1.1 HiPER publishable summary

1.1.1 Executive Summary

Space is a very harsh environment: temperatures are extreme on both sides, distances are measured in terms of millions of kilometres, and vacuum make things even worse.
To successfully explore space, there are some basic "building blocks" that are needed as a minimum:

1. An effective, reliable and cost-effective way to access Space from Earth (which means a launch system);
2. A robust spacecraft;
3. A shielding system from cosmic rays and solar flares;
4. A power generation system;
5. An efficient and reliable propulsion system.

HiPER project was aimed to give a boost to points 4. & 5. above.

A choice was made to focus exclusively on Electric Propulsion (EP) systems, and on related high power generation, either because of the know-how and expertise of the participating partners, and for the intrinsic advantages of EP technology with respect to the traditional, well known, chemical propulsion (namely, rocket engines).
For the latter aspect, it is useful to address state of the art Specific Impulse capabilities, which are at least an order of magnitude higher for EP systems than for chemical propulsion, and the related overall efficiency. On the other side, chemical do perform better –at least for now- in terms of thrust and of reliability, and do require less electric power than EP.

HiPER aimed to advance knowledge and technology one step further with respect to the original state of the art, either for the selected EP systems and for the related power generation systems.

As a starting point, a study has been conducted on a set of missions that could be operated with high power EP systems. Although space science and exploration will be the main driving force behind the technological development of EP and high power generation systems, novel techniques and methodologies will equally benefit commercial and utilitarian space missions, thus generating a very significant impact on Europe's capabilities to access and exploit space.

HiPER not only addressed technologies, but also attempted to consider major technological efforts in the framework of social and political scenarios, both internal to Europe and with respect to non-European partners. In this respect, there have been discussions and meetings with NASA and large US companies to share **HiPER** results and harmonise future roadmaps.

A number of results have been obtained in the project's timeframe, including the definition of a set of exploration and transportation scenarios; the design, prototyping and initial test of a high power (20 kW) Hall Effect Thruster, the design of a multi-gridded Ion Engine and the development of a high current cathode, the design, prototyping and initial test of two 100 kW class Magneto-Plasma-Dynamic Thrusters; the design, prototyping and initial test of an inflatable solar array with Fresnel lens concentration system, and the feasibility study for a 200 kW nuclear reactor power generation system in space.

1.1.2 Summary description of project context and objectives

HiPER project was conceived to depict a roadmap for future space exploration and transportation, which could benefit from technological advancements in Electric Propulsion (EP) technologies and from the related advancements in power generation in space.

Rationale for such ambitious goals rely on the intrinsic efficiency of electric propulsion on one side (orders of magnitude better than the “classical” rocket engines) and on its proven heritage since the late ’60 of the past century in a number of scientific and commercial missions, and on the fact that high power EP needs high power generators onboard, on the other side.

To achieve the goal an interdisciplinary team of 20 partners (8 SMEs, 3 large companies, 3 universities, 4 research centres and 2 government bodies), from 6 EU countries, has been formed, grouping most of the specialists in EP and in power generation in space.

The whole HiPER project has been divided into **five** main technical Work Packages, each of them fully dedicated to a different topic. The first two technical WPs are respectively devoted to mission analysis and to electric power generation. The other three WPs are instead focused on three different electric propulsion concepts (Hall thruster, Ion engine and Magneto plasma dynamic thruster).
Here follows a brief summary of each WP, describing the target activities and the main objectives.

Mission Analysis, Propulsion System Requirements and Recommendations work package
The main goal of this work package was the definition of future scenarios for European space transportation and exploration, and of ensuing possible missions objectives. The reference scenarios has been built by taking into account technical as well as political challenges, and the parallel evolution of non-European trends. Definition of requirements for power generation and electric propulsion systems, based on the above mentioned scenarios, have been produced as input for the other WPs. Medium term scenarios as well as more futuristic, long term scenarios have been produced and presented to various EU and international players.

In-space Power Generation work package
The goal was to design a power generation subsystem (i.e., power generation and power control unit) capable of providing power levels ranging from tens of kW to thousands of kW.
Either Solar Arrays technologies and Nuclear Reactors were studied. Both solutions have been considered and thoroughly investigated. A prototype of an advanced solar array based on concentration has been manufactured and assembled, whereas the nuclear reactor option has been preliminarily assessed and seized in terms of mass, volumes, thermal control systems and shielding from radiations.

High Power work package Hall Thruster Development work package
Within this workpackage the design, manufacturing and development of a HET prototype working at a power level of 20kW has been faced. A very preliminary experimental campaign aimed at measuring the thruster performance and to validate technological solutions envisaged during the thruster’s development has been conducted at the end of the

workpackage activities. It has to be noted that the produced prototype is the most powerful HET produced in Europe.

High Power Gridded Ion Engine Development work package
This part of the project was aimed at investigating novel concepts for thruster grid choice in order to design gridded ion engines (GIEs) efficiently operating at higher power levels.
The very novel approach of dual stage, multiple grids engine has been analytically investigated, and grids number and distance optimised for future development. At the same time, design, development and experimental campaign on high current hollow cathodes to be used as neutralizers for this class of thrusters has been conducted.

Magneto-plasma-dynamic Thruster Development work package
Within this work package the design, manufacturing and test of two prototypes of MPDTs, one operating with an externally applied magnetic field and one operating with the sole self-induce magnetic field, has been conducted.
Both thrusters have been successfully operated during preliminary tests in vacuum chambers; in parallel the first European multi-channel Hollow Cathode has been developed and successfully tested for more than 100 hours.

Considering the potential impact of the electric propulsion in a near-mid future term, the work carried out along the three years of HiPER program has a significant strategic importance. For the first time a large group of private companies, enterprises, research centres and Universities has been put together to actively discuss about the necessary steps to be taken in order to define a roadmap for the future development and exploitation of high power electric propulsion. And the effort could have hardly be more successful, resulting in a fruitful cooperation among all the involved partners, who worked together under a common objective.

An extensive theoretical and experimental research has been performed on all the principal open issues in the field of electric space propulsion, with special attention for power generation systems, mission analysis and for all the existing types of thruster assembly. The main results of this joint effort will be recalled in the following sections of the present document.

A lively dissemination activity has been carried out in parallel to technical activities, participating at international conferences and producing several high quality papers dealing with the diverse topics investigated along the last three years within the HiPER framework.

1.1.3 Project logo

1.1.4 Address of the project public website, and contact details

HiPER public website can be found at:
http://www.alta-space.com/hiper

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