPET-3-2016: SRC – In-Space electrical propulsion and station keeping b) Disruptive Technologies*.

This section for the disruptive line is composed by one table (Table 4) providing guidance for the proposals to be submitted and requirements for the technologies or concepts to be developed.

Information is provided on the content and scope that is expected including specific targets for TRL and performances.

Table 4 - Disruptive Technologies	
Description and needed Action	<p>The COMPET-3-2016 also covers a number of alternative thruster concepts that are emerging or have already gained some maturity. If these disruptive technologies can be identified early enough, accelerating the development of those technologies would help to sustain advances in performance and identifying new markets/applications. This topic focuses on promoting the Research, Technology and Development (RTD) of very promising and potentially disruptive concepts in the field of Electric Propulsion, in order to increase the currently low or very low TRL (≤ 4) of potentially breakthrough concepts which in the long term could change the EP landscape. Electric Propulsion thrusters currently at low TRL (≤ 4) and not part of the Incremental line of this SRC, shall be the main focus of this line. Proposals are expected for concepts such as HPT, ECR, MPD, PPT, micropropulsion or other innovative thruster concepts not identified here.</p> <p>The activities proposed shall include modelling, development and testing beyond the current state of the art in order to:</p> <ul style="list-style-type: none">• Understand fundamental physical processes and their impact on performance.• Improve current thruster performances (thrust, specific impulse, power/thrust ratio, magnetic thrust vectoring, throttability, efficiency, lifetime, noise, etc.).• Progress the development of associated cathodes/neutralisers, if applicable to a thruster.• Investigate alternative propellants to Xenon and/or non-conventional propellants, understood as gases constituting the atmosphere of a planet, such as oxygen, nitrogen and combinations in the case of the Earth, with consideration to potential applications.• Further analyse the impact of the thruster on the whole EP system. <p>It is important to acknowledge that there might be other elements in the EP system, aside from the thruster, with the ability to provoke a radical disruption. For example, new Power Processing Unit (PPU) concepts or architectures could substantially decrease the overall cost of the system. It is therefore also important and expected that proposals explore the potential for breakthrough innovation of Transversal Disruptive</p>

	<p>EP system concepts, such as: direct drive, radically new PPU architectures and dedicated spacecraft power system architectures and/or materials; hybrid solutions to drive different types of EP thrusters, highly innovative magnetic nozzles, modeling/design and simulation tools or testing techniques, or any other new concept belonging to the Transversal Disruptive EP system concepts category not specifically mentioned here.</p> <p>Proposals for thrusters in the Disruptive line should not be based on HET, GIE or HEMPT technologies.</p>
References	<ul style="list-style-type: none"> • Relevant ECSS Standards (www.ecss.nl) for the different elements of the EPS (i.e.: ECSS-E-ST-35C Rev.1 – Propulsion General Requirements, ECSS-E-ST-35-01C - Liquid and electric propulsion for spacecraft, ECSS-E-ST-10-03C - Testing) and for the relevant milestone documentation (ECSS-E-ST-10C). • Proposers are invited to consult other EPIC public documentation available under www.epic-src.eu (EPIC website)
Proposals indicative content	<ul style="list-style-type: none"> • Proposals shall include an initial work package dedicated to the requirements, as well as an analysis of the different potential impacts. • Proposals shall go beyond the present state of the art, preferably the expected state of the art at the time of completion if alternative technologies are being developed outside Europe. • Proposals shall explain and be ready to demonstrate how the proposed concept meets the disruptive definition proposed in this call topic and what is it the expected impact of the development in the EP landscape, including the timeframe. • Persistent monitoring of the state of art within the EP sector throughout the project will be important, and developments should ideally be planned with some degree of flexibility in order to be responsive to innovations not currently foreseen which could have a potential impact on EP systems (e.g. new materials or manufacturing techniques). • Proposals shall demonstrate the readiness and interest to carry developments further on through future calls of this SRC, by including a long-term development plan aiming to reach the higher TRLs in 2023-2024 targeted in the EPIC Roadmap Disruptive Line. A Task in the project should be dedicated to this topic. • Proposals shall also include a validation and verification plan, including milestones and one or more validation and verification methods to apply through the course of the project, which would allow to verify how the development targets are being met and how the landscape disruption shall take place in the future. These plans shall be analysed in depth through a dedicated work package within the project. • Proposals shall seek synergies while avoiding duplications with already existing or planned developments by other entities in Europe, such as ESA, EU-FP, EU-H2020, National Space Programmes and commercial initiatives.
Expected Deliverables	<p>At least the following Deliverables shall be produced:</p> <ul style="list-style-type: none"> • Business Plan including Market Analysis, • SRR, PDR data packages including Technical Specification, System Design, Preliminary Design Report including justifications, Design and Development Plan, Test and Verification Plans, Test and Verification Reports, according to the

	<p>relevant ECSS Standards (ECSS-E-ST-10C).</p> <ul style="list-style-type: none"> • Risk Assessment and Contingency Analysis report (yearly), • KPIs report (yearly), • Cost Assessment (development phases), • Dissemination and educational public material: Activity and results presentations, photos, posters, videos, professional communication and educational movies; and • Project website.
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ACRONYMS & ABBREVIATIONS

CDR	Critical Design Review
EC	European Commission
ECR	Electron Cyclotron Resonance
EEE	Electrical, Electronic and Electromechanical
EOR	Electric Orbit Raising
ECSS	European Cooperation for Space Standardization
EP	Electric Propulsion
EPIC	Electric Propulsion Innovation and Competitiveness
EPS	Electric Propulsion System
ESA	European Space Agency
EU	European Union
FP	Framework Programme
GIE	Gridded Ion Engine
H2020	Horizon 2020
HEMPT	Highly-Efficient Multistage Plasma Thruster
HET	Hall-Effect Thruster
HPT	Helicon Plasma Thruster
HV	High voltage
IPR	Intellectual Property Right
<i>Isp</i>	Specific Impulse
KPI	Key Performance Indicator
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MPD	Magneto Plasma Dynamic
PDR	Preliminary Design Review
PPT	Pulsed Plasma Thruster
PPU	Power Processing Unit
PSA	Programme Support Activity
QR	Qualification Review
REA	Research European Agency
ROM	Rough Order of Magnitude
RTD	Research, Technology and Development
SC	Spacecraft
SK	Station Keeping
SRC	Strategic Research Cluster
SRR	System Requirement Review
TBD	To Be Defined
TRL	Technology Readiness Level
WP	Work Package