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WP 3 Finalisation of prioritisation- Presentation of results

Stockholm, 11/02/2015

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1. WP 3 objectives and content

2. Prioritization and Roadmaps: the methodology

3. Incremental technologies evaluation

4. Disruptive technologies evaluation

5. The Roadmaps

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Work Package 3
Objectives and Contents

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WP Objectives

OBJECTIVES

WP3 shall prioritise the technologies (incremental and disruptive) versus the potential applications and the identified needs shall identify and define all the activities to be performed by the SRC. These will be composed in a fully detailed master plan which will describe as well how the activities should be implemented and coordinated for the whole duration of the SRC. This plan shall be complemented by a plan for the analysis and evaluation of the results during the execution of the activities within the SRC.

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WP Objectives

WP3 is led by ASI, includes 4 tasks:

- ***Task 3.1*** ***Leader: CNES***

Prioritisation of technology vs. Domains for Incremental advances

- ***Task 3.2*** ***Leader: UKSA***

Prioritisation of technology vs. Domains for Disruptive RTD

- ***Task 3.3*** ***Leader: DLR***

Activity Descriptions for prioritised Developments and IOD/IOV

- ***Task 3.4*** ***Leader: DLR***

Roadmaps and Master Plan preparation

Prioritization phase

Roadmapping

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WP 3 contents

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Elaboration of Inputs from WP2

1) State of the art

2) Mission Requirements

3) Gap analysis

4) ESA Harmonisation Roadmap

Trade-off analysis

1) Criteria definition and technologies evaluation

2) Prioritization

Roadmap and Master Plan

1) Consolidation of priorities

2) Elaboration of Roadmap and masterplan

3)Plan for the analysis and evaluation of the results of SRC activities with respect to the overall SRC roadmap

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Prioritisation and Roadmaps: the methodology

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The Process

Prioritisation phase

STEP 1 – Main Criteria Definition

STEP 2 – Technology Vs Criteria Assessment

STEP 3 – Technology Vs Application-Gaps Correlation

Roadmapping phase

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STEP 1 - Main Criteria Definition

a. *Definition of incremental advancements and disruptive technologies*
b. *List of incremental and disruptive technologies*
c. *Definition of technical evaluation criteria*

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The prioritisation methodology

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STEP 1

a) Definition of incremental advancements and disruptive technologies

Incremental advancements

Enabling 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-medium timeframe

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.

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The prioritisation methodology

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STEP 1

b) List of incremental advancements and disruptive technologies:

Technologies for *Incremental Advancements:*

- *HET*
- *GIE*
- *HEMP-T*

Disruptive Technologies:

- *Thrusters:*
  - *Helicon*
  - *MPD*
  - *FEEP*
  - *Colloids*
  - *PPTs*
  - *Neutrons Sources*
  - *QCT*
  - *ECR*
  - *Ponderomotive Thrusters*
  - *Electronegative GIE*
  - *HALO*
  - *Other thrusters*
- *Radically innovative transversal technologies (PPU/ Direct Drive/Power Management, diagnostics, nanotechs/MEMs, FCU, etc.)*

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STEP 1

c) Definition of the technologies evaluation criteria

PSA partners agreed on an evaluation criteria matrix, with 5 evaluation drivers:

1. **Costs/Feasibility**
2. **Flexibility**
3. **Competitiveness**
4. **Impact on the host –system**
5. **European non dependency**

The drivers are defined through specific subcriteria

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STEP 2 – Technology Vs Criteria Assessment

a. *Partners Joint Evaluation through Criteria Matrix, capitalizing:*

- Information acquired through WP2 analyses including Workshop in Brussels
- Steering Board and Advisory Board high level advices
- THAG analyses and related Technical Dossier

b. *The technologies are prioritized, through the criteria matrix defined in the step 1*

- by using the grades for each criteria with a weighting factor and summing the results for the specific technologies, a single score is calculated.

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STEP 3 - Technology Vs Application-Gaps Correlation

*The **primary APPLICATIONS*** considered are:

- **Telecom, Space Transportation, LEO, MEO, Interplanetary/Exploration/Science**

*The **gaps/needs per Application** are identified*, considering those suggested by institutional and industrial stakeholders during the Workshop held in Brussels (25-28/11/2014)

The importance of each *technology to each **gap/need** is evaluated* quantifying

- the gap importance per Application
- the technology matching capability for the gap itself

On the base of the previous methodology incremental and disruptive classes were treated accordingly

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The Roadmapping Phase

- *All the activities identified will populate the edition of a roadmap and master plan, showing consistency and complementarity with the existing/updated European roadmaps. The master plan will establish how to coordinate all the activities for the whole duration of the SRC.*

- *Elaboration of a plan for the analysis and evaluation of the results during the execution of the activities within the SRC. KPIs will be defined as part of the plan.*

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Status

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- ***Prioritization results** for*
  - *Incremental Technology classes*
  - *Disruptive Technologies*
- *Prioritization of the **main gaps/needs***
- ***Preliminary Roadmaps***
  - *Proposed evolution steps per*
    - *EP Technology class*
    - *Related main system elements*
    - *Other transversal aspects*

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Incremental Advancements

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Preliminary List of Main Gaps per Application – step 1

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Following WP 2 Results:

- Bruxelles Workshop
- Survey Results
- THAG Mapping Results

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

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Example of Gaps Justification Vs Application (1/2)

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		Telecom		
		Dual-mode	Lifetime Extension	Faster EOR
Costs/Feasibility	non recurring costs	May need to change existing thrusters design or delta-qualify them; PPU has to be redesigned	Will possibly have an impact on the thruster design, and will lead to a long (hence costly) qualification phase	Possible routes are: higher efficiency thrusters, higher efficiency solar panels, increased s/c available power, which are all costly
	Starting TRL and relevant justification	Lots of activities already performed at thruster level to investigate operating range; PPU technology not really an issue	No specfici re-design may be needed for HEMP-T and GIE, and some activities already preformed for HET (materials, magnetic shielding)	Increasing thrusters' efficiency is challenging; same remark for solar panels
	Development Planning and Risks Analysis			
Flexibility	Versatility w.r.t. Different applications	Dual mode may be interesting for other types of applications, e.g. LEO or interplanetary missions	May be used for applications that require high total impulse (interplanetary, space transportation)	May benefit space transportation

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Example of Gaps Justification Vs Application (2/2)

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		Telecom		
		Dual-mode	Lifetime Extension	Faster EOR
Competitiveness	Expected competitive position in the european and non european market	Main satellite commercial market	Useful if the Telecom market increase their mission duration (> 15-18 years)	Main satellite commercial market
Impact on the host - system	Expected saving on the host-system cost	No significant saving on cost is expected, unless for very particular cases	No significant saving on cost is expected if mission duration is not increased	Some cost saving due to shorter EOR operations
	Expected host-System delta performance (Mission benefits)	Expected mass savings on the order of 50-80kg for satcoms	Increased mission duration; however, level of interest is deemed low with respect to present standards (15-18 years)	Shorter EOR duration will be a differentiator

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Criteria per Technology - Step 2

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HET

Costs/Feasibility (Score 1)	Low technical risk, low recurring costs	
Costs/Feasibility (Score 2)	High feasibility, specific users identified	
Flexibility	Very flexible technology, scalable, throttable, various gases	
Competitiveness	Very competitive in the telecom market	
Impact on the host -system	major improvement in costs and performance	
European Non-Dependence	European non-dependence ensured	

GIE

Costs/Feasibility (Score 1)	Low technical risk, higher cost w.r.t. the HET (system)	
Costs/Feasibility (Score 2)	High feasibility, specific users identified	
Flexibility	Flexible technology, scalable	
Competitiveness	Very competitive where high Isp is needed, more flight heritage	
Impact on the host -system	major improvement in costs and performance	
European Non-Dependence	European non-dependence ensured	

HEMPT

Costs/Feasibility (Score 1)	Low technical risk, low recurring costs, lower TRL	
Costs/Feasibility (Score 2)	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	

List of objectives per application

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- ***Specific objectives*** *were identified for each application*

May also benefit to

- Telecom:
  - Dual-mode
  - Lifetime extension
  - Innovative & cheaper PPU concept
  - Faster EOR
  - Simplified fluidic architecture
- Space transportation:
  - High power thruster/PPU
  - Alternative propellants
  - Direct drive
  - High total impulse
- LEO (resp. MEO): optimized EPS for LEO (resp. MEO) missions
- Exploration/Science: fine thrust/micro-thrust

May also benefit to

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Prioritization of objectives

- *Objectives were **ranked** w.r.t. the following criteria:*

Costs/Feasibility	Non recurring cost
	TRL and development risks
Flexibility/opportunity	Potential use for other types of applications
Competitiveness	Expected market

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

- *Results:*

Telecom					
Dual-mode	Lifetime Extension	Innovative & cheaper PPU concept	Faster EOR	Simplified fluidic architecture	Overall launch mass savings
+++	=	+++	+	+++	=

Space transportation			
High-power thruster/PPU	Alternative propellants	Direct drive	High Total Impulse
+	-	=	=

LEO missions	MEO missions	Exploration/Interplanetary/Science
Optimized EPS for LEO missions	Optimized EPS for MEO missions	Low power/fine thrust
=	++	- -

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Ranking of thruster technologies vs applications

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- *Thruster technologies were ranked for each application w.r.t each objective:*
  - **Telecommunication**

	Dual-mode	Lifetime Extension	Innovative & cheaper PPU concept	Faster EOR	Overall launch mass savings	Overall rank
HET	+	=	+	+	+	+
GIE	-	+	- -	-	=	-
HEMPT	=	-	=	=	=	=

  - **Space transportation**

	Higher-power thruster & PPU	Alternative propellants	Direct drive	High Total Impulse	Overall rank
HET	+	=	+	=	+
GIE	-	+	- -	+	-
HEMPT	=	-	=	-	-

  - **LEO/MEO/Exploration**

	LEO	MEO	Exploration/Science
HET	+	+	-
GIE	=	=	+
HEMPT	-	-	-

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Disuptive technologies

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Disruptive Technologies

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Many other types of ion and plasma thruster emerging that may potentially be 'disruptive':

- Helicon Plasma Thruster
- MPD
- FEEP
- Colloid
- PPT
- Ion Thruster based on Neutron Source
- QCT
- ECR
- Ponderomotive
- Electronegative GIE
- HALO
- others..............

> *"A 'disruptive space technology' is an emerging technology that disrupts the status quo of the space sector by replacing the dominant technology and provides a radical improvement in performance that is perceived as valuable by a customer or part of the market, or it opens up new opportunities not possible with the incumbent technology".*

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Disruptive Technologies: Evaluation

STEP 1→ STEP 2: Main list of alternative thrusters assessed against the evaluation criteria.

Costs/Feasibility	recurring costs
	non recurring costs
	Starting TRL and relevant justification
	Development Planning and Risks Analysis
	Level of dependence on Non European key technogies
	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 whith 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	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)

Relatively small variance across the scores for the different thrusters, except for:

- ion thruster based on neutron source technology

- low score as thruster proposed at conceptual level only, therefore difficult to ascertain performance attributes.

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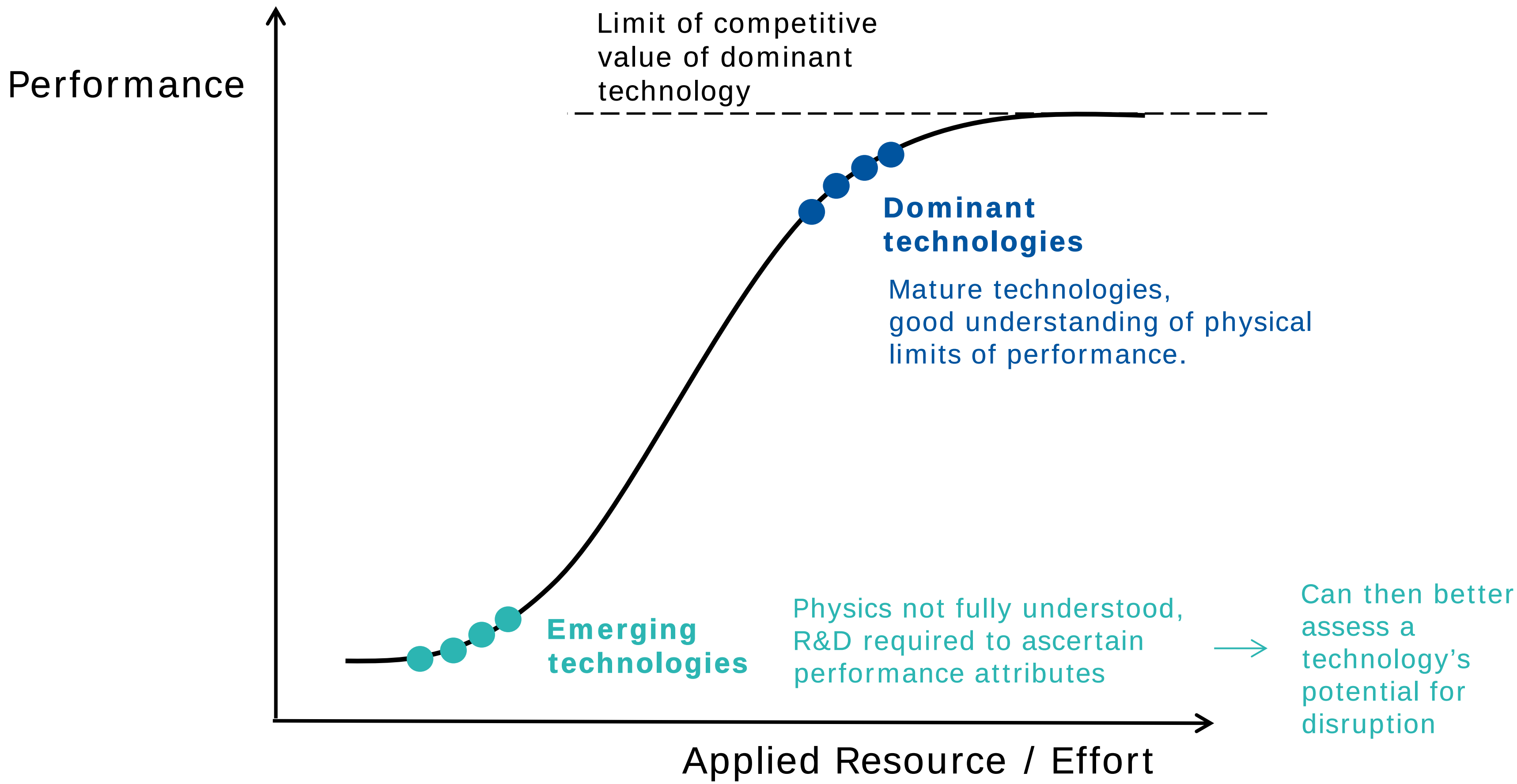
Disruptive Technologies



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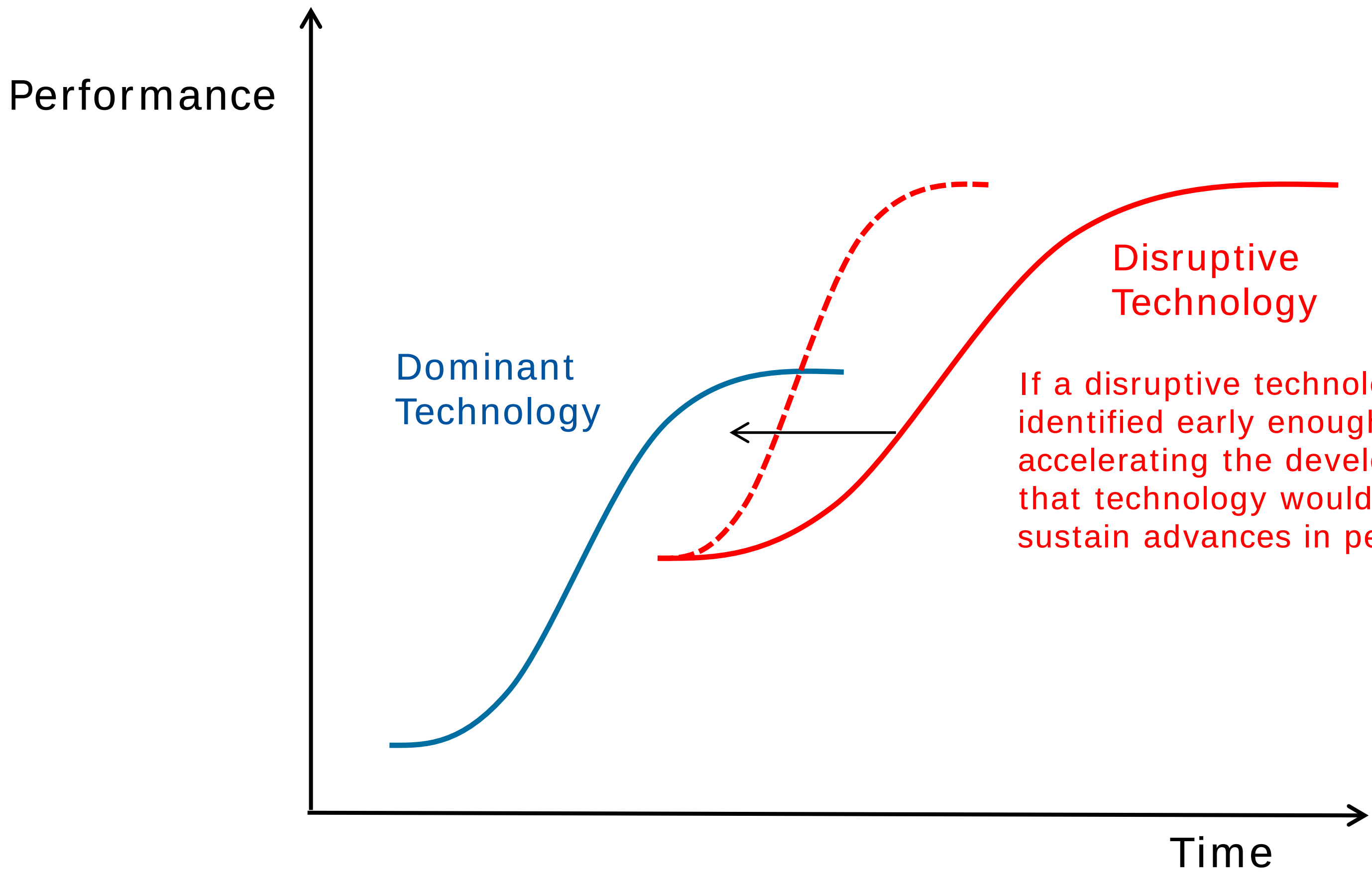
Disruptive Technologies



If a disruptive technology can be identified early enough, accelerating the development of that technology would help sustain advances in performance.

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Disruptive Technologies Evaluation

STEP 3

Technologies
HPT
MPD
FEEP
Colloids
PPTs
Neutron Sources
QCT
ECR
Ponderomotive
Electronegative GIE
HALO

Missions
Telecom
Space transportation
LEO/MEO missions
Exploration/Interplanetary/Science

Gaps
Cost reduction (recurring, to be distinguished between LEO;MEO)
Alternative propellents
Mass saving
High total impulse
Higher efficiency
low noise
lower system complexity (nanosat)
multiple mode operation
Alternative clustering configuration
High thrust controllabillity (precise FF)

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STEP 3: Micropropulsion technologies

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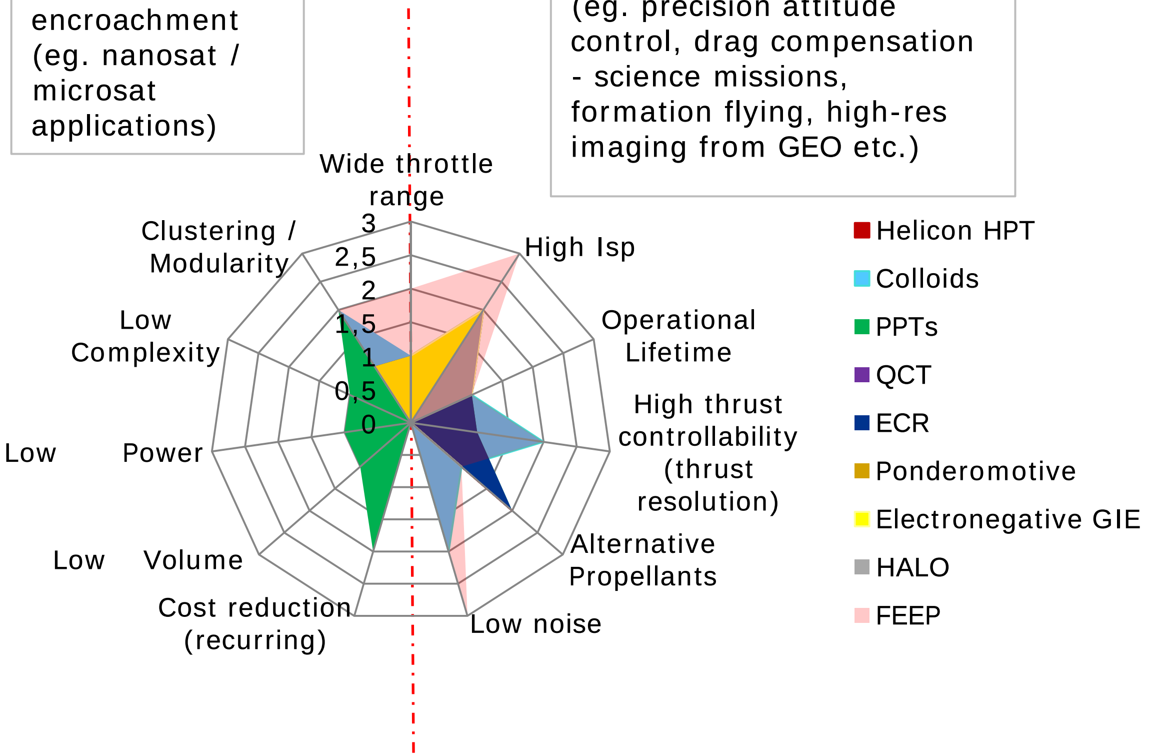
- Science missions
- LEO/MEO missions

Low-end encroachment (eg. nanosat / microsat applications)

High-end encroachment (eg. precision attitude control, drag compensation - science missions, formation flying, high-res imaging from GEO etc.)



The score is between 0 and 3 (integer), the higher the better.
Score relative to cold gas/chemical micropropulsion:
0 = worse than cg/cp,
1 = similar to cg/cp,
2 = small - medium performance gain over cg/cp,
3 = significant improvement over cg/cp

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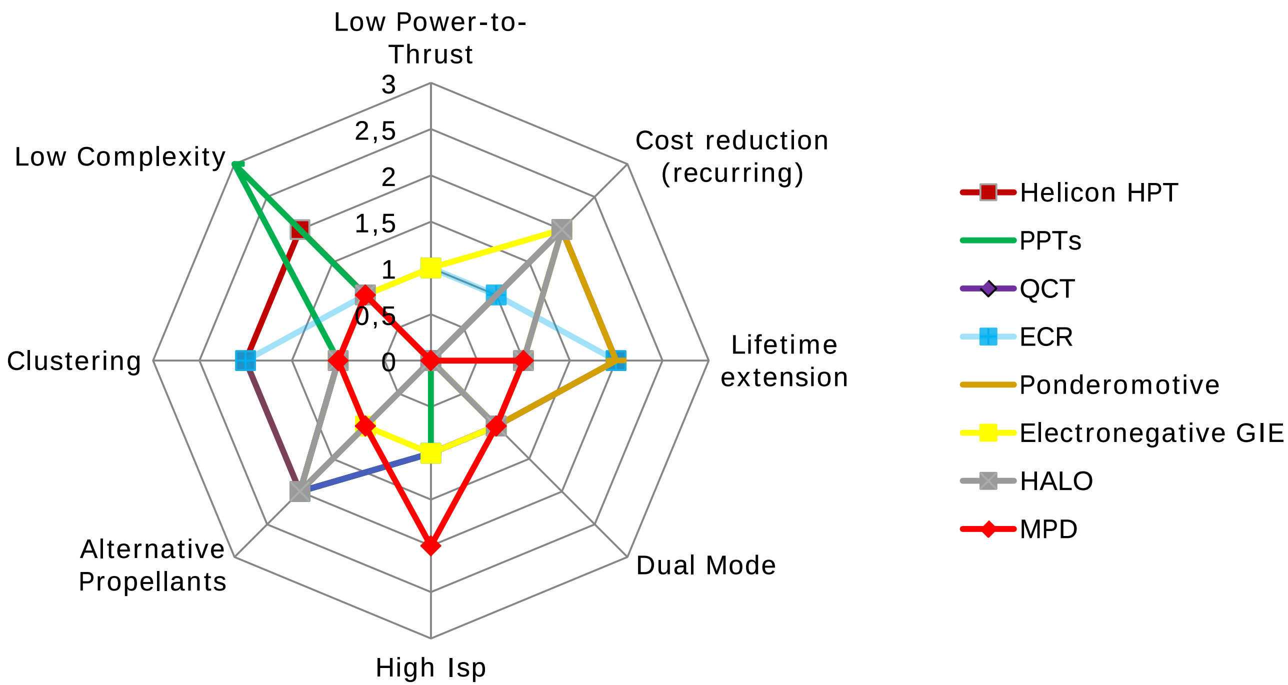
STEP 3: Intermediate Thrust, Power

- Telecom
- LEO/MEO missions
- Science missions



The score is between 0 and 3 (integer), the higher the better.
Score relative to incremental EP thrusters:
0 = worse than,
1 = similar to,
2 = small - medium performance gain
3 = significant improvement over incremental thrusters

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STEP 3: High Power, High Thrust

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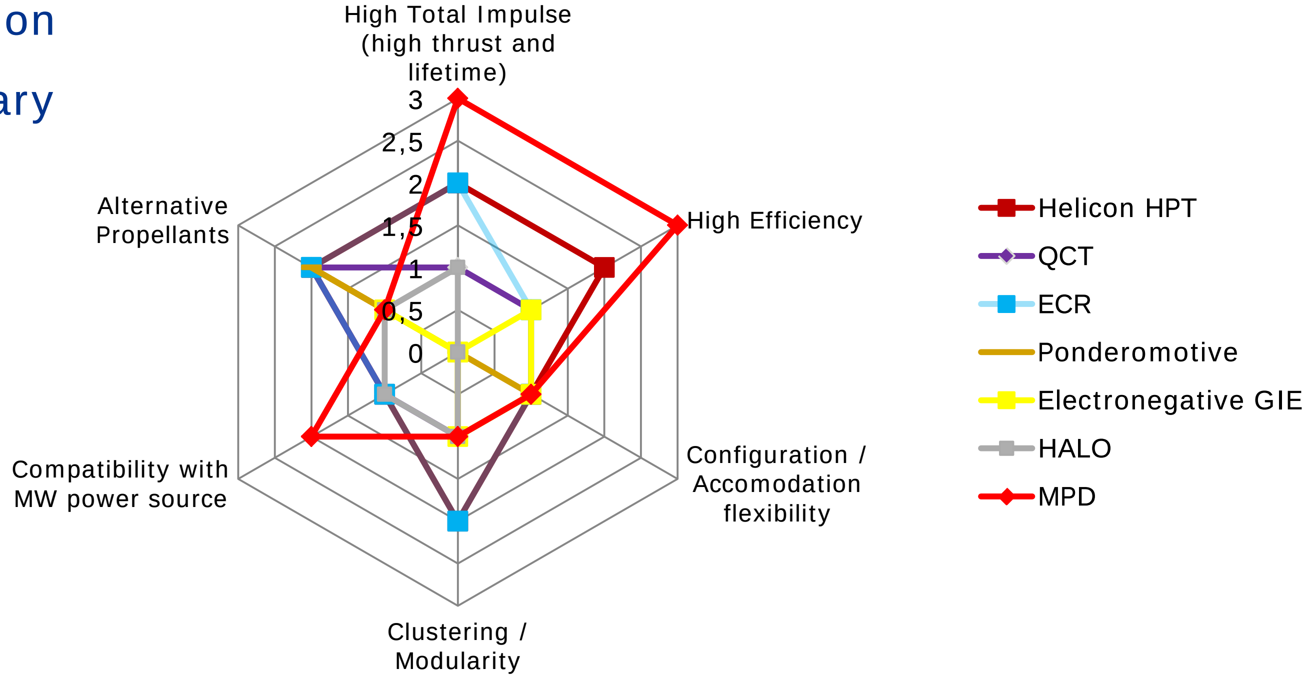
- Space Transportation
- Interplanetary
- Exploration



The score is between 0 and 3 (integer), the higher the better.
Score relative to incremental EP thrusters:
0 = worse than,
1 = similar to,
2 = small - medium performance gain
3 = significant improvement over incremental thrusters

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Disruptive Technologies - Summary

The main list of alternative thrusters have been assessed against the evaluation criteria and the identified gaps/needs for each application/market segment:

- some showing early potential to be disruptive in the propulsion sector;
- however, prioritizing emerging technologies is problematic due to difficulty in ascertaining ultimate performance attributes of low maturity technologies.

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Thank You

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Back up Slides

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The prioritisation methodology

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Costs/Feasibility	recurring costs
	non recurring costs
	Starting TRL and relevant justification
	Development Planning and Risks Analysis
	Level of dependence on Non European key technogies
	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 whith 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 competiencies/technologies already developed at european level in other national and international project
	Performances gain due to disruprtive technology advancement
	Potential Spin off for cross related fields
	Possible integration in launch systems worldwide
Impact on the host -system	Expected saving on the host-system cost
	Interface compatibility between the EP and the host system
	Expected host-System delta performance (Mission benefits)
European Non-Dependence	Contribution and impact of the technology in ensuring European Non-Dependence

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