HORIZON 2020

EPIC

Report

D3.1 Trade-Off analysis of EP systems/ technologies to be proposed for future developments(incremental advances and disruptive concepts)

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APPROVAL

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1 INTRODUCTION

In the frame of the Electric Propulsion Innovation & Competitiveness (EPIC) project, (grant number 640199) and more concretely its Work Package 3 "Activity Definition and Master Planning", this document has been produced with the aim to be the main output of Task 3.1 and Task 3.2 "Prioritisation Technology vs. Domains".

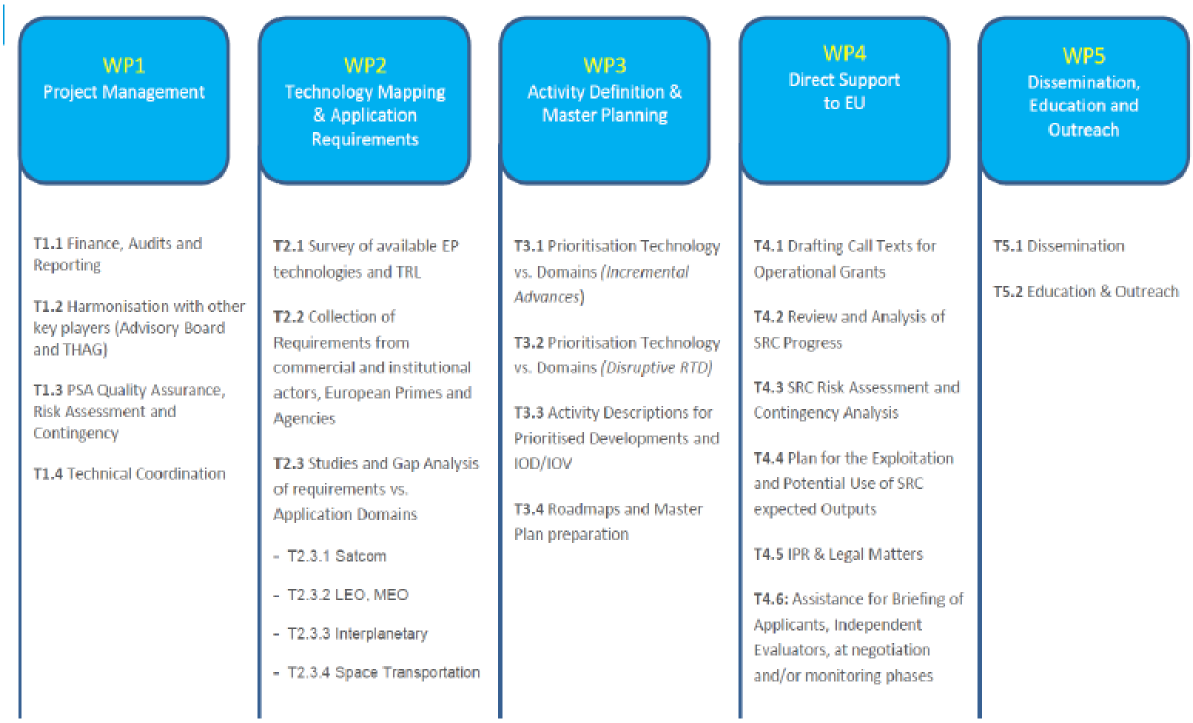


Figure 1-1: EPIC Work Logic

This document gives an overview of a Trade-Off Analysis of EP systems/technologies to be proposed for future developments (Incremental advances and Disruptive concepts), based on the critical review and gap analysis [RD9] to match the identified requirements [RD5] and the available/perspective for Electric Propulsion System (EPS) and EPS-related technologies [RD4]. The objective is to perform the prioritisation process oriented to the creation of a roadmap of technologies and activities to be developed and pursued for the evolution of the EPS in the SRC devoted to Electric Propulsion for Space within H2020.

2 REFERENCE DOCUMENTS

[RD1] *European Space Technology Harmonisation Technical Dossier – Electric Propulsion Technologies*, Ref. ESA/IPC/THAG(2014)12, Issue 3, Revision 1, Draft.

[RD2] *European Space Technology Harmonisation Technical Dossier – Space Mechanisms – Electric Propulsion Pointing Mechanisms*, Ref. TEC-MSM-2009-4-In-JML, Issue 2, Revision 2, Technical Note.

[RD3] *European Space Technology Harmonisation Technical Dossier – Power Management and Distribution*, Ref. ESA/IPC/THAG(2013)7, Issue 3, Draft.

[RD4] *EPIC D2.1 EP technologies database, Issue 1.2,* EPIC-CNES-2.1-RP-D2.1-1.2

[RD5] *EPIC D2.2 EP requirements database, Issue 1.1,* EPIC-CNES-2.2-RP-D2.2-1.1

[RD6] ESA Activities in the field of Electric Propulsion, J. Gonzalez del Amo.

[RD7] *European Space Technology Harmonisation Technical Dossier – Chemical Propulsion -Components*, Ref. TEC-SGH/2011/97/CPCTD, Issue 3, Revision 2, Draft A.

[RD8] *EPIC D2.3 EP Workshop, Issue 1.1,* EPIC-CNES-2.3-RP-D2.3-1.1

[RD9] *EPIC D2.4 Studies and Analysis of requirements vs. application domains report, Issue 0.1,* EPIC-CNES-2.3-RP-D2.4-1

3 ACRONYMS & ABBREVIATIONS

ALP: Ablative Laser Propulsion

EBB: Elegant BreadBoard

ECRA: Electron Cyclotron Resonance Acceleration thruster

ECSS: European Cooperation for Space Standardization

EO: Earth Observation

EOL: End of Life

EOR: Electric Orbit Raising

EP: Electric Propulsion

EPPM: Electric Propulsion Pointing Mechanism

EPS: Electric Propulsion System

FEEP: Field Emission Electric Propulsion

GEO: Geostationary Earth Orbit

GIE: Gridded Ion Engine

GSO: Geo Synchronous Orbit

HEMP-T: High Efficiency Multistage Plasma Thruster

HET: Hall Effect Thruster

HPT: Helicon Plasma Thruster

IBS: Ion Beam Shepard

IT: Total Impulse

MPD: Magnetoplasmadynamic thruster

NEP: Nuclear Electric Propulsion

NGGM: Next Generation Gravity Missions

NSSK: North-South Station Keeping

PCU: Power Conditioning Unit

PCDU: Power Conditioning and Distribution Unit

PIT: Pulsed Inductive Thruster

PPT: Pulsed Plasma Thruster

PPU: Power Processing Unit

PR: Pressure Regulator

PSCU: Power Supply and Control Unit

QCT: Quad Confinement Thruster

R&D: Research and Development

SEP: Solar Electric Propulsion

SRC: Strategic Research Cluster

TRL: Technology Readiness Level

VAT: Vacuum Arc Thruster

4 ASSESSMENT OF GAP ANALYSIS

The development of current most promising European EP concepts for space operations and transportation is achieved through a trade-off study which allows highlighting key drivers oriented to innovation and competitiveness. On the basis of gap analysis results [RD9], incremental steps for maturation and/or innovative steps are formulated for the advancement of EP technologies which are not yet covered by the current European R&D plans (ESA, national agencies). EP system and related technologies are assessed in terms of technical features, needs, requirements, trends, markets and applications, with the aim to clearly identify a set of trade off options from which relevant advancements are expected.
Two classes of technological advances are identified:

- Incremental: enabling advances in technologies already mature which require major advances in the performances/capabilities of the thruster itself and its related subsystem equipment (including power processing unit (PPU), feeding systems, architectures, etc.), in order to increase substantially their Technology Readiness Level (TRL) to enable them in-orbit in a short-medium timeframe (3 to 5 years).
- Disruptive technologies: Research, Technology and Developments (RTD) in the field of EP, including electric power for propulsion; this could correspond to currently very low TRL but very promising technologies.

4.1 Incremental Advances

Based on the actual trend and technology state-of-the-art [RD4] and the performed gap analysis [RD9], specific objectives for incremental advances on EPS are identified for three thruster technologies, which are Hall Effect Thruster (HET), Gridded Ion Engine (GIE), High Efficiency Multi-stage Plasma Thruster (HEMP-T), with respect to the main application areas:

- Telecom:
    - Dual-mode operation
    - Lifetime extension
    - Innovative and cheaper PPU concept
    - Alternative propellants
    - Faster electric orbit raising (EOR)
    - Improved fluidic architecture
    - Overall launch mass savings
- Space transportation:
    - High power thruster/PPU
    - Alternative propellants
    - Direct drive
    - High total impulse
    - High efficiency solar arrays
- LEO (resp. MEO): optimized EPS for LEO (resp. MEO) missions
- Exploration/Science:
    - Fine thrust/micro-thrust
    - High total impulse
    - Alternative propellants
    - High power
    - Wide thrust range

The assessment of aspects which are considered transversal with respect to all the target applications, is also considered, by means of European non-dependence and competitiveness.

The EPIC Consortium also decided to include any thruster based on the HET, GIE and HEMP-T technologies (independently of the power, thrust levels, etc.) as part of the incremental line, despite the fact that they could also well fit in the disruptive line because of less extended R&D and therefore determination of the full potentialities and impacts.

This is the case for instance of the micropropulsion thrusters such as µRIT or µHEMP-T or the very high power thrusters such as 20 kW HET, DS3G-DS4G and HTM-20350 for instance [RD4].

4.2 Disruptive technologies

Aside from the dominant EP thruster technologies of HET, GIE and HEMP-T within Europe, a number of alternative thruster concepts are emerging or have already gained some maturity. These alternatives hold the potential to disrupt the propulsion sector if they can:

- provide a radical improvement in one or more performance attributes that are perceived as more valuable than those of a dominant thruster technology; or
- enable new applications not possible with existing technologies.

The same gaps identified within the different application domains for HET, GIE and HEMP-T will also be development drivers for disruptive technologies, although, as stated, disruptive concepts must offer radical improvements over the state-of-art of any dominant thruster if they are to be adopted in place of more mature technologies that have already received substantial investments.
Application domains particularly challenging to current EP systems include micropropulsion and very high thrust applications:

- Micropropulsion: propulsion systems capable of providing low but highly accurate thrust levels in the sub-µN to mN throttling range, will be enabling for complex space missions requiring precision attitude control for formation flying or drag compensation. Performance attributes needed for these demanding Science or Earth Observation missions therefore include: high thrust controllability, low thrust noise and wide throttle range, while offering high specific impulse in order to minimise propellant on these missions typically of 5-10 years in duration, or potentially even longer. Other performance attributes such as low recurring cost, low complexity, very low power and volume will also enable low-end encroachment of EP devices on small satellite platforms, enhancing the capability of these spacecraft.

- Very high thrust / high power Applications: it is considered that electric propulsion will be enabling for advanced missions requiring very high total impulse levels (i.e. high thrust up to N levels and long lifetime), such as for interplanetary missions or space 'tugs' between LEO and GEO. In order to achieve these very high thrust levels, EP thrusters must have the capability to be operated in clusters or be able to process high levels of electrical power, potentially up to MW level. High efficiency and low complexity will therefore also be drivers for these systems. Innovative power sources will also be critical for these advanced missions that will be enabled by EP.

5 TRADE OFF ANALYSIS

Incremental and disruptive technologies identified in the previous gap analysis assessment are evaluated with the aim to produce a technology prioritisation, i.e. as a strategic projection versus application domains and identified needs.
This process is based on accurate EP technologies mapping, critical review of their characteristics and development perspectives, analysis of the future mission requirements. The trade-off analysis here presented is the instrument through which the prioritisation process is performed.
The adopted method is carried out through the following steps:

1. <u>Prioritisation of Technologies versus evaluations criteria</u>
2. <u>Prioritisation versus applications and relevant gaps.</u>

This 2-steps process allows to evaluate the Electric Propulsion Concepts capturing the general aspects which guarantee the return of investment and verifying their coherence with the technology needs (gaps) of each applications, which will drive the design solutions adopted in future missions.

The prioritisation process started discussing the following definitions of Incremental Advancement and Disruptive Technologies:

Incremental advancement:
Enabling advances in technologies already mature which require major advances in the development of the thruster itself and its associated subsystem equipment (including the entire subsystem composed of power processing unit, PPU, feeding systems, architectures, etc.), in order to increase substantially their TRL to enable them in-orbit in a short-medium timeframe.

Disruptive technologies:
Research, Technology and Development (RTD) of very promising and potentially disruptive technologies/concepts in the field of EP and EP-related technologies, in order to allow the increase of the currently low TRL of breakthrough concepts which in the long term could change the EP landscape.

On the ground of the above mentioned definitions, two lists of Electric Propulsion elements are identified:

- Technologies for Incremental Advancements, focused essentially on pushing the global market competitiveness, in the medium time frame, of the European electric propulsion thrusters for:
  - HET
  - GIE
  - HEMP-T
- The Disruptive Technologies, focused on testing and verifying technologies able to produce a disruptive enhancement in the Electric Propulsion performances. The class includes:
  - The following types of thrusters:

– Helicon	– QCT
– MPD	– ECR
– FEEP	– Ponderomotive Thrusters
– Colloids	– Electronegative GIE
– PPTs	– HALO
– Thruster using Neutrons Source as ion stage (the ionisation chamber uses the same principle as the one of a neutron source)	– Other thrusters

  - Radically innovative transversal technologies (PPU/ Direct Drive/Power Management, diagnostics, testing techniques, thrust vectoring techniques, nanotechs/MEMs, FCU, etc.).

5.1 Prioritisation on high level benefits

Evaluation criteria, associated to high level benefits and return of investments, are identified in order to exhaustively explore potentials and drawbacks for the incremental or disruptive EPS under evaluation.
For each evaluation criteria a set of grade and relevant numeric scores were established. Each set of grades is associated to a definition to allow a shared and consistent evaluation by the EPIC partners. The numeric scores could be positive or negative, depending on the suitability or not of the characteristic taken into consideration.
Although the evaluation criteria and associated benefits are the same for incremental advances and disruptive technologies, the grades definitions and relevant numeric scores are different for the two classes, to capture different objectives and aspects.
The evaluation criteria, associated to high level benefits, are the following:

- Cost/feasibility
  Recurring and non-recurring costs are evaluated, together with starting TRL and relevant justification, development planning and risks analysis, level of dependence on non-European key technologies, level of dependence on non-

European testing facilities, diagnostic capability, level of dependence on flight qualified technologies, critical components (PPU, Flow Control Unit, etc.).

- Flexibility
  Versatility w.r.t. different classes of missions (for each EPS the possible classes of missions have to be identified and evaluated), versatility w.r.t. different applications (for each class of missions the possible applications have to be identified and evaluated), versatility w.r.t. propellants (compatibility with different propellants), throttability, controllability (i.e. fine thrust regulation, modularity), commonalities w.r.t. other EPS building blocks, scalability.

- Competitiveness
  expected competitive position in the European and non-European market should be evaluated (specifying if in the cases of short/medium or long term scenario) also taking into consideration future missions, valorization of competencies/technologies already developed at European level in other national and international projects, performances gain achieved through disruptive technology advancement, potential Spin-off initiatives for cross related fields, as well as the integration capability within launch systems worldwide.

- Impact on the host system
  EPS should be evaluated considering the expected saving on the host-system (in terms of weight, power etc.), the interface compatibility between the EPS and the host system, the expected host-system delta performance (Mission benefits).

The EPIC PSA deeply discussed coming to a consensus on scores assignment and relevant justifications, which are reported in details in Annex 1, par. 9.1 (Incremental Advances Evaluation Matrix) and in Annex 1, par. 9.2 (Disruptive Technologies Evaluation Matrix).
The evaluation through the above mentioned criteria produced a prioritisation of technologies versus high level benefits.
To add flexibility to the assessment process, the panels were also given the option of identifying technologies that they think should have a higher priority with respect the one achieved by their scores. These modifications could be implemented if well justified and shared by experts and the Steering Board.

5.2 Prioritisation on applications

In parallel to the prioritisation of technologies versus evaluation criteria, a prioritisation on the basis of application domains has been carried out. Evaluating the efficiency of technologies in answering the future applications needs, this second prioritisation has allowed a double check on the quality of the prioritisation based on high level benefits already performed.
The starting point has been the complex and exhaustive analysis performed in the WP2, the output coming from the first Workshop held in Brussels [RD8] and the results of THAG mapping meeting. A synthesis has been performed to identify for each Class of Electrical Propulsion systems (Incremental advances and Disruptive Technologies) all the possible area technology gaps to be filled in order to achieve the targeted advancement.
The correlation among each technology (disruptive and incremental) and the gaps identified has been verified and graduated, with a numerical score from 0 to 3: higher numbers implied greater potential of a given technology to cover the gap under analysis.

A particular effort has been required to associate the gaps to the area of interest or applications. For Technologies aimed to Incremental advances, it has been possible to clearly distinguish the technology gaps for each application domain.

Telecom	Dual-mode
	Lifetime Extension
	Innovative & cheaper PPU concept
	Alternative propellants

	Faster EOR
	Improved fluidic architecture
	Overall launch mass savings

Space transportation	Higher-power thruster & PPU
	Alternative propellants
	Direct drive
	High Total Impulse
	High efficiency solar arrays

LEO missions	Optimized (performance/ costs) EPS for LEO missions

MEO missions	Optimized (performance/ costs) EPS for MEO missions

Exploration/Interplanetary/Science	High Total Impulse
	Alternative Propellants
	High Power
	Low Power / Fine Thrust

The importance of each gap/need is ranked, assigning numerical scores (the higher the better) to quantify the ability to meet the following objective:

- Non-recurring costs
- TRL and development risks
- Potential use for other types of applications
- Expected market
- Expected host-System delta performance (Mission benefits)
- Expected saving on host-system costs

The numerical score is taken as "gap weight" for the subsequent analysis.

A similar approach is applied to Disruptive Technologies, although some adjustment has been implemented to manage the high uncertainty level of system definition and performances typical of low TRL breakthrough concepts.
The gaps are associated to three general classes of power and thrust ranges. Namely:

Micropropulsion (1 µN to 1 mN)	Wide throttle range
	High Isp
	Operational Lifetime
	High thrust controllability (thrust resolution)
	Alternative Propellants
	Low noise
	Cost reduction (recurring)
	Low Volume
	Low Power

	Low Complexity
	Clustering / Modularity

Medium thrust (1 mN to 100 mN)	Low Power-to-Thrust ratio
	Cost reduction (recurring)
	Lifetime extension
	Dual Mode
	High Isp
	Alternative Propellants
	Clustering
	Low Complexity

High power, high thrust (> 100 mN)	High Total Impulse (high thrust and lifetime)
	High Efficiency
	Configuration / Accommodation flexibility
	Clustering / Modularity
	Compatibility with MW power source
	Alternative Propellants

The correlation with applications domains are not clearly understood in this phase of the study and will be addressed when the disruptive technologies will be more mature.

6 PRIORITISATION FOR INCREMENTAL ACTIVITIES

The technologies for Incremental Advancements, focused essentially on pushing the global market competitiveness, are:

- HET
- GIE
- HEMP-T

The evaluation criteria have been analysed versus the technology gaps for each application domain; the criteria have been divided in several sub-criteria, reported in the Table 6.1 in order to better highlight the technical characterization of each technology gap.

Costs/Feasibility	Recurring costs
	Non-recurring costs
	Starting TRL and relevant justification
	Development Planning and Risks Analysis
	Level of dependence on Non-European key technologies
	Level of dependence on Non-European testing facilities, diagnostic capability
	Level of dependence on flight qualified technologies
	Critical components (PPU, FCU, etc.)

Flexibility	Versatility w.r.t. Different classes of missions (for each EP engine identify the possible classes of missions)
	Versatility w.r.t. Different applications (for each class of missions identify the possible applications)
	Versatility w.r.t. propellants (compatibility with different propellant)
	Throttability, controllability (i.e. fine thrust regulation, modularity)
	Commonalities w.r.t. other EP building blocks
	Scalability
Competitiveness	Expected competitive position in the European and non-European market (specify if short/medium or long term scenario) taking into consideration future missions
	Valorization of competencies/technologies already developed at European level in other national and international project
	Performances gain due to disruptive technology advancement
	Potential Spin off for cross related fields
	Possible integration in launch systems worldwide
Impact on the host - system (including the launcher)	Expected saving on the host-system (weight, power etc.)
	Interface compatibility between the EP and the host system
	Expected host-System delta performance (Mission benefits)
	Thruster exhaust effect: ions impact, deposition on spacecraft surface, electron local density and effect on radio frequency (RF) beam.
European Non-Dependence	Contribution and impact of the technology in ensuring European Non-Dependence

Table 6.1: Main criteria matrix

A technical characterization of these criteria has been carried out to underline the impact of each criterion versus each technology gap. This correlation matrix Criteria Vs Gaps is needed to better understand the following prioritisation process, this step can be considered as a “Step 0”, since no prioritisation or scoring has been done.
This evaluation is not dependent on the selected thrusters; the comments are general and can be correlated to each considered technology (see Annex 1, par 9.2).
The following criteria have been used; with a subset the most relevant sub criteria.

The Costs/Feasibility criteria:

Costs/Feasibility	non recurring costs
	Starting TRL and relevant justification
	Development Planning and Risks Analysis

The Flexibility criteria:

Flexibility	Versatility w.r.t. Different applications (for each class of missions identify the possible applications)

The Competitiveness criteria:

Competitiveness	Expected competitive position in the European and non-European market (specify if short/medium or long term scenario) taking into consideration future missions

The Impact on the host-system criteria:

Impact on the host -system	Expected saving on the host-system cost
	Expected host-System delta performance (Mission benefits)

The achieved results for Step 1, "Prioritisation of Technologies versus evaluations criteria" applied to each thruster are presented in Annex 1, par. 9.1; in the following table the main justifications are reported.

HET	
Costs/Feasibility	Low technical risk, low recurring costs, High feasibility, specific users identified
Flexibility	Very flexible technology, scalable, throttable, various gases
Competitiveness	Very competitive in the telecom market, faster EOR
Impact on the host -system	Major improvement in costs and performance
European Non-Dependence	European non-dependence ensured

GIE	
Costs/Feasibility	Low technical risk, higher cost w.r.t. the HET (system), High feasibility, specific users identified
Flexibility	Flexible technology, scalable, various gases and liquid metals
Competitiveness	Very competitive where high Isp is needed, has more flight heritage
Impact on the host -system	Major improvement in costs and performance
European Non-Dependence	European non-dependence ensured

HEMP-T	
Costs/Feasibility	Low technical risk, low recurring costs, lower TRL, High feasibility, specific users identified
Flexibility	Very flexible technology, scalable, throttable, various gases

Competitiveness	Competitive, faster EOR
Impact on the host -system	Improvement in costs and performance
European Non-Dependence	European non-dependence ensured

To complete the “Prioritisation versus applications and relevant gaps”, it is important to give a weight to each of the identified gaps. These weights will be used to multiply the scores of each single thruster technology and results are showed in Annex 1, par. 9.1. The gap weights are obtained through an evaluation based on the importance of each used sub criteria.
The detailed results achieved for the overall prioritisation of thruster technologies, evaluated for each application and with respect to each gap, correspond to the ranking presented in Annex 1, par. 9.1 and Calculation Sheets.

7 PRIORITISATION FOR DISRUPTIVE ACTIVITIES

The alternative thruster concepts identified within the frame of this activity were assessed against the same evaluation criteria as for HET, GIE and HEMP-T, (Annex 1, par. 9.2). There was only a small variance across the scores for the disruptive thrusters due to limited published data available for these technologies (and therefore limited knowledge) compared with HET or GIE, for example, which have undergone extensive R&D and performance characterisation programmes by several independent groups. The ion thruster based on neutron source technology received a low score as this has been proposed at conceptual level only and is therefore much more difficult to evaluate against criteria.

Although performance evaluation is considered to be one of the strongest metrics for indicating the ‘disruptive’ potential of a technology, the result of this assessment indicates the difficulty in evaluating emerging technologies; they often underperform compared to dominant technologies in their early development phases and more R&D is required to properly ascertain their optimal performance attributes for a particular application.

If a disruptive technology can be identified early enough however, accelerating the development of that technology would help to sustain advances in performance. Additionally, advanced technology planning should be aligned with market drivers or application needs for the propulsion sector in order to aid European competitiveness.

Each of the alternative thrusters was therefore assessed against the gaps/needs identified within each application domain. The technologies were assessed against the benchmark of the current dominant technology for an application domain (e.g. cold gas propulsion for micropropulsion applications). Results are shown in the following radar plots, which provide a visual indication of how the thruster concepts are currently perceived to compare.

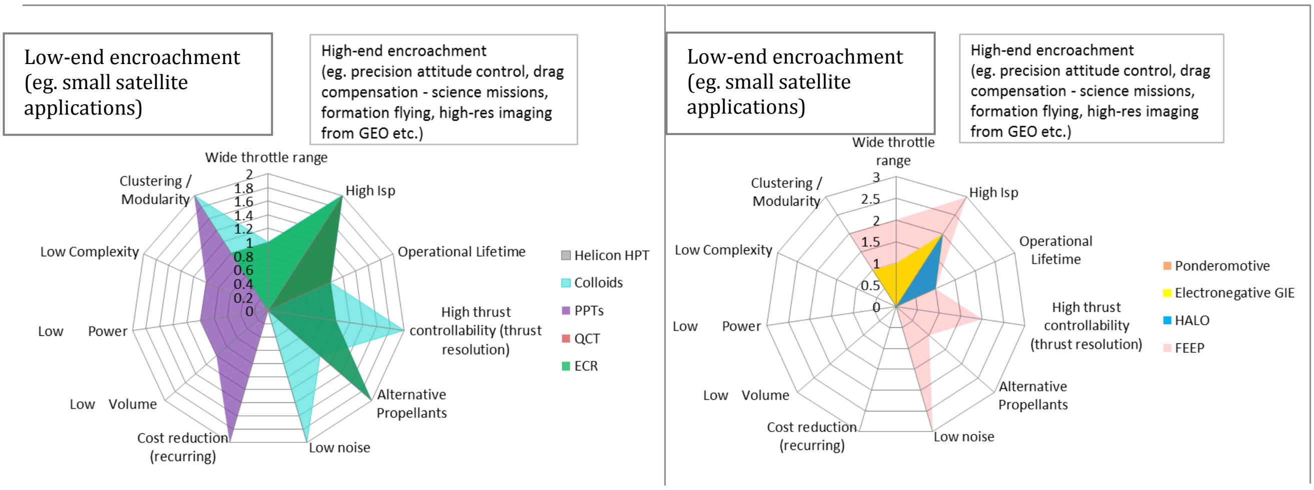


Figure 7-1: Current perception of the performance attributes of thrusters suitable for micropropulsion applications.

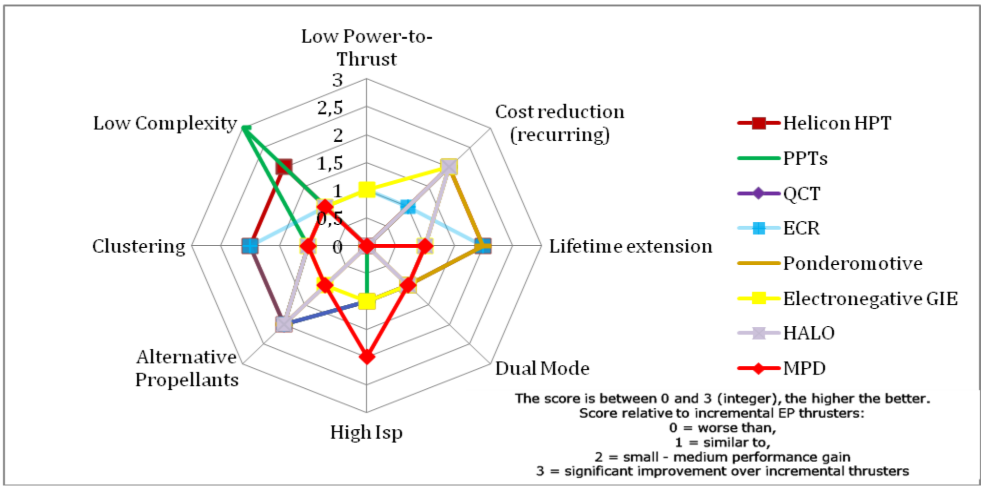


Figure 7-2: Current perception of the performance attributes of thrusters considered suitable for Telecom, LEO/MEO and science mission applications.

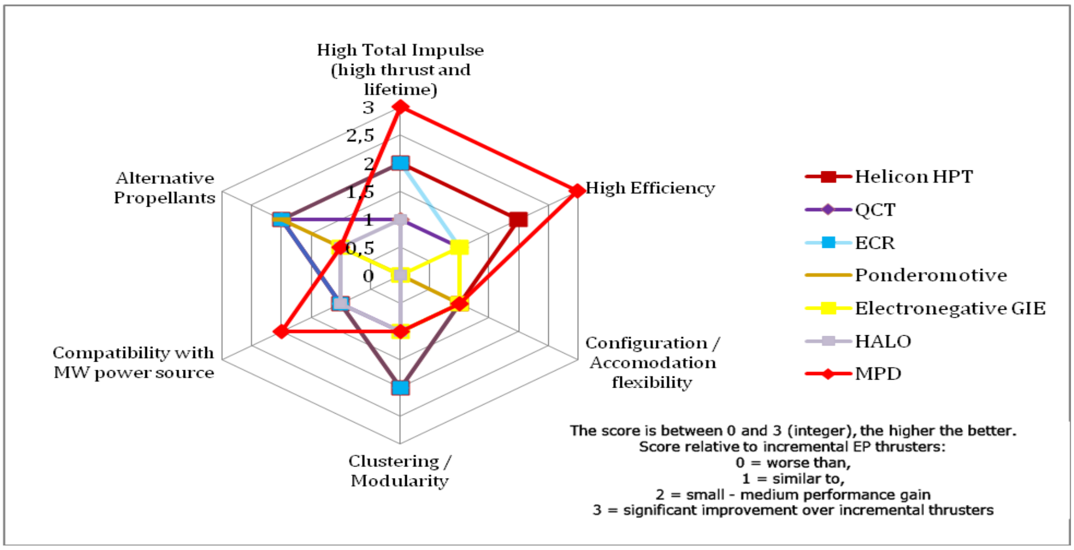


Figure 7-3: Current perception of the performance attributes of thrusters considered suitable for high power, high thrust applications.

Most of the alternative thrusters are already perceived to provide some improvement in at least one attribute over a dominant thruster technology. However, it is typically a specific combination of several performance attributes that will make a thruster disruptive in a particular application domain. It is also possible that an unexpected, radical improvement in one attribute could enable a new application not previously considered. The evaluation of the potential ‘disruptiveness’ of a technology is therefore complex and must be considered within the context of an intended application.
In addition to disruptive thrusters technologies a transversal line shall cover disruptive innovations to benefit of EP systems in a broad extend. Such a transversal technology improvement shall allow improvement for example in the context of PPU. A high expectation has been expressed in direct-drive systems in order to simplify the PPU. A direct drive concept involves major components of the spacecraft system as the solar array, the power regulation PCU (Power Conditioning Unit), the PPU and the EP thrusters. Concepts, and their feasibility and competitiveness still have to be demonstrated for different types of EP technologies. Another area of interest is the integration of PPU into the PCU in order to simplify the overall spacecraft power supply architecture and herewith offer more cost efficient EP systems. Furthermore new disruptive PPU architectures are of interest in case that the achievable cost reduction is obvious and significant. Disruptive innovation may also deal with lightweight and high efficient solar panels.

8 CONCLUSION

The prioritisation exercise performed for *incremental* technologies has been threefold:

- Prioritisation of technologies with respect to generic criteria (so-called “high level benefits”), assessing comparatively overall potential of each thruster technology
- Prioritisation of capability/performances gaps identified for the various applications (telecom, space transportation, LEO, …)
- Prioritisation of technologies with respect to those capability/performances gaps, assessing comparatively the potential of each technology to fulfil these gaps. Prioritisation of gaps has been used as weight for the overall ranking of technologies.

The alternative thruster concepts and transversal activities identified as *disruptive* advances, within the frame of this activity, have been assessed against the evaluation criteria and the identified gaps/needs for each application domain. Most of these concepts show some potential to be disruptive; however, prioritising these technologies is problematic due to the difficulty in ascertaining optimal performance attributes of low maturity technologies. The goal of the first call for the disruptive technology line should therefore be to promote Research, Technology and Development of very promising and potentially disruptive concepts within the field of Electric Propulsion in order to advance their TRL and better assess the impact they could have on the EP landscape.
It is recommended that bidders be invited to present a clear case within proposals as to why a thruster should be considered ‘disruptive’ and to identify what mix of performance attributes they are targeting, or will validate within their work, that will satisfy an identified gap and have a disruptive impact on the EP landscape.

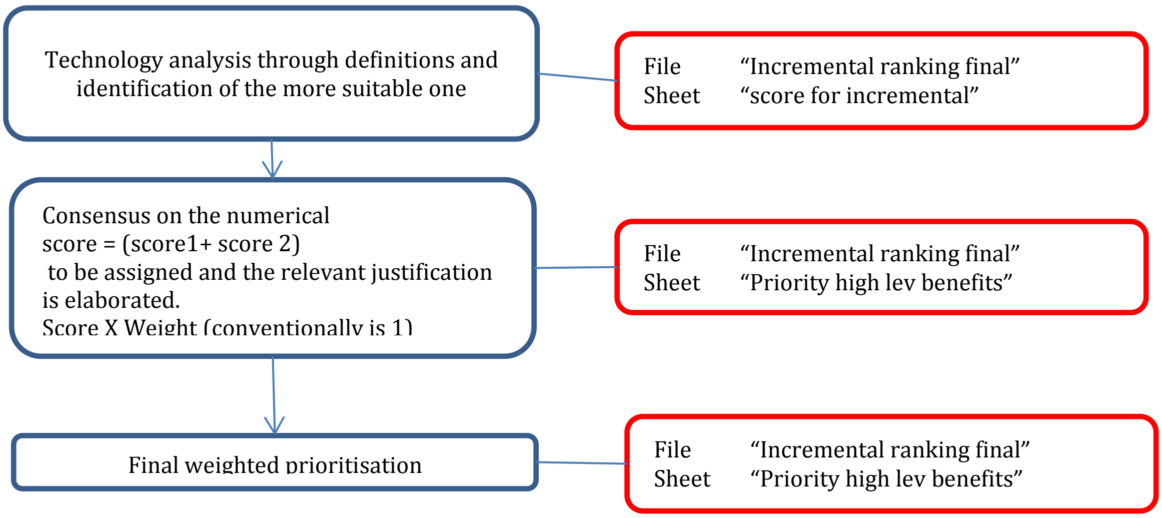
The results of prioritisations are used as the basis for the building of the incremental and disruptive roadmaps and one of the drivers for the respective budget allocation to the different technologies.
In particular, the prioritisation of gaps and their corresponding applications will be one of the inputs for objectives and activities specified in the EP SRC 1st call, for each of the incremental and disruptive technology.

9 ANNEX 1

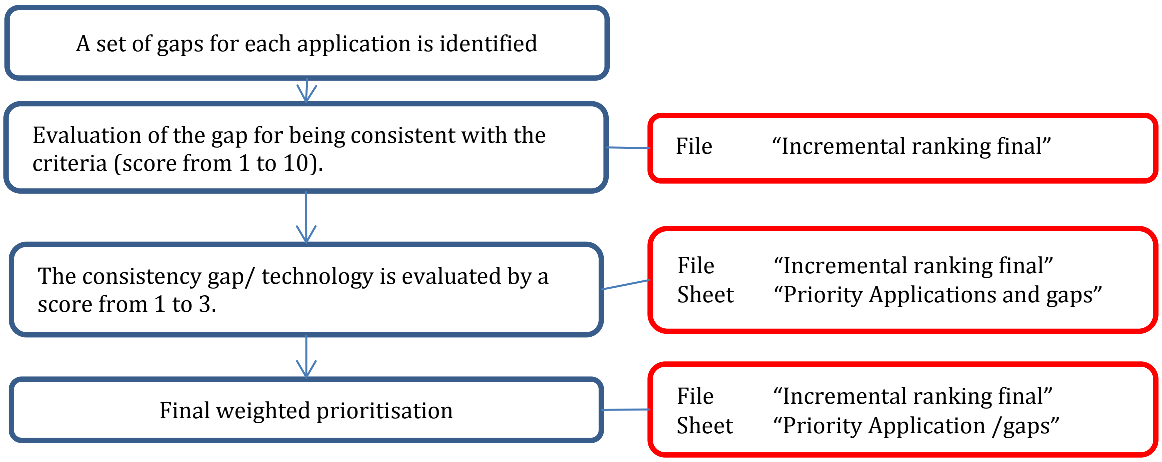
9.1 Prioritisation process: Incremental

The annex contains the file elaborated for the prioritisation ("Incremental ranking final.xlsx"). The two prioritisation processes (on high level benefits and applications) with blocks diagrams defining the prioritisation process (blue boxes) and with the relevant calculation sheets (red boxes).
The correlation among gaps and technology is justified in the sheet "Criteria VS application Just." of the "Incremental ranking file".

PRIORITY ON HIGH LEVEL BENEFITS



PRIORITY ON APPLICATION



THE EXCEL FILE

Incremental Ranking Final.xlsx

9.2 Prioritisation process: Disruptive

The annex contains the file elaborated for the prioritisation ("Disruptive ranking final.xlsx"). The two prioritisation processes (on high level benefits and applications) are synthetized with blocks diagrams defining the prioritisation process (blue boxes) and with the relevant calculation sheets (red boxes).
The correlation among gaps and technology is justified in the sheet "Criteria VS application Just." Of the Disruptive ranking file".

PRIORITY ON HIGH LEVEL BENEFITS

Technology analysis through definitions and identification of the more suitable one

File "Disruptive ranking final"
Sheet "Scores"

Consensus on the numerical score
Score=(score 1+score2)
to be assigned and the relevant justification is elaborated.
Score X Weight (conventionally is 1)

File "Disruptive ranking final"
Sheet "Priority high lev benefits"

Final weighted prioritisation

File "Disruptive ranking final"
Sheet "Priority high lev benefits"

PRIORITY ON APPLICATION

A set of gaps for each application is identified

The consistency gap/ technology is evaluated by a score from 1 to 3.
Final weighted score is:

File "Disruptive ranking final"
Sheet "Priority high lev benefits"

Final weighted prioritisation

File "Disruptive ranking final"
Sheet "GAP_TECH ****"

THE EXCEL FILE

Disruptive Ranking Matrix_Final-rev1.xls: