FINAL REPORT ON DISRUPTIVE POWER & PROPULSION

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ABSTRACT

This document is the deliverable D10.2 of the WP 10

This document is a final report based on the documentation issued in DiPoP work packages 20,30 and 40 on Disruptive Power & Propulsion

KEY WORDS DiPoP, final, report, Disruptive, Power , Propulsion, Applications, Recommendations

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1 References documentation:

[R 1] FP7-SPACE-2011-284081 Grant agreement core; annex I DOW; annex II;…. signed 18/10/2011
[R 2] www.DiPoP.eu
[R 3] D20.1 Final report on Space Power & Propulsion Technologies
[R 4] D20.2 Space Power & Propulsion Recommendations for further EC R&D / FP8
[R 5] D23.2 Nuclear Electric Propulsion / Electric Power Procession Unit Report
[R 6] D23.3 Nuclear Thermal Propulsion /Thermal Power Procession Unit Report
[R 7] D23.4 Final Report Advanced Propulsion Systems & Power Procession Unit
[R 8] D30.2 Fission nuclear power generation roadmap update
[R 9] D30.3 Nuclear Power Sources Final Report
[R 10] D31.3 Updated Technical Note on 30 kWe fission sources for space applications
[R 11] D32.3 Updated Technical Note on 200 kWe fission NPS for space applications
[R 12] D33.2 Final Report Public Acceptance and Recommendation of Public Dissemination
[R 13] D33.3 Generic Study of Safety and Sustainability
[R 14] D40.1 Final report on space power & propulsion application analysis
[R 15] D40.2 Recommendations for further EC R&D / FP8 analysis on space power & propulsion application

2 Purpose

The document is a final report based on the documentation issued in work packages 20,30 and 40 on Disruptive Power & Propulsion provided by the Consortium partners for the DiPoP project.
This final report highlights the main issues and recommendations.

3 Recommendations on Non-Fission Space Power and Propulsion

It is very important to give recommendations to the EC for further investment in R&D respectively Horizon 2020 not only from scientific and technological point of view.
Therefore in the course of the project DLR and CAU (Christian-Albrechts-Universität zu Kiel) have setup a large list of disruptive space power and propulsion technologies.
Those technologies were analyzed and sorted according to standard hierarchy's techniques with DLR experts. The reports [R 3] and [R 4] exhibit the top ten disruptive technologies that have been found by DLR.

Among the exhibited techniques one shall point out for space power (excluding fission power that is presented in next chapters) the following techniques:

- High temperature superconductors

  Lower mass of wires but current materials must be cooled to very low temperatures
  High-temperature superconductors (abbreviated high-Tc or HTS) are materials that have a superconducting transition temperature (Tc) above 30 K (−243.2 °C). From 1960 to 1980, 30 K was thought to be the highest theoretically possible Tc. Developments have continued and let to the discovery of new high temperature superconductors like Bismuth copper oxide (BISCCO) or Yttrium Barium copper oxide (YBACUO) with critical temperature in excess of 90 K. New Fe-based superconductors were identified in 2008 (critical temperature ~50K). Performance data: 300 times lighter wires are possible; Power density: 20.000 A/cm² (currently used transmission lines have around 100 A/cm²)

- Thinned multi junction cells and panel

  Strongly absorbs sunlight, thinner film than other semiconductor materials.However co-evaporation gives uniformity issues over large areas. It is also difficult to co-evaporate elements in an inline system. Co-evaporation causes high growth temperatures raising thermal budget and cost
  CIGS (Copper Indium Gallium Diselenide) is used as light absorber material for thin-film solar cells. Because the material strongly absorbs sunlight, a much thinner film is required than of other semiconductor materials. CIGS's absorption coefficient is higher than any other semiconductor used for solar modules. The market for thin-film PV grew at a 60% annual rate from 2002 to 2007 and is still growing rapidly, Therefore, a strong incentive exists to develop and improve deposition methods for these films that will allow lower cost and increased throughput. The most prevalent CIGS fabrication technique in the laboratory is co-evaporation.

- Stirling cycle thermoelectric radioisotope generator

  Increase specific power of RTGs but Isotopes are scarce resources, Ethical and social issues of using (too much) plutonium
  The ASRG (Advanced Stirling Radioisotope Generator) is a radioisotope power system using Stirling power conversion technology and is being designed for multi-mission use in environments with and without atmospheres for both deep space and for example the Mars atmosphere. Because of the Stirling cycle the efficiency is 4-5 times higher than current radioisotope generators the plutonium inventory is 4 – 5 times lower for the same electrical power level. It is designed to have a lifetime of 14 years and has a specific power of 8,5 We/kg (in comparison a Multi-Mission RTG [MMRTG] has only 2,8 We/kg)

- Quantum-Dot Solar cell

  High potential efficiency, Mechanical flexibility and low cost, clean power generation but until now, low levels of efficiency
  By using two or more p-n solar cell junctions, tandem cells made of different semiconductors, a multi- hetero-junction design yields a better match to the solar spectrum than a single-junction cell. Efficiency of up to 66% (In comparison: Efficiency record of flexible solar cells: 18,7%; Overall efficiency record: Thin-film gallium-arsenide cell with 27,6%), Quantum dot solar cells are an emerging field in solar cell research that uses quantum dots as the photovoltaic material, as opposed to better-known bulk materials such as silicon, copper indium gallium selenide (CIGS) or CdTe. Quantum dots have band gaps that are tunable across a wide range of energy levels by changing the quantum dot size. This is in contrast to bulk materials, where the band gap is fixed by the choice of material composition. This property makes quantum dots attractive for multi-junction solar cells, where a variety of different energy levels are used to extract more power from the solar spectrum. The potential performance of the quantum dot approach has led to widespread research in the field. Early examples used costly molecular beam epitaxy processes, but alternative inexpensive fabrication methods have been developed. These attempts rely on

quantum dot synthesis using wet chemistry (colloidal quantum dots – CQDs) and subsequent solution processability of quantum dots. CQD solar cells currently hold the performance record for quantum dot solar cells.

- Unitized regenerative fuel cell (URFC)

  Higher energy density but Optimization for two way use is needed.
  An URFC could replace batteries for telecommunication satellites because the energy demand is rising up to30kW which is hard to deliver with a light weight battery for a long time. The fuel cells can also run the process backwards for recharging which means it can make hydrogen and oxygen out of water and solar energy. The fuel cell is much lighter than a generator and an electrolyser and has the highest storage capacity of all non-nuclear storage systems.

Among the exhibited techniques for propulsion one shall point out the following techniques:

- SABRE Engine (may be subject to intellectual property rights)

  Saves on propellant weight, increasing payload fraction, but high complexity.
  SABRE (Synergistic Air-Breathing Rocket Engine) is a concept for a hypersonic precooled hybrid air breathing rocket engine for propelling the proposed Skylon launch vehicle into low Earth orbit (LEO). The design of SABRE comprises a single combined cycle rocket engine with two modes of operation. The air breathing mode combines a turbo-compressor with a lightweight air precooler positioned just behind the inlet cone. At high speeds this precooler cools the hot, ram compressed air leading to an unusually high pressure ratio within the engine (enabled by the high density of cooled air). The compressed cold air is subsequently fed into the rocket combustion chamber where it is ignited with stored liquid hydrogen. The high pressure ratio allows the engine to continue to provide high thrust at very high speeds and altitudes. The low temperature of the air permits light alloy construction to be employed which gives a very lightweight engine - essential for reaching orbit. In addition, SABRE's precooler does not liquefy the air letting it run more efficiently.

- Alternative Solid Propellants: CL-20

  High performance, High energy content, Very high energy density but Relatively sensitive to both impact and friction
  CL-20 is the highest energy single component compound known to date and, in addition, has the highest density of any known organic energetic substance. It has a better oxidizer-to-fuel ratio than conventional HMX or RDX. CL-20 produces 20% more energy than traditional HMX-based propellants, and is widely superior to conventional high-energy propellants and explosives. CL-20 has better detonation properties than octogen, higher energy density, but lower impact and friction sensitivity. Specific impulses in the range of 320 s are expected (against 295 s maximum with ammonium perchlorate-based propellants)

- Micro Electric Space Propulsion (MEP)/ Microparticle Propulsion

  Flexible, Lightweight, High- efficiency, Scalable micropropulsion but no real spaceflight experience exists yet. This type of thruster uses microparticles as propellant. Much of the engine is etched directly onto a wafer-thin piece of silicon via micro-electromechanical systems technologies, known as MEMS, that are more commonly used in the semiconductor industry. Measuring no thicker than a half-inch (1 centimeter, including the fuel) and with tens of thousands of accelerators able to fit on an area smaller than a postage stamp, these "stick-on" thrusters could power tiny spacecraft over vast distances. Performance data: ISP:100 - 10.000 s.

- Pulsed inductive thruster (may be subject to intellectual property rights)

  Requires no electrodes but energy efficiency is low.
  Pulsed inductive thrusters (or PITs) are a form of ion thruster spacecraft propulsion. A PIT uses the Lorentz force created by perpendicular electric and magnetic fields to accelerate a propellant. A nozzle releases a puff of gas (usually ammonia or argon) which spreads across a flat induction coil of wire about 1 meter across. A bank of capacitors releases a pulse of electric current lasting 10 microseconds into the coil, generating a radial magnetic field. This induces a circular electrical field in the gas, ionizing it and causing the plasma to revolve in the opposite direction as the original pulse of current. Because their motion is perpendicular to the magnetic field, the ions are accelerated out into space. Unlike an electrostatic ion thruster, a PIT requires no electrodes (which are susceptible to erosion) and its power can be scaled up (in principle) simply by increasing the number of pulses per second. A 1-megawatt system would pulse 200 times per second.

- Ambient Plasma Wave Propulsion

  No propellant required but Complexity of system, is high. Untested
  The propulsion system is based on helicon waves. They produce higher density plasmas than other types of plasma engines. The system can work as a rocket engine in zero-g as well as an atmosphere-breathing engine. The key advantage would be that the propulsion system can use ambient atmosphere as propellant for drag compensation of satellites (HET and GIT can also use ambient atmosphere).

A roadmap for micro-particle thrusters has been set in diagram 1 for the 'true' or solid micro-particle thrusters and for liquid droplet or 'colloid' thrusters. The interactions between the tasks are sketched within the time frame.
Also the roadmap of proposed development for Primary Electric Propulsion (EP) is illustrated in diagram 2 below. The general picture is shown with the 4 main areas of tasks: acquisition of technologies, development, fundamental research and supportive technologies researches.

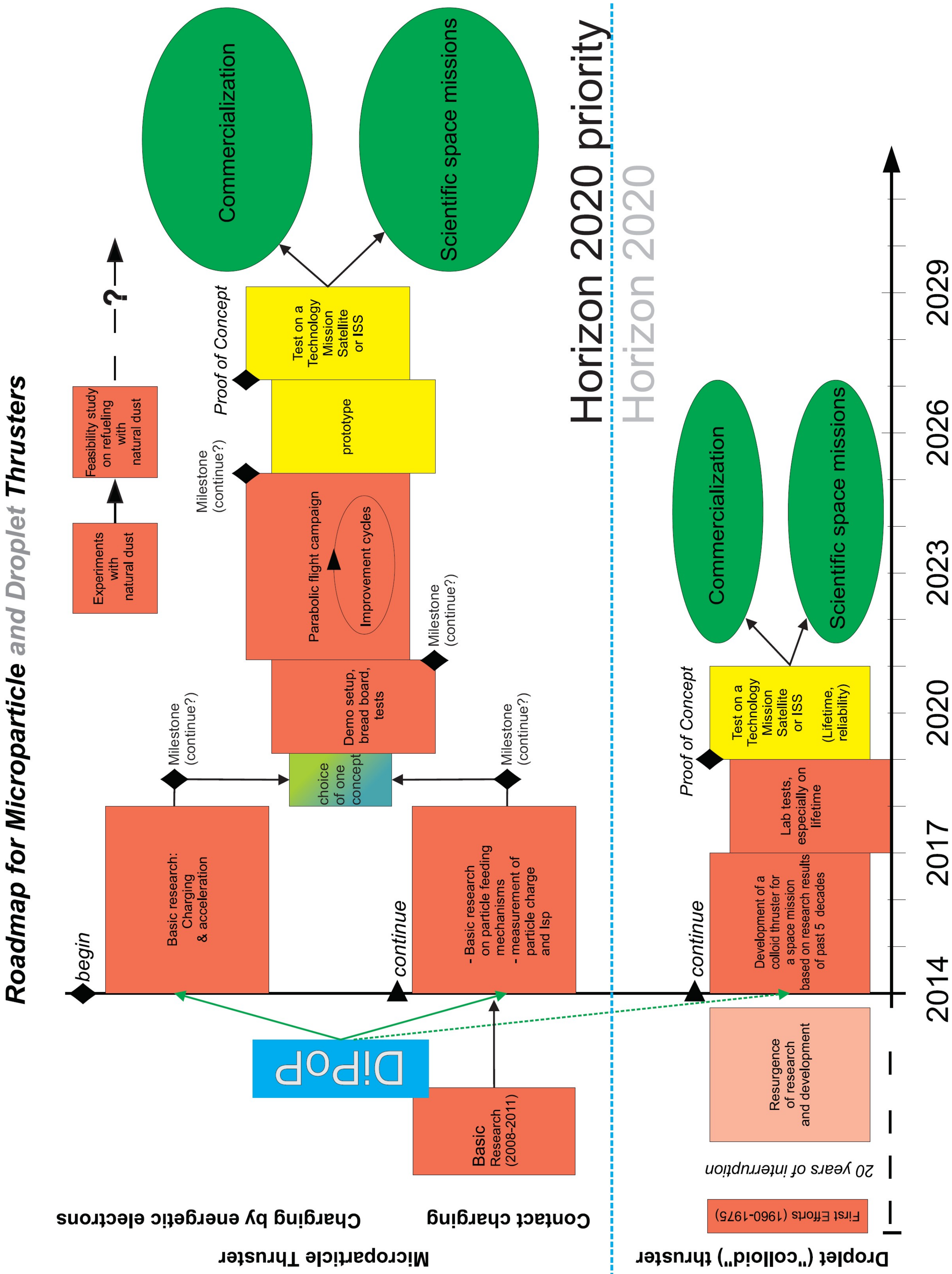

Diagram 1.: Roadmap for European Micro-Particle Propulsion Until 2029.

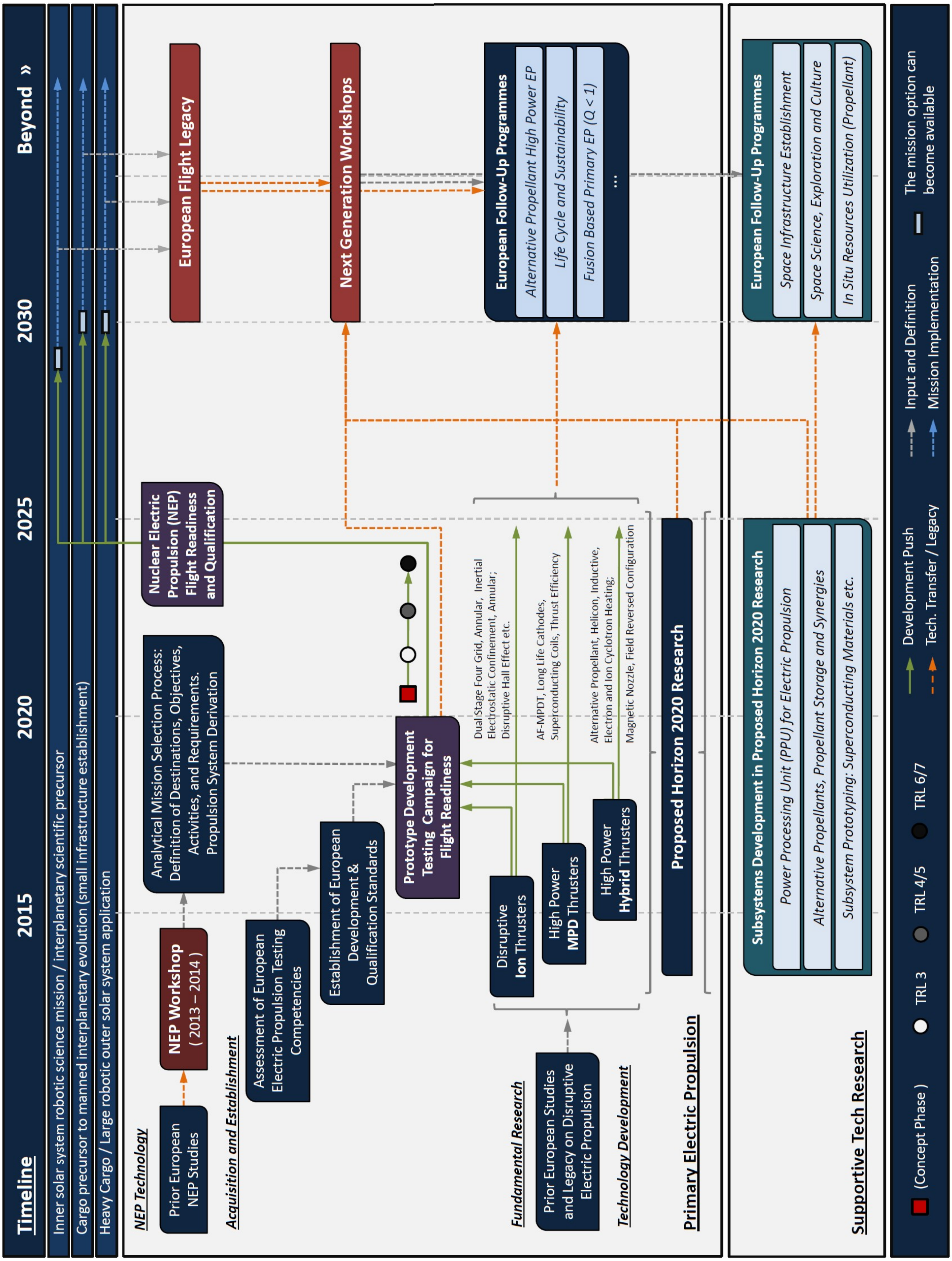

Diagram 2.: Roadmap for European Primary Electric Propulsion

4 Recommendations on Nuclear Electric propulsion and PPU

An assessment of mission and nuclear electric propulsion system options and power management and distribution and electric propulsion power processing issues has been undertaken by SEP. The analysis identifies also the constraints on design options from external factors such as mission requirements and launch capability.

Although most electric propulsion (EP) technologies can probably be adapted for the full range of missions it is not possible given the extent of current knowledge to identify one which achieves this better than any other. Consequently the preferred way ahead at this stage is for a nuclear electric propulsion generator (NEP) to be compatible with all the available EP technologies (see Figure 1).

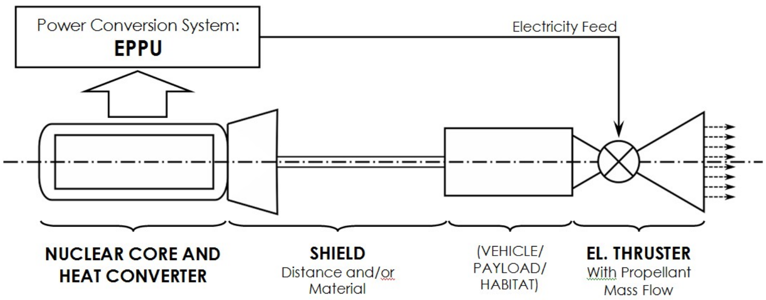

Figure 1 Nuclear electric propulsion (NEP) basic principles

Overviews of the technologies available and of the specific needs induced by Nuclear power generator have been reviewed. Among them:

- Mission and Nuclear Electric Propulsion System Options
- Electric Propulsion Technology Options
- Thermal to Electrical Energy Conversion.
- Power Management and Distribution (PMAD)

The main conclusion (summarized in [R 5] with a Basic Evaluation Matrix) is that there are many factors to take into consideration, many of which are mission dependent.

Consequently, an awareness of the principal advantages and disadvantages of the various technical options is the best that can be achieved in any early stage.

Also many features of the technology options are to some extent overlapping and have significant variations in potential performance.

Another aspect to consider is that performance measurement error for more advanced technical options can be significant. Laboratory thruster test results have been known to be very different from subsequent in-orbit performance. Although techniques for improving in-orbit thruster performance measurement have improved many system aspects, particularly high power electrical processing and conditioning, are at an early stage of research.

And finally it is also important not to underestimate the cost and time to develop a prototype technology to a mission ready capability.

5 Recommendations Nuclear Thermal Propulsion / Power conversion systems

The analysis lead by IRS Stuttgart focuses on Thermal Propulsion (TP) which has principally better overall efficiencies and higher system mass specific power for the same energy source due to the omission of one stage of conversion systematically proper to Electrical Propulsion (EP)

Both disruptive and advanced systems have been summarized. The distinction consists in the readiness of the base technology (TRL). Systems like NERVA which have undergone extensive investigation and even ground testing, and merely lack in-flight experimentation can be considered as disruptive. In contrast, Fusion Propulsion which relies on nuclear thermal fusion not yet fully technically available is considered as an advanced concept. For the latter, a decisive breakthrough can be expected in the next two decades and thus fusion propulsion has been reviewed too.

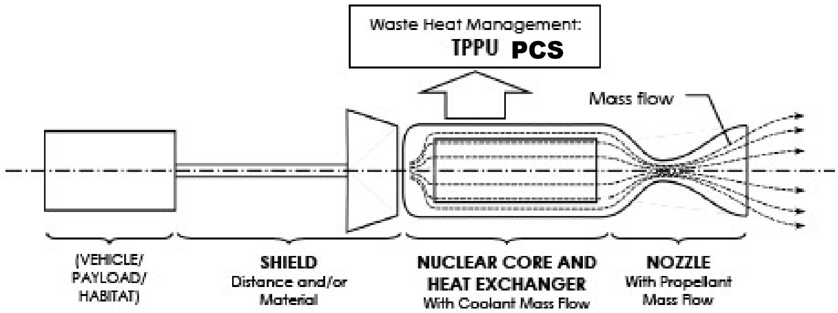

Figure 2 Nuclear thermal propulsion (NTP) basic principles

The Nuclear Thermal Concept comprises a propulsion power (see Figure 2) that provides heat by the system's core, which is a nuclear reactor. The heat is then used to heat a working medium which is finally exhausted as a propellant. The working medium is therefore the reactor coolant, and must therefore absorb all the reactor power. A thrust force is generated by the principle of conservation of momentum. Typically, hydrogen is selected as a working medium for its light atomic mass and hence high heat capacity making it an outstanding coolant. Its atomic mass also makes it an easily accelerated and thus an excellent propellant. However, the cause of its unsurpassable assets is also the cause of its drawbacks. Liquid Hydrogen is cryogenic, and requires continuous cooling for long missions.

Power conversion systems (PCS) (formerly named Thermal Power Processing Units (TPPU)) have been briefly considered and have been identified to be a vital subsystem of nuclear propulsion. Nuclear systems always involve enormous fluxes of heat. During engine operation it is the propellant that takes care of the cooling. After shutdown, nuclear reactions continue, decaying in time (typically) with a power law. This heat must be radiated away by an auxiliary heat waste system, if the reactor configuration itself is not sufficient. The PCS manages these heat fluxes and can even recover waste heat for ancillary purposes.

The main conclusion (summarized in [R 6] [R 7] with an Evaluation Matrix of concepts of NTP) provides a preliminary assessment of the NTP concepts. Even with technology available in the short or medium term significant breakthrough ventures are possible. Already rather modest NEP systems enable significant enhanced interplanetary transportation.

Even more audacious inhabited missions are feasible in the medium term if NTP approaches could be enacted.

An exemplary voyage to Mars could consist in a space craft of 100 metric tons departing from an infrastructure in low Earth's orbit.

While this outlook to open new, significant classes of space flight missions makes a certain case for the application of nuclear power in space and while the available data on Disruptive Power and Propulsion appears to sustain the technical aspect of such projects, a consideration of present days Public Perception of the enacted concepts reveals other challenges. In fact, the major impediment may be seen in the public's reluctance to implement nuclear technologies; these are for the time being enjoying only feeble support due to the Fukushima accident.

A roadmap of proposed tasks for the development of a European Nuclear Thermal Propulsion System is illustrated in diagram 3. The general picture of the roadmap is shown with the 4 main areas of tasks: acquisition of technologies, development, fundamental research and supportive technologies researches. The interactions between those tasks are sketched within the time frame.

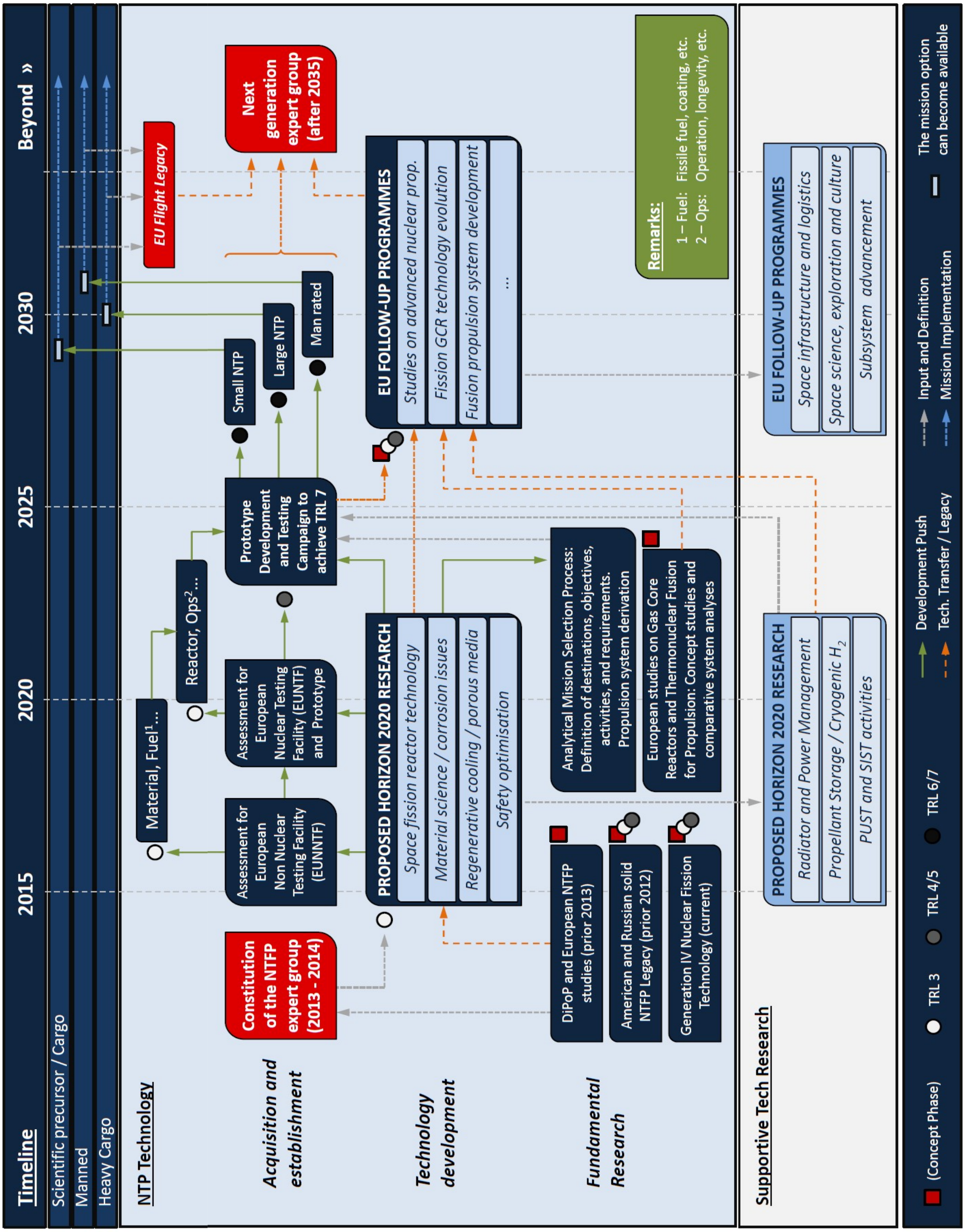

Diagram 3 : Nuclear Thermal Propulsion Roadmap for Europe proposed by DiPoP

6 Recommendations for Fission Nuclear Power Source in Space Applications (30, 200 kWe)

The analyses lead by SEP and ISIS have been focused on the selection of space applications that can most benefit from a 30 or a 200 kWe fission nuclear power generator, taking into account the resources Europe requires to develop the capability.

It takes account also of technical progress in Europe and relevant resources and capabilities in Russia and the US. The power of 30 kWe was selected because this was considered to be the lowest sensible size of fission nuclear power generator and a power of 200 kWe was selected as the largest fission nuclear power generator capable of launch by Ariane 5 ECA.

The missions analyzed in [R 10] and [R 11] include:

- ❖ Missions to the Outer Planets
- ❖ Removing 'dead spacecraft'/debris: if safety issues can be satisfactorily addressed
- ❖ Near Earth Objects (NEO) management (as part of SSA), NEO mining and ground-penetrating radar, NEO asteroids or comets Earth collision avoidance

This last application has to be highlighted because clearly the defense of the planet is seen as a compelling argument for public acceptance of fission reactors if there is no other way of deflecting a large earth-bound NEO asteroid, keeping in mind that safety and sustainability would have to be at least as good as for other application.

It is also worth noting that the trend is for the known number of NEO asteroids of diameter lower than 100 m, which can impact the Earth with possible major disastrous consequences, will double in the next 10 years according to Figure 3.

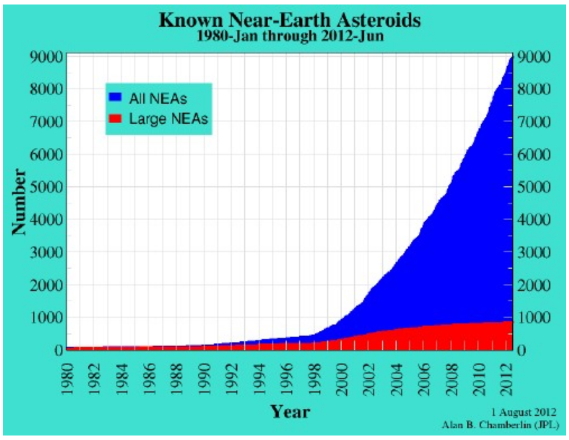

Figure 3 Evolution of the cumulated number of NEOs with the time of their discovery

A comparison for NEO deflection between NEP and NTP has been considered, leading to the fact that each situation must be considered on its merits but a simple sample comparison between the Ariane 5 launch of a 5MW NTP (direct impact) and a 200 kWe NEP (gravitational deflection) gives some idea of the advantages and disadvantages of each method. Assuming a NEO asteroid mass of 200 000 tons (diameter = 60 m) and an NTP mass at impact 3 tons, relative speed 15km/s and transverse impact speed 0,225 m/s, the time to reach a 7000 km deviation is estimated to be 360 days. The advantages of NTP are fast trip time and full angular deflection obtained at impact. The disadvantages of NTP are the initial firing arc at Earth escape must be very precise and the mid-course correction by NTP requires a large store liquid hydrogen during months of transit and a large volume of hydrogen tank. For the same NEO characteristics 200 kWe NEP giving 8N of thrust over 6 months will give a larger deflection ($0.64ms^{-1}$) but will take much longer to rendezvous with the NEO in the first place.

So, if there is sufficient warning time (a critical requirement) and if the asteroid trajectory is not anomalous, NEP would appear to be the more attractive option because there is more control and lower risk of ineffective impact or even missing impact. Matching trajectories or speed and endgame maneuvering when a NEP reaches the asteroid may require some form of chemical propulsion. In essence, and if warning time is sufficient, the decision between NEP and NTP might require much more analysis, and be made on a case by case basis.

The NEP analysis carried on has included technical and capability considerations and expertise, and the necessary infrastructure has been discussed in detail with European, Russian and US partners through an Advisory Board. At the second meeting of the Advisory Board the Director general of the Keldysh Research Centre, Moscow, gave a direct invitation for Europe to participate in Russia's MEGAWAT Class Nuclear Power and Propulsion System (NPPS) development. This is a unique opportunity for Europe to gain essential practical experience of space fission nuclear power..

Ideally one nuclear power generator design could be used for all the applications, thus only requiring the development of one set of technologies. This alone would be expensive with the requirement to qualify the system and its various components for the 10 year lifetime envisaged for planetary missions of interest. In practice, there does appear to be a need for both a lower and a higher power range. It is therefore important to try to identify as many common features as possible as a way to manage efficiently development cost and schedule.

The power level of both the 30 kWe and the 200 kWe nuclear reactor that are the focus of DiPoP finds no parallel in the commercial and military world of nuclear reactors. Compactness, flyweight, and reliability over lifetimes of order many years pose special problems. Some, especially life and reliability, have already been solved in submarines by means that are in part completely different and partly similar, but where the information is proprietary or classified.

The findings of the analysis performed on the applications are the following:

- For 30kWe applications include NEP small robotic missions to the outer solar system, NEO surveys and high power instrument operation.
- For 200 kWe applications include NEO deflection to avoid Earth collision and mining and exploration missions to the outer solar system infrastructure (possibly in support of a manned mission) for interplanetary transportation.

The conclusions of this analysis can be summarized as the fact that a first step is to define the different activities in sufficient detail to be able to cost them realistically. This can then provide an input to the consideration of space nuclear fission power research in the EC Horizon 2020 programme. Consideration should also be given to developing an industrial business case for a space nuclear fission generator programme. Without 100% R&D funding the very long station time precludes commercially viable returns on investment unless 'spin-off' to shorter term applications can be identified. Also industry needs to be confident that investment in personnel and infrastructure will have a long term, sustainable future.

The final recommendations [R 12] can be summarized as:

1. The EC is invited to initiate a program line (within the Horizon 2020 programme) to:
   - Identify and prioritise science and exploration objectives and applications requiring fission nuclear power,
   - Exploring or initiating a short term collaboration in the Heavy Spaceship and NPPS project (as invited by SSC Keyldysh Research Center General Director) potentially including space-qualified Turbo-alternator technology,
   - Exploring the European space system and subsystems mounting capabilities in high Earth orbit and ISS usage for that purposes and NPPS project,
   - Assessing the technical development, needed to achieve the performance, of high temperature Brayton power conversion cycle including both reactor and turbo-alternator technology.
   - Build a full database of the relevant European expertise and infrastructure,
   - Establish a timetable to achieve a European regulatory safety framework for nuclear power sources in space and the infrastructure to deliver it.
2. The EC is invited to hold a workshop with all relevant European (and potential collaborating nations) nuclear and space organisations to mainly define specific research and development projects based on High Temperature reactors, HT turbo-alternators, HT radiator materials
3. The ESA is invited to make provisions for:
   - Analysis of candidate missions identified in the workshop within the General Studies programme,
   - The feasibility study of a candidate mission with a view to defining the resources required to deliver it either by Europe alone or in collaboration.

The Roadmap for Fission Nuclear Power Generation Roadmap development is illustrated diagrammatically in diagram 4. The general picture of the roadmap is shown with the 4 main areas of tasks: missions, technical programs, infrastructure and expertise. The interactions between those tasks are sketched within the time frame.

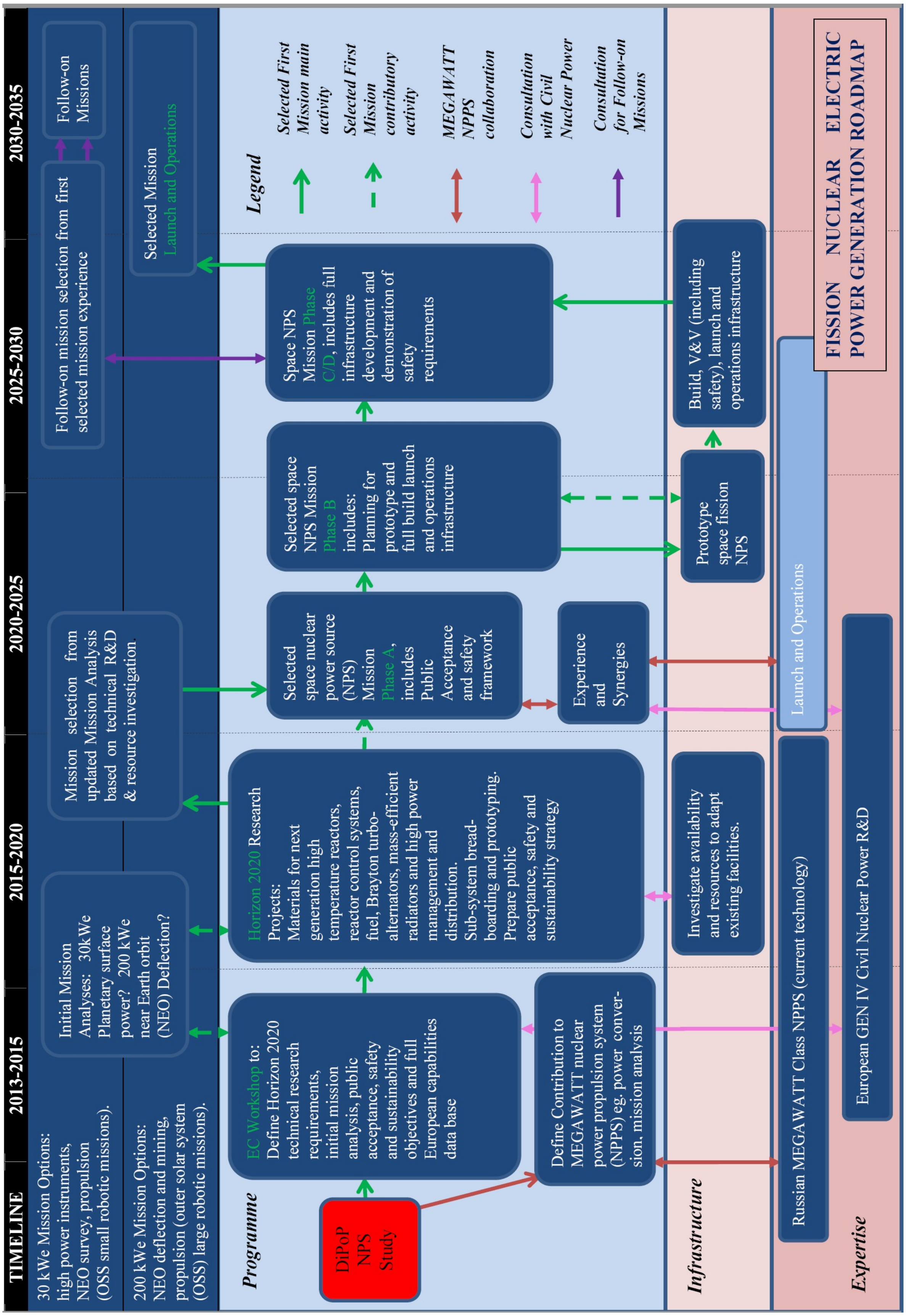

Diagram 4 : DiPoP Fission Nuclear Power Generation Roadmap

7 Recommendations for Public Acceptance, Public Dissemination, Safety and Sustainability

The work on Public Acceptance, safety and sustainability was developed in support of the assessment of Europe's ability to develop a space nuclear fission programme. Some of the principles may also be adapted to the introduction of other disruptive technologies.

Analysis of the aspects of nuclear power (particularly in space) associated to public acceptance and safety issues has been led by IRS Stuttgart. It is highlighted the need for an interdisciplinary approach to public acceptance, and the need to avoid the possible alienation of experts through asymmetry in their communication with the public. For a new **disruptive technologies**, there will always be concerns about the safety of a technology, or its ecological effect.
The analysis summarizes the rules the communication should achieve for enabling the general public's acceptance of a project. Some of those rules [R 12], [R 13] are recalled below. Communication should be

- transparent and intelligible, to enable people to assess the sincerity of the participants,
- and enable participation, for the same reason.

Also, the content of the communication needs to make people understand

- the relative and absolute numbers connected with funding,
- the funding source(s),
- merit and benefits of the technological project to the society.

Hence, strategies and preliminary recommendations regarding experts have been proposed:

- Consider their social setup, behaviour and attitude towards project and the public,
- Consider their language skills and levels,
- Follow the development of communication and its instruments,
- Consider values and ethics,
- Commit to technology assessment,
- Apply measures according to their finding.

In addition specific analysis on the general aspect of safety and sustainability led to high level advice that should not be forgotten when undertaking the development of fission power in space. In particular some nuclear safety lessons learned are recalled here:

- Develop accident failure scenarios in partnership with the nuclear power source, spacecraft and launch vehicle developers
- Conduct coordinated, rigorous nuclear launch safety analyses, reviews and evaluations with agencies involved in the launch authorization process
- Recognize that each spacecraft /launch vehicle configuration is unique
- Support a 'safety culture' by creating incentives to continually assess and consider implementation of safety enhancements
    - Include 'nuclear safety' elements in all major reviews
    - Establish and integrate a nuclear safety risk analysis team into the entire design and development process for an RPS application
    - Independent evaluation of safety analyses coupled with the White House having responsibility for launch nuclear safety authorization creates a strong and sustained incentive to reduce nuclear risk

Already in the project DiPoP one can highlight that the spirit of the rules of safety and sustainability has been implemented within this specific dedicated work-package.

Finally dissemination of the information has been found an essential part for enabling the public acceptance. An according dissemination strategy has been developed with two main branches, one for the scientific and one for the general public. The first will rely on the hard facts and the results of the project, the other on social permeation and activities aiming at an enhanced public understanding of science. The reason to do so is to enhance the solidarity towards the project's responsible and thus the acceptance of the project and its follow-ups

8 Recommendations for Space Power and Propulsion Applications

The summary of space power and propulsion technologies (fission and non-fission) studied within EC DiPoP project are described above in chapters 3 to 6, including the corresponding roadmaps for microparticle propulsion, for nuclear thermal propulsion, for primary electric propulsion and fission nuclear power generation.

Besides the recommendations of chapter 3, the propulsion technologies (high power electric propulsion) in line with chapter 4,5 and 6 (with 30 kWe and 200 kWe Nuclear Electric Propulsion (NEP) applications) shall be developed in parallel with Electric Propulsion (EP) energy sources.

In addition the analysis lead by DLR [R 14] concludes with two major ideas:

- The public acceptance

  Achieving public acceptance for realizing and using disruptive space power and propulsion technologies studied in DiPoP can be achieved - with full success - through a rational/emotional balance treatment. For this reason, such disruptive space power and propulsion technologies and applications studied in DiPoP are an interdisciplinary project, which demands long term effort.

- The international achievements of the independent European leadership in space power and propulsion technologies applications in future space missions.

  Achieving international enforcement, especially under an European leadership or in minimum with a true, equal balanced partnership of Europe with other space nations is a goal. For reaching that status, EC could push a manned space flight to an asteroid because that is a public as well as a political attractive goal (for preparing a protection of population in case of hazard or for Space Situational Awareness (SSA)). Manned asteroid flight demands future technology level achievements, which could bring European space industry in much higher levels while restructuring activities and business (raw material mining in asteroids) of European space organisations and industry.
