Electrical Thrusters in the EC MEGAHIT* and DEMOCRITOS* Projects

*Megawatt Highly Efficient Technologies for Space Power and Propulsion Systems for Long-duration Exploration Missions

*Demonstrators for Conversion, Reactor, Radiator And Thrusters for Electric Propulsion Systems

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Overview

1) Introduction
   a) ‘History’: DiPoP => MEGAHIT => DEMOCRITOS

2) European-Russian MEGAHIT
   a) study outputs: worldwide interests for MW NEP and high level spacecraft requirements,
   b) proposal: key technology plan including stakeholders and subsystems,
   c) plan for a political as well as public supportable reference space mission and
   d) MEGAHIT global roadmap for international realization of NEP respectively INPPS (International Nuclear Power and Propulsion System)

3) DEMOCRITOS

4) Conclusions and Hints
RANGE OF POTENTIAL APPLICATIONS:

30 kWe prioritisation:
Planetary surface power generation, Small robotic exploration and NEO survey, high power radar.

200 kWe prioritisation:
NEO deflection, survey, mining, outer planet robotic exploration, large infrastructure transportation.
1) Introduction: DiPoP (low power) roadmap

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<tr>
<td>30 kWe Mission Options: high power instruments, NEO survey, propulsion (OSS small robotic missions).</td>
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<td>Initial Mission Analyses: 30kWe Planetary surface power? 200 kWe near Earth orbit (NEO) Deflection?</td>
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<td>200 kWe Mission Options: NEO deflection and mining, propulsion (outer solar system (OSS) large robotic missions).</td>
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**Programme**

**DiPoP NPS Study**

- EC Workshop to: Define Horizon 2020 technical research requirements, initial mission analysis, public acceptance, safety and sustainability objectives and full European capabilities database.
- Define contribution to MEGAWATT nuclear power propulsion system (NPPS) e.g. power conversion, mission analysis.

** Horizon 2020 Research Projects:**
- Materials for next generation high temperature reactors, reactor control systems, fuel, Brayton turbo-alternators, mass-efficient radiators and high power management and distribution.
- Sub-system breadboarding and prototyping. Prepare public acceptance, safety and sustainability strategy.

**Selected space NPS Mission Phase B includes:** Planning for prototype and full build launch and operations infrastructure.

**Selected space NPS Mission Phase C/D:** Includes full infrastructure development and demonstration of safety requirements.

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**Experience and Synergies**

**Prototype space fission NPS**

**Build, V&V (including safety), launch and operations infrastructure**

**Legend**

- Selected First Mission main activity
- Selected First Mission contributory activity
- MEGAWATT NPPS collaboration
- Consultation with Civil Nuclear Power
- Consultation for Follow-on Missions

**Infrastructure**

- Investigate availability and resources to adapt existing facilities.
- Russian MEGAWATT Class NPPS (current technology)

**Expertise**

- European GEN IV Civil Nuclear Power R&D

**FISSION NUCLEAR ELECTRIC POWER GENERATION ROADMAP**
The **ENPS 2005** recommendations progressed significantly. **Advisory Board** guidance leads to a coherent European NPS Roadmap. **Space and Civil/Submarine** fission NPS requirements differences remain. **NPS Advisory Board advise** focus on higher power in applications prioritisation of:

- **30 kWe**: power sources for planetary infrastructure/high power instruments,
- **200 kWe**: Earth threatening NEO deflection/outer solar system exploration.

**Technical**: 30 kWe and 200 kWe gas cooled or LM closed cycle Brayton

**Europe** has the potential capability and interest but needs:
- technical and infrastructure development and practical experience.

**Collaboration**: Europe Generation IV NPS, Russia MEGAWATT Class NPPS.

**Public Acceptance** Management integral early part of any project.

**European Safety** Framework for NPS and infrastructure to deliver required.

**Sustainability** requires long term programme of R&D for multiple missions.

**NPS R&D priorities** for EC Horizon 2020 (short, medium longer term) identified.

**Mission analysis** needs space science & exploration, R&D and nuclear organisations.
2) European-Russian MEGAHIT project

- MEGAHIT topics:

The topics addressed by MEGAHIT cover all the areas of space nuclear electric propulsion. The technological plans cover eight topics:

1. **Fuel and core**, relating to nuclear technologies and including shielding.
2. **Thermal control**, addressing heat transfer and radiating devices.
3. **Conversion**, addressing the technologies of conversion of thermal energy into electricity at high power level.
4. **Propulsion**, relating to electric thrusters technologies
5. **Power management and distribution**, relating to the high power converters and distribution cables between the generator and spacecraft.
6. **Spacecraft arrangement and system architecture**, addressing the system architecture, lightweight structures and assembly in-orbit.
7. **Safety and regulations**, addressing the nuclear safety and other regulations.
8. **Communication and public awareness**, addressing the necessary steps to take to successfully communicate a nuclear space project to the public.
2) European-Russian MEGAHIT project

- MEGAHIT roadmap:

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Successful project realization is a truly global project and comparable with the Apollo and ISS projects.
2) European-Russian MEGAHIT project: roadmap

Successful project realization is a truly global project and comparable with the Apollo and ISS projects.
2) European-Russian MEGAHIT project: INPPS General Architecture / Subsystems

Successful project realization is a truly global project and comparable with the Apollo and ISS projects.
2) European-Russian MEGAHIT project: reference

Successful project realization is a truly global project and comparable with the Apollo and ISS projects.
2) European-Russian MEGAHIT project: Robotic Autonomous Assembly

Successful project realization is a truly global project and comparable with the Apollo and ISS projects.
2) European-Russian MEGAHiT project: mission

Successful project realization is a truly global project and comparable with the Apollo and ISS projects.
3) DEMOCRITOS project

- 2015-2016: EC Horizon 2020 DEMOCRITOS  
(Demonstrators for Conversion, Reactor, Radiator And Thrusters for Electric Propulsion Systems)

- DEMOCRITOS very good content + schedule: DiPoP + MEGAHIT roadmaps + Russian NPPS

- Demonstrator Concepts regarding NEP
  1) DEMOCRITOS-GC (Ground Component): a) interaction of the major subsystems (thermal, power management, propulsion, structures and conversion) between each other and with a (simulated) nuclear core providing high power (~100kW) and b) preliminary designs of all INPPS subsystems and ground based test benches  
  2) DEMOCRITOS-CC (Core Component): concepts of nuclear space reactor, specification of a core demonstrator including analysis of the regulatory and safety framework  
  3) DEMOCRITOS-SC (Space Component): preliminary design of INPPS, detailed assembly and servicing strategy in orbit

- forming a cluster around NEP (invitation to external stakeholders plus workshop + PSA/SRC EPIC)  
- propose ideas for ground and flight demonstrator realizations  
- expanding international cooperation Europe/Russia + Brazil, other nations - demonstrator realizations
4) Conclusions and Hints


MEGAHIT: [www.megahit-eu.org](http://www.megahit-eu.org) (documents, roadmap/recommendations)

In the focus for INPPS demonstrations and realization:
- politics (strong guidance),
- public,
- space industry,
- space organisations and related organisations,
- space & space facing nations and
- ground and hardware tests

**INPPS – PROMOTE and TAKE PART!**

Successful project realization is a truly global project and comparable with the Apollo and ISS projects.