Overview of Brussels' EPIC workshop

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Workshop's objectives

1. Collect information with regards to **in-space EP technologies** and assess their corresponding TRL:

    a. **Thrusters**: including, but not limited to, Hall Effect Thrusters (HET), Gridded Ion Engines (GIE), High Efficiency Multistage Plasma Thrusters (HEMP-T), Pulsed Plasma Thrusters (PPT), Magnetoplasmadynamic thrusters (MPD), Quad Confinement Thrusters (QCT), Arcjets, Resistojets, Field Emission Electric Propulsion (FEEP), Colloid or Electrospray thrusters, Helicon thrusters

    b. **Subsystem components**: valves, pressure regulators, flow controllers, power processing units (PPU), mechanisms (e.g. pointing mechanism or deployable arm), tanks.

    c. **Test facilities** (including diagnostics).

    d. **Power generation** (including new power concepts).

    e. **System architecture**.

    f. **Development tools**.

2. Collect high-level requirements from **future mission perspectives**: LEO, MEO, GEO, Space transportation, Exploration, Science.

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Workshop in a nutshell

1. Held in Brussels between 25-28 November 2014
2. **156 registered participants** from 16 countries, representing more than **75 different companies, institutes or agencies**
3. 21 sessions comprising **90 presentations** made by speakers from 12 European countries
    a. Mission requirements (14 presentations)
    b. System aspects (5 presentations)
    c. Hall Effect Thrusters, Gridded Ion Engines, HEMPT (16 presentations)
    d. Pulsed Plasma Thrusters, cathodeless thrusters (7 presentations)
    e. Other thruster concepts (7 presentations)
    f. EP subsystem components, cathodes (12 presentations)
    g. Test facilities and diagnostics (11 presentations)
    h. Power Processing Units (9 presentations)
    i. Development tools (7 presentations)

*Presentations are **available online:***
http://www.epic2014.eu/test-presentations/

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Mission requirements: telecommunications

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1. 5 presentations
2. Very few figures, but one motto: **competitiveness**, which entails:
    a. **Dual-mode** operation (0.3N @ 5kW, 300V ; Isp>2,500s @ 800V)
    b. **Higher power** (e.g. 10kW) and **total impulse** (>20MN.s)
    c. **Innovative/cheaper PPU**
        - **Cost reduction** e.g. through optimized architecture
        - **Commonality** with the platform
        - New **components** (e.g. SiC, GaN, digital or mixed ASICs)
        - **Non-dependence**: hard-rad MOSFET, FPGA
        - 5kW power cells
    d. **Sub-system cost**
    e. Simplified or cost-effective **fluidic architecture**
    f. **Faster EOR**

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Mission requirements: LEO / MEO

1. 6 presentations
2. Requirements (LEO):
    a. Thrust in the range **4-50mN** with an Isp >1,300s
    b. High **number of cycles**: ~10,000
    c. Low **power-to-thrust ratio**: 10-20 W/mN
    d. From **200W up to 2kW**
3. **Nanosat applications' needs** were also addressed
4. Requirements (MEO):
    a. High reliability (>0.997)
    b. Thrust **>250mN**
    c. 1,650<Isp<4,000s
    d. 5.5kW<P<9.5kW at 50V or 100V (TBC)
    e. Target recurring price: **<4M€**

→ *Comparable with thrusters used on comsat for EOR*

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Mission requirements: Space transportation

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1. 3 presentations

2. Several studies on **space tugs** or **EP upper stages**

3. Requirements:

    a. High thrust: 0.5N minimum, **>2-3N desired**
    b. Low power-to-thrust ratio: <15W/mN
    c. High total impulse: **>50MN.s**
    d. High power: **>20kW**
    e. Possible need for an **alternative to xenon**

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Thruster technologies: HET

1. 8 presentations

2. Thrusters available at powers ranging from 100W to >20kW, at various TRL

3. Proposed future activities:

    a. **Dual mode** operation
    b. Increase TRL at **high power**
    c. Increase **lifetime / total impulse**
    d. Optimized operation with **alternative propellants**
    e. Work on **direct drive**

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Thruster technologies: GIE

1. 6 presentations

2. Thrusters available at powers ranging from <50W to 5kW, at various TRL, with exploratory work performed at higher power (<20kW)

3. Proposed future activities:

    a. Reduce **overall cost of technology** (including PPU)
    b. Lower **power-to-thrust ratio**
    c. Optimization for **high power operation**
    d. Use of **alternative propellants**
    e. Possible need for an **alternative to xenon**
    f. Work on **direct drive**

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Thruster technologies: HEMPT

1. 2 presentations

2. One thruster under qualification at 1.4-2.8kW; prototype tested at greater power (4-10kW)

3. Proposed future activities:

    a. **Dual mode** operation
    b. Increase TRL at **high power**
    c. Increase **lifetime / total impulse**

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Thruster technologies: others

1. 13 presentations

2. Pulsed Plasma Thrusters, Vacuum Arc Trhusters:
    a. nanosat application
    b. solid or liquid propellant
    c. TRL3 to TRL 6

3. Cathodeless thrusters: ECR and helicon prototypes tested at 15-30W

4. FEEP: from TRL 1 to TRL 6-7

5. QCT, Halo: TRL 3

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Power Processing Units

EPIC

1. 9 presentations

2. Products already available in the wide range of power for a variety of thruster technologies, from TRL 3 to TRL 9

3. On-going developments for **higher power** (~5kW)

4. Proposed future activities:

    a. **Cost reduction**
    b. **Multi-thruster** compatibility
    c. Develop **European critical parts**
    d. Integration of PPU with PCU
    e. Develop **5kW power cells**
    f. Use of **GAN MOSFETs** in the anode power cells

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Other

1. Fluidic components: 4 presentations

2. Other EP subsystem components: 4 presentations

3. Test facilities:
    a. 6 presentations
    b. Large number of facilities throughout Europe, with **testing capability up to 50kW**
    c. On-going programs on **EMI/EMC testing**
    d. Wide range of **plasma diagnostics**

4. Variety of **numerical development tools**

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Conclusion

1. **Successful and fruitful** event

2. Provided an **up-to-date view of EP products and activities in Europe**

3. Gave useful indications on **future orientations**, both in terms of **applications and technologies**

The EPIC consortium would like to thank once more all participants for their high-quality contributions.

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