European Commission

H2020 Programme 2018-2020

SPACE-13-TEC-2019
In-Space electrical propulsion and station keeping

Guidance document

Version 1.0
16 October 2018

SPACE-13-TEC-2019:

GUIDELINES FOR STRATEGIC RESEARCH CLUSTER ON IN-SPACE ELECTRICAL PROPULSION AND STATION KEEPING - HORIZON 2020 SPACE CALL 2019

November 2017

1. INTRODUCTION

This paper presents the specific guidelines for the applicants to topic SPACE-13-TEC-2019 (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). 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, 2019 and 2020), 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 SPACE-13-TEC-2019.

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 SPACE-13-TEC-2019, the EPS does not include neither the thrust orientation mechanisms nor the tanks, and therefore is **composed of the thruster, fluid management system and the power components only.**

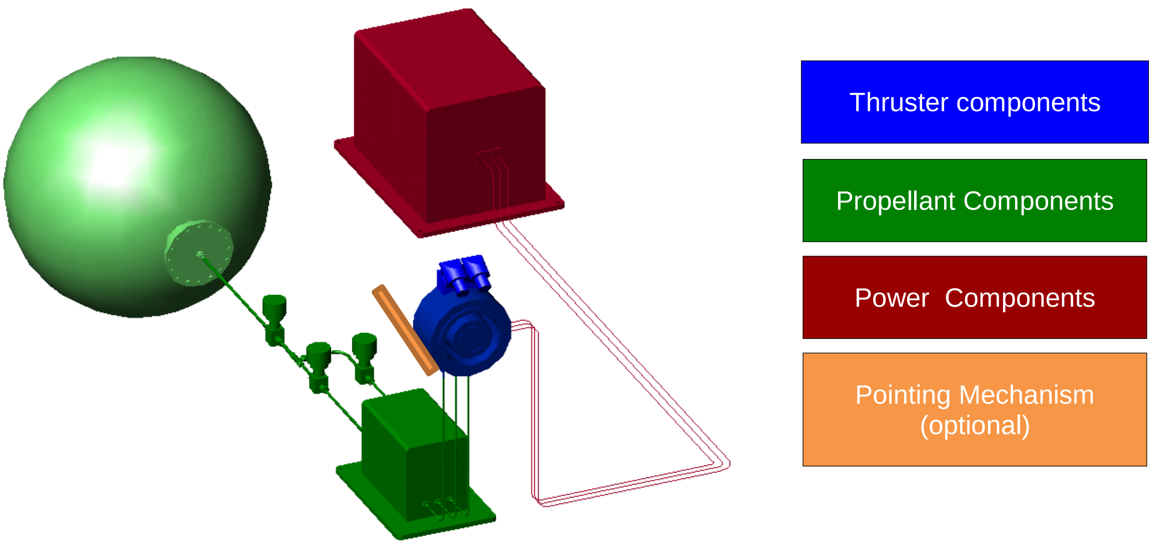

Figure 1: Electric Propulsion System Main components

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 with **2019 Call** for disruptive technologies, and with **2020 Call** for incremental technologies**.**

2.2.1. 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 TRL (<4) and higher TRL ≥ 4 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.

Emerging technologies that are potentially ‘disruptive’ often underperform compared to the dominant technology in early development phases – the underlying physics may not be fully understood for example and more R&D is required to properly ascertain performance attributes. Examples can be: disruptive improvement of performances, enabling of new operational scenarios, reducing costs of the full system etc. Every disruptive effect has to be specifically correlated with its final application. Thus, the concept of space disruptive technology, hereby defined, is not linked to any specific TRL value.

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 radical new PPU architectures, magnetic nozzles, alternative propellants, testing techniques, new materials, simulations codes, 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 from low TRL (<4) to higher TRL ≥4. Some thruster types may still be in a concept stage and other in testing in relevant environment phase.

Disruptive thruster concepts will not include or address any incremental thruster technologies (HET, GIE, HEMPT), or variants (e.g. micro-HET, micro-GIE, dual-HET, ECR-GIE, etc.). 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 µN-GIE and µN-HEMPT or their high-power counterparts like 10 kW HET thrusters are taken as incremental, whereas FEEP 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.

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, which might for instance allow 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 disruptive technologies, 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 and medium TRL concepts such as Helicon Plasma Thrusters (HPT), Electron Cyclotron Resonance Thrusters (ECRT), Magneto Plasma Dynamic Thrusters (MPDT), Pulsed Plasma

Thrusters (PPT), Field Emission Electric Propulsion thrusters (FEEP), micro-propulsion electric thrusters, and any other innovative electric thruster concepts, **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 (but not the ones based on HET, GIE and HEMPT technology).

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

- direct drive enabling technologies,
- radical innovations in PPU,
- magnetic nozzles,
- alternative propellants,
- testing techniques,
- new materials,
- modelling and simulations codes,
- new PPU and electrical system architecture for EP,
- hybrid solution to drive different types of EP thrusters,
- any other promising and potentially disruptive concept not specifically mentioned, not necessarily related to the technology if is used in a disruptive way,

Several disruptive projects started in the 2016 Call timeframe, and might continue or not with a second phase in the 2019 Call timeframe. In the first call, the disruptive technologies projects were not expected to develop a full EP system. Their task was to demonstrate the potential of the technology to achieve the ambitious goals of this line in the medium-to-long term. These projects included modelling and testing.

For the **second phase in the disruptive 2019 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 or the exploration of more and new disruptive technologies the second Call period will be performed through the same or new modalities applied as for first Call period for disruptive technologies. The number of technologies to be funded is defined in the text of the second disruptive 2019 Call. Not all technology developments developed in the first phase might continue, and new ones might start on the second phase.

2.2.2. 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 with the 2019 and 2020 Calls :

- 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 2019 and 2020 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 focused 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 (2019 and 2020 Calls) 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 will be detailed. The objective for this second phase is to support the more promising technologies towards higher TRLs, and to promote and explore more and new disruptive technologies, in order to achieve the SRC expectations and, potentially, to prepare these technologies for a potential IOD/IOV.

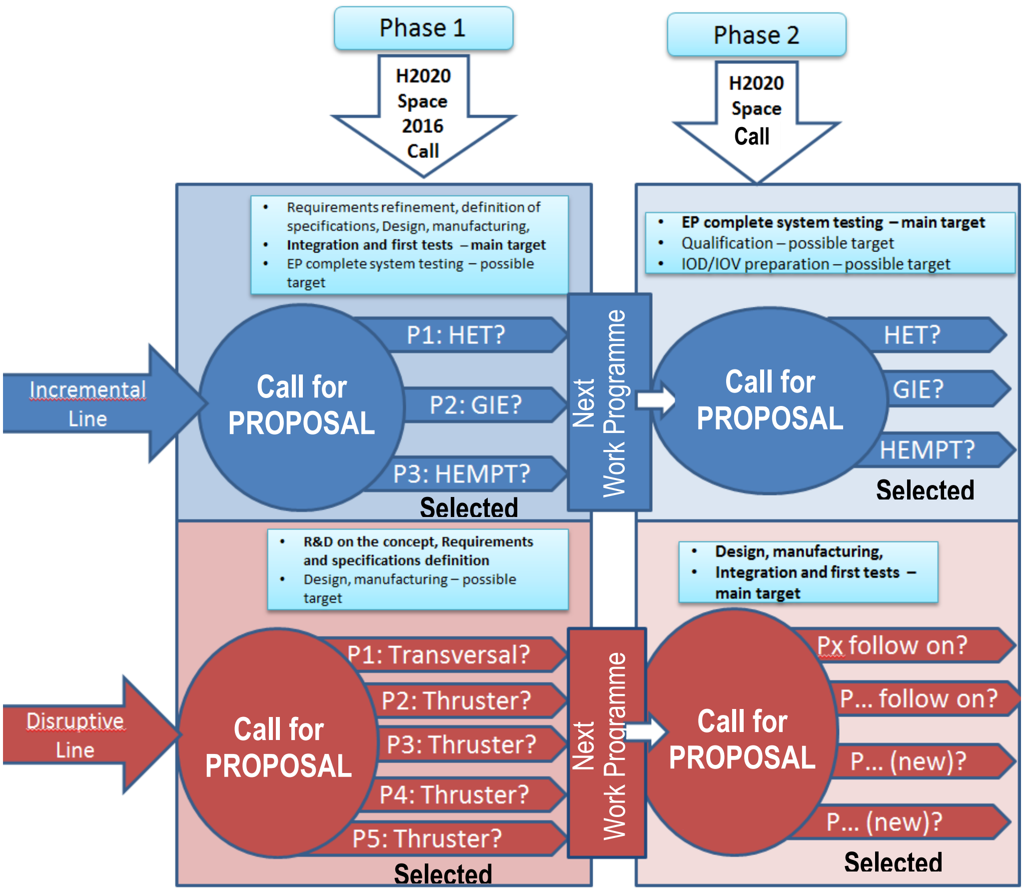

Figure 3: High-level SRC Roadmap evolution

2.2.3. 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, thrusters, 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 more disruptive technologies is to find thruster concepts (and respective cathode, if applicable) and other EP transversal disruptive technologies 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

DISRUPTIVE LINE

This section provides additional information in order to clarify what is expected from the proposals to be submitted in response to *SPACE-13-TEC-2019: SRC – In-Space electrical propulsion and station keeping (Disruptive Technologies).*

This section for the disruptive line is composed by one table (Table 1) 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 1 - Disruptive Technologies	
Description and needed Action	The SPACE-13-TEC-2019 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 TRL (<4) and higher TRL ≥4 of potentially breakthrough thruster concepts and transversal technologies which in the long term could change the EP landscape. **Electric Propulsion thrusters** not part of the Incremental line of the SRC, **shall be the main focus of this Disruptive Technology line**. Proposals are expected for concepts such as Helicon Plasma Thrusters (HPT), Electron Cyclotron Resonance Thrusters (ECRT), Magneto Plasma Dynamic Thrusters (MPDT), Pulsed Plasma Thrusters (PPT), Field Emission Electric Propulsion thrusters (FEEP), micro-propulsion electric thrusters, or other innovative thruster concepts not identified here. The activities proposed shall include modelling, development and testing beyond the current state of the art in order to: • 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. 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 some proposals exploring the potential for breakthrough innovation of **Transversal Disruptive technologies**, such as: radical new PPU architectures, direct drive enabling technologies, highly innovative magnetic nozzles, alternative propellants, testing techniques, new materials, simulations codes, hybrid solutions to drive different types of EP thrusters, testing techniques, or any other new concept belonging to the Transversal Disruptive EP technology category not specifically mentioned here. Proposals for thrusters in the Disruptive line should not be based on HET, GIE or HEMPT technologies, or its variants (e.g. micro-HET, micro-GIE, dual-HET, ECR-GIE, etc.).
References	• 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	• 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, 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	At least the following Deliverable documentation has to be provided according indication provided in ECSS-E-ST-10C and include but it's not limited to: • Business Plan including Market Analysis, • SRR, PDR, and CDR (if applicable depending on the TRL) 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 relevant ECSS Standards. • Risk Assessment and Contingency Analysis report (yearly), • KPIs report (yearly), • Cost Assessment (development phases), • Dissemination and educational public material: Activity and results presentations, papers and articles presented, photos, posters, videos, professional communication and educational movies; and • Project website.

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
Isp	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