HORIZON 2020

EPIC

Report

D5.8
Workshop 3 Report 2017

Due date of deliverable:	01/03/2018
Actual submission date:	11/12/2017
Start date of project:	01/10/2014
Work package/Task	WP5/T5.1
Lead Beneficiary	CDTI
Lead Author	J. Lopez Reig
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Status	Final
Dissemination Level	Public
Reference	EPIC-CDTI-5.1-RP-D5.8-1.0

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640199

APPROVAL

Title: D5.8 Workshop 3 Report 2017	
Issue 1.0	
Author Jorge López Reig	**Date: 11/12/2017**
Approved by	**Date:**
EPIC Steering Board	

CHANGE LOG

Reason for change	Issue	Date
Creation	1.0	11/12/2017

CHANGE RECORD

Issue 1.0			
Reason for change	**Date**	**Pages**	**Paragraph(s)**

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1 INTRODUCTION

In the frame of the Electric Propulsion Innovation & Competitiveness (EPIC) project, (grant number 640199) and more specifically it's Work Package 5 "Dissemination Education and Outreach", this document has been produced with the aim to report in detail the organization, results and conclusions of the EPIC Workshop 2017 (Workshop 3) as part of the activities performed in by the EPIC PSA regarding Dissemination, (Task T5.1) during the third year of execution of the project. These activities are in line with the agreed Dissemination plan [RD1] containing the dissemination objectives, target groups identified, and the structure, means and activities to ensure successful and wide dissemination of project results as well as maximising the project visibility.

The present document is the deliverable D5.8: *Workshop 3 Report 2017*.

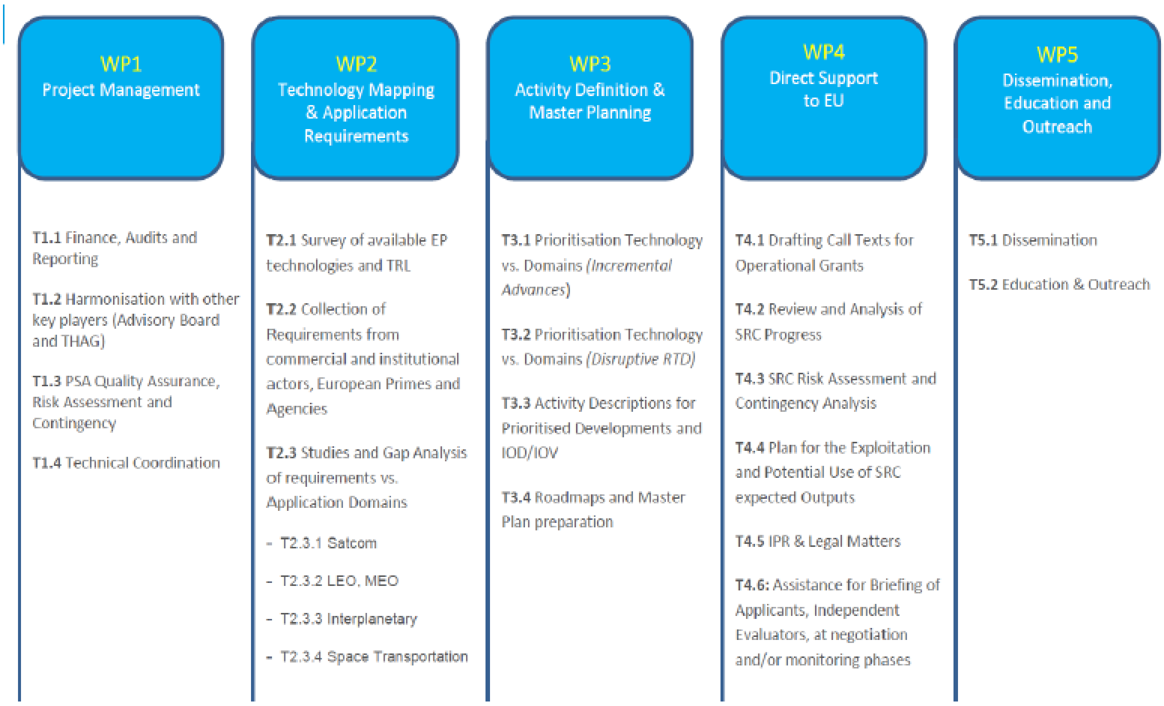

Figure 1.1: EPIC Work Package Structure

2 REFERENCE DOCUMENTS

[RD1] EPIC-CDTI-5.1-RP-D5.1 Dissemination plan
[RD2] D4.3 SRC Collaboration Agreement (CoA)
[RD3] EPIC-DLR-3.4-RP-D3.4 Workshop 2 Report (Stockholm 2015)
[RD4] EPIC-CNES-2.2-RP-D2.3 Workshop 1 Report (Brussels 2014)

3 ACRONYMS & ABBREVIATIONS

Airbus DS: Airbus Defence & Space
ASI: Agenzia Spaziale Italiana
BELSPO: Belgian Science Policy Office
COSMOS: Continuation of Cooperation Of Space NCPs as a Means to Optimise Services
CDTI: Centro para el Desarrollo Tecnológico Industrial
CNES: Centre National d'Études Spatiales
DLR: Deutsches Zentrum für Luft- und Raumfahrt

EBB: Elegant Bread Board
EC: European Commission

ECRA: Electron Cyclotron Resonance Acceleration thruster

ECSS: European Cooperation for Space Standardization

EO: Earth Observation

EOR: Electric Orbit Raising

EP: Electric Propulsion
EPIC: Electric Propulsion Innovation and Competitiveness

EPPM: Electric Propulsion Pointing Mechanism
ESA: European Space Agency

ESP: European Space Propulsion
EU: European Union

FCU: Flow Control Unit

FEEP: Field Emission Electric Propulsion

FMS: Fluid Management System

GEO: Geostationary Earth Orbit

GIE: Gridded Ion Engine

GTO: Geostationary Transfer Orbit
H2020: Horizon 2020

HEMP-T: High Efficiency Multistage Plasma Thruster

HEO: Heliosynchronous Earth Orbit

HET: Hal Effect Thruster
IEPC: International Electric Propulsion Conference

IPPLM: Institute for Plasma Physics and Laser Microfusion

LEO: Low Earth Orbit

LIF: Laser induced Fluorescence

LSI: Satellite Large System Integrator

MEMS: Micro Electro Mechanical System

MEO: Medium Earth Orbit

MHT: Mini Helicon Thruster

MIB: Minimum Impulse Bit

MPD: Magneto Plasma Dynamic

MSL: Mars Space Limited
NCP: National Contact Points

NEO: Near Earth Object

NGGM: Next Generation Gravity Missions

NSSK: North-South Station Keeping
OG: Operational Grant

PCU: Power Conditioning Unit

PCDU: Power Conditioning and Distribution Unit

PIT: Pulsed Inductive Thruster

PPT: Pulsed Plasma Thruster

PPU: Power Processing Unit

PR: Pressure Regulator
PSA: Project Support Activity

PSCU: Power Supply and Control Unit

QCT: Quad Confinement Thruster

R&D: Research and Development

R&T: Research and Technology

RPA: Retarding Potential Analyzer

RF: Radio Frequency

RPA: Retarding Potential Analyser

SPF: Single Point of Failure

SRC: Strategic Research Cluster

TAS: Thales Alenia Space

TED: Thales Electron Devices

TRL: Technology Readiness Level
UKSA: UK Space Agency

VAT: Vacuum Arc Thruster

VLEO: Very Low Earth Orbit
WP: Work Package

XIPS: Xenon Ion Propulsion System

XFCU: Xenon Flow Control Unit

4 DISSEMINATION OBJECTIVES

In line with [RD1], the EPIC PSA dissemination and exploitation activities are aimed at:

- Promoting the EPIC PSA project, its progress and results.
- Improving access to useful inputs from the SRC Operational Grants.
- Contribute to ensuring that the EPIC and Electric Propulsion SRC achievements are known to the potential users and future potential bidders for SRC Operational Grants.
- Improving the knowledge and acceptance of the SRC and therefore contribute to the subsequent exploitation of the project results by end-users or by a potential next SRC phase beyond 2020.
- Guaranteeing that the EPIC project is exploited to its full potential.

The dissemination activities are the responsibility of and coordinated by CDTI (as leader of Task 5.1 "Dissemination" and of WP 5), but this task includes the participation of all PSA Partners.

EPIC Dissemination activities will be performed as far as possible in coordination with the COSMOS network which is the network of National Contact Points (NCP) for the Space theme under the EU's Horizon 2020 (http://ncp-space.net/); and in collaboration with the PSA Partner organisation NCPs for Space.

The EPIC PSA will also encourage the dissemination of results by the SRC Operational Grants holders, in a united and coordinated way as much as possible, so that all possible channels are exploited, always under the coverage of the SRC Collaboration Agreement (CoA) [RD2].

5 SCOPE OF THE WORKSHOP

The EPIC Workshops one and two were the ones organised by EPIC during the first year of execution of the PSA. The first one was in Brussels: 25-28/11/2014 (http://www.epic2014.eu/) organised by CNES and BELSPO; and the second one was in Stockholm: 11-12/02/2015 (http://epic-src.eu/?page_id=12) organised by DLR with the help of the THAG Swedish Delegation. Information on the EPIC Workshops performed during the first year of EPIC execution are already included in detail in their respective deliverables [RD4] Workshop 1 report and [RD3] Workshop 2 report.

The main objective of the EPIC Workshops is to present the Horizon 2020 Electric Propulsion SRC activities to the electric propulsion community and stakeholders and to collect and assess the latest electric propulsion technology developments in Europe. EPIC Workshops are the fundamental element of the SRC dissemination of SRC activities, and the collection of information for the EPIC SRC Roadmap. They have two objectives: an extensive exposure of the EPIC team ideas to the external world (commercial, scientific, programmatic, etc.), and gathering of inputs, and to expand to the maximum the outputs produced during the EPIC project.

The first objective was achieved mainly during the two first EPIC Workshops (Brussels in 2014 and Stockholm in 2015). The second objective (also accomplished during the two first EPIC Workshops), is going to be achieved during next three EPIC Workshops (Madrid in 2017, London in 2018, The Netherlands (ESTEC) in 2019); where dissemination will be organized to communicate on the roadmap implementation and give a periodic status of the situation to all stakeholders interested. EPIC team will ensure the participation and presentation of all Operational Grants funded at the time, to show a coordinated approach and maximise the dissemination of the SRC progress and achievements.

The EPIC Workshop 2017 was organized by CDTI and held on 24-25 October 2017 in Madrid, at: CDTI (Madrid), Spain; with the active involvement of all PSA Partners: 24-25/10/2017 (http://epic-src.eu/workshop-2017/).

The EPIC Workshop 2017 program covered the following topics:

- PSA and SRC progress and activities
- H2020 Work Programme EP SRC topics
- Stakeholders interaction with Satellite Operators and Satellite Large System Integrators
- Incremental SRC OGs: objectives, proposed approach, team, progress, and early results
- Disruptive SRC OGs: objectives, proposed approach, team, progress, and early results
- Trends in Power Processing Units
- New developments on EP Incremental and Disruptive Technologies (promising thrusters and transversal technologies)
- Dissemination and education SRC activities

EPIC PSA makes public the presentations of the EPIC Workshop 2017 in the EPIC web: http://epic-src.eu/workshop-2017-presentations/

6 WORKSHOP SUMMARY

6.1 Welcome (Chair: J. López Reig, CDTI)

- Jorge LÓPEZ REIG, CDTI: CDTI Welcome, Inauguration Workshop
- Jorge LÓPEZ REIG, CDTI: Introduction, and organization logistics
- José GONZÁLEZ DEL AMO, ESA: PSA Welcome, and EPIC Workshop Objectives

6.2 H2020, EP SRC and PSA (Chair: J. Gonzalez Del Amo, ESA)

- Tanja ZEGERS, European Commission: SRC & EPIC policy context, H2020 WP 2018-2020
  - EC explained the context of the H2020 programme and how the EPIC PSA and SRCs fit in this concept: safeguard and further develop a competitive, sustainable and entrepreneurial space industry and research community and strengthen European non dependence in space systems; boost innovation between space and non-space sectors.
  - EC explained that the final objective is that the technology developed in the SRCs can have a fly opportunity that is currently being envisaged by EC in a different programme. Electric Propulsion technologies developed within EPIC could have flight opportunities in the future within this EC programme.

- Florence BEROUD, REA: Implementation of the SRCs
  - REA explained the context of the SRCs and PSA of EPIC within the overall programme and the next steps to be done.

- José GONZÁLEZ DEL AMO, ESA: EPIC PSA and activities
  - The PSA explained the context of the SRCs and the EPIC PSA activities, recalled the SRC EPIC Roadmap, presented the ongoing SRC 2016 Call Operational Grants, and outlined the next SRC steps.

6.3 Incremental SRC Operational Grants (Chair: L. Martin-Perez, DLR)

- Idris HABBASSI, Safran Aircraft Engines: CHEOPS Consortium for Hall Effect Orbital Propulsion System
  - CHEOPS Presentation on the HET Technology and its interest for the space industry. Presentation included the project ambition, challenges and expected impacts. The main points highlighted in the presentation are: GEO 7 kW dual mode; LEO PPU COTS if eligible; High Power direct drive; Technical

data of EPS developments on slide 13; LEO SRR mid-September; Exploration and Transportation SRR mid-November; GEO SRR 2018.

  - Question regarding the IOD/IOV readiness of the developments: Answer: IOD/IOV readiness of the project depends on the application field.
  - Question regarding LEO: time to market is fast, so IOD/IOV readiness for the LEO EPS possible in 2021-22: Answer: the issue is being discussed in the consortium.

- Farid INFED, ArianeGroup: GIESEPP: GRIDDED ION ENGINE STANDARDISED ELECTRIC PROPULSION PLATFORMS
  - GIESEPP Presentation of the project, Key slides: objectives (slide 4), impact and ambition (6), achievements (18) and challenges (23, 24 and 25). The main points highlighted in the presentation: Dual mode is the key issue; Project team thinks in terms of building hardware; Alternative propellants ensuring functionality not performance; AST building block will be a success beyond this project (2L with radical EPR+FCU); EPR electronic not mechanical; 1G no redundancy and this implies low cost, fast; Design for automation and serial production; Clustering approach for high power: no single failure source; Plug and play design: absolutely targeting one PPU for all.
  - Question regarding the IOD/IOV readiness of the developments: Answer like CHEOPS: IOD/IOV readiness for the LEO EPS possible in 2021-22.

- Ernst BOSCH, Thales Deutschland GmbH: HEMPT-NG – Development to provide European competitive EP solutions for future space missions
  - HEMPT-NG Presentation of the consortium and project objectives. Highlight of the advantages of the HEMP-technology (lowest system complexity, simplicity, long lifetime by erosion-free operation, cost-effectiveness and reliability). The main points highlighted in the presentation: Market situation is changing and this requires flexible design to match with everything; Baseline thruster HEMP 3050 not verified in orbit, but has reached TRL 8 with an endurance test of 9.000 hours; High production and testing capacity in Thales Ulm: heritage from existing production line of travelling wave tubes; Technical data of EPS developments on slide 13.
  - Question regarding the IOD/IOV readiness of the HEMPT-NG EPS: HEMPT-NG will push the development of the LEO-thruster – IOD possible in 2021.
  - Final remark from Tanja Zegers to project coordinators regarding IOD/IOV readiness: let the preferences be known to the Commission in order to set up the mission.

6.4 Satellite Large System Integrators (Chair: P. Lionnet, Eurospace)

- José GONZÁLEZ DEL AMO, ESA: Disruptive thruster technologies for telecom & constellations markets
  - Disruptive technology developments both in term of promising thrusters and horizontal technologies are very important to develop the Electric Propulsion telecom market, including the GEO, LEO and constellations.

- Vincent JACOD, Airbus Defence & Space: Electric Propulsion Market Trend
  - Defines various thruster market categories:

- EP for station keeping (1-2.5 kW) - this is the historic product line, available for the past decade. On this market segment Europe is out, compared to the US. Europe is not competitive. Only 10 SC sold over a decade with these systems. Still, the market is there, with some customers still expecting fast orbit transfer (with chemical) and EP station keeping. For this product line we are in transition stage.
- At higher power range (3 to 5kW) we have an all in one solution allowing orbit transfer and station keeping. This technology is now validated on Eurostar (max power 16kW). Airbus also develops the NEO platform (max power 25kW). On this segment the competition will be very strong. Airbus considers that it has, for the time being, a leadership position on large platforms. Reducing the EP subsystem price is a major target, for which CHEOPS will be instrumental.
- At lower thrust range (LEO constellations market, less than 1 kW) the all in one solution is also favoured with the Airbus DS THORs product. First in orbit validation is expected mid-2018. The evolution in this segment is expected on the cost area. Customers are expecting major cost reductions. A key success factor will be the mergence and durability of constellation systems and the demand associated to it. However whether or not the technology will remain the same is an open question. This is where the disruptive project lines may play an important role.
- At the higher end of the spectrum (12-20kW) Airbus DS is unsure whether this solution is technically viable from the power generation point of view. The market need is still TBD, probably related to the in-orbit servicing part of the market. The exploration market is 'validated' but not significant in volume.
- Q&A: Question: why is Europe out of competition on the historic (low) end of the market?. Answer: the main competitor for Europe is Loral, not Boeing. And Loral is rolling out systems at lower cost than Europe. And prices of European EP subsystems are twice as high as Loral. The Chinese competition is also emerging. Europe only has 12% of the station keeping EP systems market.
- Q: it was announced that Airbus DS is proposing on orbit servicing solutions. What are the EP challenges in this respect?. A: this is not so clear yet. The biggest challenge is the time to market at this point. Being able to roll out the solution when customer expects it will be the key winning point. The market for servicing will be quite small in the end, and the first to be there will probably win it all.

- Philippe LAMOTTE, Thales Alenia Space: TAS drivers towards electric propulsion versus satellites applications
    - Summary of EP uses: EP is already implemented in many missions, and TAS expects this to grow. For telecoms of course, it is well documented, including for constellations. Regarding science and observation systems the use is expected to grow as well. The use of EP in MEO/LEO constellations is expected to grow too, including for nano and micro satellites (up to 300kg). Overall the EP market is very dynamic with paradigm shifts happening fast.
    - Drivers for EP systems: For all applications cost reduction is a main driver, hence the growing recourse of commonalities in EP supplies to reduce cost of procurement. The other drivers for EP system evolution are many, starting with enhanced functionalities, and down to the various parameters, such as propellant mass (having impact on ISP e.g.) and other constraints, such as the accommodation of thruster (plume) etc.
    - The market analysis exhibits applicability of EP to three classes of satellites and covers a large range of power, from the sub kW to above 7 kW. Globally EP will be applicable to many mission segments and areas. The market segmentation by thrust also applies.
    - The way forward: HET will continue leading the TLC applications; Ion Grid will lead for high ISP with strong mass requirements; HEMPT is considered highly flexible and able to modulate in the mid thrust range. Alternative propellant is also seen an area of evolution. New EP (disruptive) technology will be targeting the very small satellite market, with very small thrust.
    - TAS believes that all technologies will find their use.

- Regarding equipment and technologies, the way forward is the following: PPU is introducing new technologies and innovation in architectures. An essential area of competitiveness. EP fluidic chain, pressure regulation and valves. EP verification & AIT: simplify and optimise, at least for small satellites a compact EP module can simplify the architecture and reduce the costs. The integration of power electronics in power modules can also be a good factor for simplification and acceptance.
- Q&A: Question: About alternative propellant, we have seen the market evolution and see how much Xenon will be used. What kind of alternatives can be foreseen considering the limited supply of Xenon worldwide? A: For small satellites iodine could be a solution. Large thrusters will still have to rely on Xenon at this point, so there is not really any alternative.

- Birk WOLLENHAUPT, OHB Systems: OHB's reflections about the first study phase
  - Presents the impact of launcher flexibility regarding the mission requirements of EP. The chart shows the link between transfer time, ISP and the needed injection height to achieve a complete orbital transfer in less than 90 days (a duration which is considered a main selling point for GEO applications).
  - The performance range of various technical solutions for EP is thus strong affected by the launcher injection height.
  - About flexibility: BW notes that there is not one single approach to be considered, that each thruster has an area of flexibility of use, which can be wider depending on the technology used. Thrusters are non-longer qualified for one single mission. Also one cannot afford a single qualification mode for each service.
  - The cost reduction approach is one of the main expectation form the EPIC initiative. Key cost drivers are identified: Requirements multiplication: in this context we may need to address how ECSS standards shall evolve and how we can make industry driven standards; PPUs cost and cost of electronics: the reduction of EEE parts costs. Particularly where the market is dominated by US suppliers. The question of radiation does also have strong impacts on the overall costing approach; Mass production appropriate testing approaches; Industrialisation aspects: the question of modularisation of the EP approach is mentioned.
  - Q&A: Question: qualification how can we share the qualification approach? From an operator point of view it would be better to organise the common qualification, and avoid thruster manufacturers not sharing the qualification information. Today each qualification is owned by each prime. About equivalence at operating point we need to have a real exhaustive justification and a demonstration to enable us using another qualification. It is just starting to be exhaustive. A: I agree.
  - Q: about the main areas to drive down costs, by qualification simplification. How can do it practically to promote this? A: the qualification flexibility is a core problem, but the answer is beyond the responsibility of a single company.
  - Q: There is a missing statement about risk sharing. Improving the business case is important, but how do we promote European solutions and at the same time decrease the risk? A: No real answer here.

6.5 Satellite Operators (Chair: R. Pavone, SME4Space)

- David MOSTAZA-PRIETO, Hispasat: Hispasat and Electric Propulsion
  - Hispasat presented the company as satellite operator, its strategy and satellites regarding electric propulsion, and its vision on the impact of electric propulsion in geostationary operations and the present and future of electric propulsion in GEO platforms (hybrid and full electric).

  - The conclusions shared, pointed out these messages: electric propulsion is a successful way to enhance competitiveness of GEO satellites (more operational lifetime, higher payload mass, lower launch mass); current state of the art is adequate for Station Keeping; improving thrust-to-power ration would have great impact on Electric Orbit Raising.

- Cosmo CASAREGOLA, Eutelsal: ELECTRIC PROPULSION: EUTELSAT STANDPOINT
  - Eutelsat presented the company as satellite operator and its strategy, track and achievements regarding electric propulsion.
  - Eutelsat presented its analysis on why the electric propulsion is attractive for Electric Orbit Raising: installed power on Telecom GEO platform continuously growing; competition is driving down the launch costs; EP is an attractive value proposition also for EOR. Also presented that the EP usage consequence is the further reduction of the cost per transponder on orbit which will enable that new design of telecom platforms with electric propulsion with primary functions are now proposed by all major spacecraft manufacturers.

- Eric KRUCH, SES: SES Perspective on Electric Propulsion
  - SES presented the company as satellite operator and its perspective, satellites regarding electric propulsion.
  - Presented SES analysis on the drivers for electric propulsion: cost of launching compared to terrestrial solutions; more economical but less powerful launchers; increasing mass of commercial satellites; need to reduce drastically the satellite launch mass. SES trade-offs on electric propulsion were presented in terms of launch mass, time to orbit, system implications and change in the launcher industry landscape.
  - Commercial GEO satellites are strongly dependent on financial aspects and SES looks at the overall S/C in orbit price per sellable unit (Transponder, bit,..). The satellite vendor presents the most optimal propulsion subsystem(s) to SES for each specific mission.
  - As conclusion for electric propulsion improvements, SES pointed out to investigate: increasing the thrust per power ratio while keeping sufficient high specific impulse, combining satellites with faster electric orbit raising capability and light chemical last stage added to launchers; and modular S/C design approach.

6.6 Round table "Electric Propulsion in the telecom and constellations markets" (Chair: R. Pavone, SME4Space)

- with: Vincent JACOD, Airbus Defence & Space; Philippe LAMOTTE, Thales Alenia Space; Markus PEUKERT, OHB Systems; Antonio ABAD, Hispasat; Cosmo CASAREGOLA, Eutelsal; Eric KRUCH, SES

- The first question addressed *"Which are the current major trends in telecom and constellations market?"*
- The second question addressed *"How is your company facing these trends?"*
- The third question addressed *"Which are the actual constrains for implementing full electric satellites for telecom and constellations application?"*
- The fourth question addressed *"Which are the actual constrains? How could these constraints be overcome?"*

- The fifth question addressed *"Which are the future challenges we should keep in mind and start to address w.r.t. telecom and constellations market?"*

6.7 Disruptive SRC Operational Grants (Chair: N. Cox, UKSA)

- Louis / Eric GRIMAUD / BRIDOT, Safran Electronics & Defense: GANOMIC: Disruptive technologies for PPU cost & volume efficiency
  - GANOMIC presentation included details on the consortium partners and roles in each work package, deliverables, meetings with PSA, and the main project objectives: improvement of power performances (power level and power by weight) - single 7.5 kW building block power module; high voltage management - first step 800 V (dual mode Hall effect); modularity and configurability - generic anode discharge power module with software digital robust & adaptive control loops; and shrink cost - recurrent cost divided by 3 at PPU level.
  - The project schedule, progress and the core technologies (high frequency soft switching power converter topology, PCB embedding packaging & assembly, digital robust controller & observer) were presented together with the key technology roadmap.
  - Finally the first preliminary results were shared: 1st power converter mock-up in manufacturing process; 1st standard of modular planar transformer under characterization; PCB embedding test vehicles of GaN transistors in thermal cycling test; robust adaptive control algorithm w/ output current observer set.

- John STARK, Queen Mary Univ. of London: HIPERLOC-EP: Development of Electrospray Colloid Electric Propulsion as a low cost disruptive propulsion technology
  - HIPERLOC-EP presentation included details on the consortium partners and roles in each work package, deliverables, progress, activities completed, market analysis accomplished, mission & performance considerations and the system highlights (all propellant and power is propulsive, no neutralizer, interface: only a power and data bus, PS&FS thermally integrated with CTH and PPU, propellant isolated from ground).
  - The project main objective is to develop an Electric Propulsion System based on Electrospray Colloid Electric Propulsion (efficient, performance comparable with current commercial platforms, fully scalable) with cost an order of magnitude below current systems, oriented to large scale microsatellite constellations and commercial microsatellite platforms.
  - The updated update technology verification targets were presented: Isp > 1000 s, Specific Thrust >= 56 mN/kW, Thrust target >= 500 µN, Total Impulse = 2000 Ns.

- Denis PACKAN, ONERA: MINOTOR H2020 project for ECR thruster development
  - MINOTOR presentation included details on the consortium partners, ECRA technology and its potential advantages, project objectives and achievements, and content of work packages and its relations.
  - The technical hurdles were presented showing no stoppers (PPU efficiency, magnetic torque, EM field, magnet heating and reflected power) together with the ECR thruster developing challenges (plasma physics more complex, no direct experimental knowledge of the total current and of the ion energy, good vacuum levels needed).
  - The main project objectives for thruster and PPU are (starting from TRL 3): understand the physics; demonstrate performances, and extrapolate; determine possible uses: GO/NO GO, and prepare development roadmaps.

- The project has made good progress, including dissemination (2 journal publications in preparation, 8 papers at IEPC-2017).

6.8 Incremental Technologies PPUs (Chair: J. López Reig, CDTI)

- Fernando PINTÓ, Airbus Defence & Space: PPU activities in Airbus DS Space Equipment
  - Airbus DS presented their PPU equipment and major trends for all technologies (HET, GIE, HEMPT):
    - for high power and electric Orbit Raising thrusters with "medium" Isp: Dual Mode, cost reduction, modular design to answer power increase THs evolutions.
    - for small power and electric Station Keeping thrusters with "medium" Isp: cost, flexible design to answer power increase THs evolutions.
    - for electric Orbit Raising thrusters with "very high" Isp: major trends: Dual Mode, cost reduction, modular design - power increase THs evolutions, common building blocks.
    - for small power and electric Station Keeping thrusters with "high" Isp: cost, flexible design to answer power increase THs evolutions.
  - EP market is evolving and the SRC cluster in electric propulsion is the right tool to prepare European industry for EP future trends. EPIC GIESEPP and HEMPT-NG activities are the key elements to increase product competitiveness and be able to answer future market trends.

- Guillaume / Javier / Nicoletta GLORIEUX / PALENCIA / WAGNER, Airbus Defence & Space (FR / ES / DE): PPU developments for Incremental Technologies (HET / GIE / HEMPT) and common building blocks
  - For PPUs for HET thrusters, 2 developed PPUs were presented: Elektro, medium power PPU for telecom satellite application (5kW class HET thrusters); and low power PPU for constellation application (300W class HET thrusters); and the next steps were for the HET PPUs.
  - For PPUs for GIE thrusters (T series and RIT), PPUs (T5, T6, T7, RIT10EVO, RIT2X), GIESEPP activities and the next steps were presented for the GIE PPUs.
  - For PPUs for HEMPT thrusters, PPUs (HEMP 3050), HEMPT-NG activities and the next steps were presented for the HEMPT PPUs.

- Frédéric VARASTET, Safran Electronics & Defense: Safran PPU roadmap
  - Safran Electronics & Defence reviewed the status of electrical propulsion current generation and future trends in terms of cluster approach and technology development. Outlined the drivers for technology gaps: mass, thermal dissipation and cost. Also outlined the technological requirements for power density & efficiency: mass/volume and cost; and for dynamic range: flexibility of mission, platforms architectures and cost.
  - The technological & modular roadmaps was presented in terms of technology. Power density & power efficiency (new power switches topologies, new semiconductors: GaN, SiC, new inductance technologies: planar, magnetic materials). Thermal management (new packaging: dissipation constraints in switches design, system in package and embedded 3D-packaging). Cost (dual-application technologies with aeronautical mass production, power modules).

- Eric BOURGUIGNON, Thales Alenia Space Belgium: GEO Dual Mode PPU and LEO HEMPT PPU

- Thales Alenia Space Belgium presented the background (PPU Mk1 & PPU Mk2 PPU Mk3), the GEO Dual Mode PPU and the LEO HEMPT PPU.
- TAS-B has designed, developed and qualified the competitive PPU Mk3 product dedicated to 5kW HET and 100V satellite platforms with short time to market. Thanks to the H2020 EPIC, TAS-B is designing and developing two PPU competitive products: In the frame of CHEOPS, Dual Mode HET PPU for GEO/NAV applications; in the frame of HEMPT-NG, HEMPT PPU for LEO applications.

6.9 Incremental Technologies (Chair: F.-X. Thibaut, BELSPO))

- Farid INFED, ArianeGroup: Shape Memory Alloy Valve – New Technology for Telecom Satellite Applications
  - ArianeGroup presented the principles of the SMA technology and the motivation and advantages to use it vs. pyrotechnical valves. Presented the product overview in terms of status and progress.

- Michel POUCET, Bradford Engineering BV: Development of the Next-Generation Fluid Management Technologies for LEO, GEO & Navigation Satellites
  - Bradford Engineering BV presented: its heritage and standard designs in PR Systems and FCUs; the next-generation FMSs goals for GEO/NAV: high-reliability, 30% cost reduction / 4-8 thruster architecture; and goals for MEGA/LEO: low-cost, tailored-reliability, <100-200 kEuro, 1-2 thruster architecture.
  - The Bradford Engineering BV subsystems developments are focused on: functions combination and components similar & affordable. At component level their activities are focused on: development of next generation pressure transducers and design/qualification of alternative valves.
  - Their preliminary results on HI-REL GEO-NAV/LEO preliminary architecture and on MEGA-LEO – high pressure XFCUs are the following ones: fewer components, less control loops, less interfaces and same flexibility and reliability.

- Kevin HALL, QinetiQ: Development of a Ring Cusp high power thruster
  - QinetiQ presented the company heritage in electric propulsion, its GIEs (T5 – 700 W, T6 – 5 kW, T7 - up to 7 kW) and the advantages of GIEs (high fuel efficiency: Isp ~ 4000s, wide operating envelope, wide throttling range, narrow beam divergence).
  - QinetiQ participation in GIESEPP is enabling QinetiQ to develop a T7 Ring Cusp variant of its Gridded Ion Engine technology - improving performance and reducing cost to meet market needs.
  - The following conclusions were presented: market for electric propulsion technology is increasing; GIEs, such as QinetiQ’s T-series, offer the greatest fuel efficiency options to customers; H2020 EPIC is realising incremental changes to QinetiQ’s proven technology to improve competitiveness in global market (T5 industrialisation to improve competitiveness, adopting Ring Cusp configuration into T7, introducing dual-mode functionality).

- Mariano ANDRENUCCI, SITAEL S.p.A.: DEVELOPMENT OF A 20 kW CLASS HALL THRUSTER FOR SPACE TRANSPORTATION AND EXPLORATION
  - SITAEL presented the high power electric propulsion case and its applications, the company activities and heritage on electric propulsion (HETs, development lines, high power HETs, and test facilities).

- The high power HET thrusters development (20 kw Class) activities were explained in detail (TRP, design, test campaigns), and the planned activities in the CHEOPS project and in the DSG/PPE.

- Daniele PAVARIN, University of Padua: Helicon research at University of Padua and T4i
    - The University of Padua presented their team and heritage, the Helicon technology, the main advantages of the Helicon technology, and its development in this field in the University of Padua, and finally the Mini Helicon Thruster (MHT) for small platform from T4i.
    - The main Helicon benefits were outlined: no electrodes, enabling new missions and long lifetime; no neutralizers and grids enabling low production cost; versatile technology enabling flexibility to adapt different missions.
    - The Helicon developments were presented with its main characteristics (power: 50 W, thrust: 1,3 mN, Isp: 1350 s, mas: 1,2 Kg, gas: Ar) and the details of a developed balance to test RF thrusters.
    - Finally the Mini Helicon Thruster (MHT) development at T4i was presented, including objectives (lower cost, lower complexity, and lower mas), the actual performances and the roadmap.

- Pablo FAJARDO, Universidad Carlos III Madrid: An advanced simulation code for Hall effect thrusters
    - Universidad Carlos III Madrid presented their EP2 team as a well-recognized expert group in plasmas and space propulsion, their participation in the CHEOPS H2020- project, simulation capabilities and developments (NOMADS 2D hybrid code, PIC code, electron fluid model), and preliminary simulation results.
    - The code developments for HET simulation is focused on a new 2D Hybrid code with PIC for heavy particles + fluid model for electrons. This Hybrid code is potentially expandable to other thrusters, and their main characteristics were described.
    - Future simulations will include both parallel and total electron temperature, and further developments will explore further parallelization, and validation with experimental data.

- Jochen SCHEIN, Universität der Bundeswehr/Transmit: RIT technology for space debris removal
    - Universität der Bundeswehr presented the LEOSWEEP project and its role in the RIT design and tests performed at DLR. LEOSWEEP is a FP EU project study for using a RIT thruster for debris removal applications.
    - Also past activities and capabilities were presented: vacuum arc thruster for cubesats; performance diagnostics; test facilities; DC arcjets new developments; RF neutralizer; beam diagnostics; high speed spectroscopy (temporally and spatially); and modelling molecular dynamics interaction at atomic level.

6.10 Round table "Trends in Power Processing Units" (Chair: M. Gollor, ESA)

The Round-Table discussion regarding “Trends in Power Processing Units” was held with participants from major PPU suppliers: Mr. Fernando Pinto (Airbus DS), Tommaso Misuri (Sitael), and Eric Bourignon (Thales-Alenia-Space Belgium), furthermore one subsystem integrator, OHB Sweden, was represented by Mr. Alain Demaire. The chairman was M. Gollor from ESA.

- The first question addressed *"Major market trends observed for PPU today"*.
    - The ADS speaker emphasised, that their products are cost efficient, but typically there is a demand for a lot of functions. The demand for dual-mode (high-voltage) could increase the cost of a PPU. There is still pressure to decrease cost to stay competitive. It is important to keep more than one thruster technology in Europe. New applications and technologies are coming and thus investment in technologies is important (GaN, COTS, HV). Key topics are to focus on: Time-to-market, modularity, flexibility.
    - SITAEL speaker addressed that their group is working on synergies and common building blocks. However there are many possible applications. In this context the matrix with HET/GIE/HEMP vs Low/Mid/High Power would make 9 cases necessary. Therefore is not possible to develop a PPU which covers all cases due to often different constraints. Direct drive architecture could this be a solution for some applications to could reduce size/cost of the electronics for some cases in the future. The concept has been tested by SITAEL, but lot of work is remaining.
    - The speaker of TAS-B emphasized, that the market has good standards. A trend is seen towards dual mode to reduce Xenon, but system optimization view is very important. Competition is increasing. Very high power thrusters are needed and are an opportunity for e.g. space-tug, but there are much less applications. It is important to have a focus on non-recurring cost, because there are not a high numbers of items expected. Constellations require really disruptive approaches with low prices, COTS and fully automated sequence to avoid manual operation. In this context a good synergy between PPU/thruster manufacturers is needed to avoid any overdesign.
    - The speaker of the system integrator OHB highlighted, that an EP subsystem is very sensitive to changes (e.g. cathode) therefore margins have to be chosen carefully to cover this. It is also important to avoid re-design and re-qualifications if the same PPU to be used on various platforms. Components, COTS, connectors, switches become even more important if higher voltages are to be addressed.

- The second question addressed *"What is the current status with respect to the trends"*.
    - The ADS speaker noted that their own PPU product portfolio still gaps (very) high power application. ADS works on dual mode, but high voltage is challenging. Wr.t high voltage high power applications: it is needed to work on modularity.
    - SITAEL speaker explained, that they do developments in various directions, but focused on hall-effect thruster. Integrated work on thruster level and PPU is their asset to obtain EPSS specification in low power, in 4kW-20kW range. Constellations are going to change everything. SITAEL has started to reduce costs significantly, but propulsion system must be reliable enough to deorbit, therefore they must also be reliable from the beginning.
    - The speaker of TAS-B reported, that today they have 2,5kW module available, increasing to 5kW per module, scalable up to 20kW. There is a focus on thermal dissipation aspect. For the low power: thermal domain is not very important, therefore more simplified design and automated manufacturing is possible.
    - The speaker of the system integrator OHB highlighted, that they do not develop the (PPU) products and thus they take what is offered by the market. Testing has to be simplified in cooperation between LSI and PPU manufacturer. This has to be improved. He recommended to standardize the way of testing and simplify margins in analysis. As the trend is to shorter time-to-market, a single test would be appreciated. Not clear yet: why are we so conservative? However at the end we need to be reliable.

- A discussion with the plenum around the following questions: *How can you get low cost and high reliability?* The following statements were recorded:

- It's about volume, different approaches are possible then. Therefore one should separate between two different approaches for Low and High/Mid power levels.
- Qualification of equipment is very important to be sure that there is no hidden defect in the development. Volume makes the change, regular production standardization to produce the same product for various manufacturers.
- Spin-in products could be an opportunity, open the doors for synergy to increase volume (PCBs, components, etc.).
- Volume is important. Architecture and a compromise on flexibility of the thruster. More simplified specifications for the electronics (PPU) will help.
- Is there any activity running in the domain of direct drive? The only activity appears to be with SITAEL with testing a direct drive system. Direct drive could simplify the system architecture (in some cases/applications).
- Cost reduction and high reliability: What happens if 2…3 satellites get out of control or there are collisions, debris etc. What about the over-all consequences? Will the current business case of PPU jeopardized by the topic of constellations?
- There is no choice. If industry is not reacting there is the danger to run out of business.
- More autonomy of the spacecraft is needed, because monitoring of a spacecraft is very expensive.

- The last question asked: *"Are there deficits of the current H2020 (EPIC) activities from perspective of PPU? What should be improved?"*.
  - The speaker of ADS speaker highlighted that EPIC is a good success: keeping more than one (thruster) technology in Europe is a real advantage for Europe. In terms of low power applications it is important when reducing the cost that they do not think about reducing the quality and reliability. Improvements is seen for medium power: Technologies and modularity. For high power: modularity and other important trends (e.g. scalability). 40% cost reduction is for important for tomorrow. To achieve this a significant support for PPU suppliers is required.
  - The speaker of SITAEL and TAS-B agreed with ADS speaker. SITAEL speaker spotted a general minor deficit, that development is not always aligned with the market trends (reaction time funding/roadmaps sometime too slow). IOD/IOV is very important, also for electronics and could shorten time to market. The speaker of TAS-B emphasized, that it is a very good step to perform coupling tests already at breadboard level. EPIC second phase is strongly needed to continue. Adjustment of planning vs market needs/applications needs to be optimized. Investments are needed for complete PPU development including qualification. The speaker of OHB appreciated from subsystem integrator's perspective, that EPIC created competition. The space community relies a lot on SME, therefore it should be ensured, that this initiative does not hurt the SME.

6.11 Disruptive Thruster Technologies I (Chair: F. Castanet & C. Boniface, CNES)

- Franz Georg HEY, Airbus Defence & Space: Electric Propulsion Opportunities for Future Scientific Explorations Missions
  - Airbus DS presented their vision of the needs on thrusters for future exploration scientific mission propulsion (LISA like missions) to have ultra-low thrust noise (with precise characterization) and be,

efficient, simple, light weight. Needs are also identified for Asteroid or Comet lander missions with requirements on electronic propulsion thrusters to be High thrust to mass ratio and low PTTR.

- In answer to questions, the EP thruster for lander missions has to be robust to dust in its design and the power system has to rely on the use of batteries.

- Alberto GARBAYO, AVS Added Value Solutions: Disruptive EP technologies at AVS
  - AVS is an European SME experimented in ions and plasma sources, radio frequency cavities development and diagnostics associated with test benches who longs to be a new player in electric propulsion around 2020. They offer Microwave electro-thermal thruster for CubeSats using plasma in resonant cavity (high thrust, low Isp) as an alternative to Resistojets Microwave platforms (foreseen TRL5 Q2 2018), a water cathodeless (no-neutaliser) ECR thruster for small satellites (national UK program with 2025 timeframe objective) and also Induced non-intrusive fluorescence diagnostic device for EP thrusters.
  - In answer to questions, they have not looked at diagnostics for pulsed plasma thrusters.

- Georg HERDRICH, Baylor University/ Institut für Raumfahrtsysteme (IRS): Overview on IRS electric and advanced electric propulsion activities
  - Prof. HERDRICH was not availability in Madrid for personal reasons and the presentation could not be presented; nevertheless the presentation slides are available on the EPIC Website.

- Luc HERRERO, COMAT: Vacuum arc thruster development
  - COMAT is a company experienced in designing, developing, qualifying and selling equipment for space since 1977, and particularly for EP, the Plasma Jet Pack @ technology module family (0-30W for nanosatellites (currently TRL 4) and 100000 continuous firings), 0-150W for small satellites (beginning January 2018)) covering all phases of a mission from orbit rising to de-orbiting. The proposed 30W concept relies on a cathode 0V (W, Ti, Al) acting as solid propellant (providing high specific impulse (5000s) and thrust up to 2N) and also on robust power electronics. It could be ready for an IOD in 2018 and commercialization in 2019.
  - In answer to questions, the short planning between TRL4 and flight relies on the very simple definition of the thruster and its PPU and on the 150000 testing duration from TRL0 to TRL4.

- Jean-Luc MARIA, EXOTRAIL: Exotrail miniature HET for CubeSats
  - EXOTRAIL is a spin off company funded in July 2017 proposing ITAR free Hall Effect Thruster for small satellites and mission services for space industry, with the objective to develop for beginning of 2018 a fully integrated miniaturized Hall Effect thruster prototype for 5 – 100 kg satellites (TRL6). After prototyping (2014), manufacturing, AIT and testing at subsystem level (2016-2017), the complete thruster characterization is planned for April 2018 (with interest for IOD demonstration of the complete system), with R&D optimizations started in parallel for a scale up version in 2020 to be time to market.

6.12 Disruptive Thruster Technologies II (Chair: J. López Reig, CDTI)

- Christophe KOPPEL, KopooS Consulting Ind: Liquid PPT for attitude and orbit control of space vehicles
  - KopooS Consulting presented an overview of the PPT technology, the comparison between solid PPT with Liquid PPT, and the application of LPPT to the Attitude and Orbit Control for CubeSat.
  - Conclusions presented: the main advantages of the Liquid PPT with respect to solid PPT or single other thrusters are on operational and on performance: L-μPPT is fully compliant with the Cubesat specifications; L-PPT is designed for orbit control and fine attitude control; and LPPT is one of the promising concept for orbit and attitude control.

- Francesco GUARDUCCI, Mars Space Ltd: EP Technologies Development at Mars Space Ltd
  - Mars Space presented their developments: Very High Temperature Resistojet with an innovative heater design and technology in order to maximize the overall thruster efficiency; PPTCUP, a Pulsed Plasma Thruster for CUbeSat Propulsion compliant with the cubesat standard and with flight qualification completed; Nano PPT, designed to provide attitude and translation control on a 20 kg nano-satellite; NSTP-2 Project to develop Mini Ion Engine for high delta-V Cubesat missions; the Ring Cusp Discharge Chamber, their GIESEPP activities; and the LaB6 Cathodes.
  - Mars Space future activities were outlined, including a the development and preliminary performance assessment of hollow cathode based on alternative insert material (C12A7:e- electride) in collaboration with ATD.

- Mercedes RUIZ HARO, SENER: Development and tests of HPT-05
  - SENER presented the status of the development of the Helicon Plasma Thruster HPT-05, covering the HPT-05 expected performances based on UC3M-EP2 models; the HPT-05 system experimental platform; the UC3M-EP2 Electric Propulsion Laboratory setup; and some results on parametric analysis and on beam divergence and different antennae.
  - Propulsive performances are still low: Propellant utilisation: 20% Ar (900W), 50% Xe (extrapolated); Thrust: 6.6mN (at 500 W); Thrust efficiency: 2.9% (500W).
  - The next steps for the HPT evolution are: New evolved HPT-05M platform (performances improvement with focus on Te increase); Tests of HPT-05M in two different facilities (performances assessment); Analysis and design activities aimed to improve performances (gain knowledge) and Development of a breadboard model (increase TRL).

- Ane AANESLAND, ThrustMe: Next generation ion thruster with imbedded neutralizaiton and propellant
  - ThrustMe, presented a Neutralizer-Free Gridded Ion Thruster Embedded Into A 1U Cubesat Module. The minituarization challenges are: no pressurized gas, no additional neutralizer, and a much simpler PPU. The physic basis of the concept was presented, and the experiment validation (prototypes from 150 W to 35 W) was shown.
  - The Target specs for the A 1U overall propulsion system (with integrated propellant and PPU) were presented: Size 1U, <1.3 kg, Total power 35-60W, Propellant Xenon or Iodine, Thrust 0.2 – >0.7 mN, Isp >1000 s, # ignitions >100.
  - Thrust measurements at ONERA were shown using a micro-newton thrust balance.

- Luis CONDE, Universidad Politécnica de Madrid: Development and current status of the ALPHIE (Alternative Low Power Ion Engine) plasma thruster

- UPM presents the ALPHIE design based in a new technology of a plasma accelerator for satellite propulsion in space (small 10 X 15 cm), (Power 450 W), application for small and medium sized satellites (100-200 Kg) and commercial target for the growing LEO/MEO satellite market.
- New technology for plasma acceleration: only 3 DC power supplies; only one cathode; variable throttle; and Grids are not used for ion acceleration. ALPHIE performances: Variable specific impulse: Up to the order of ISP ≃3000 s with (estimated), thrust of up to 2-4 mN and trust-to-power ratios of about T/p ≃0.05 mN/W. DC power below 900 volts. Simplify PPU design and reduces power to 200-300 W.
- ALPHIE development status: TRL 4 (laboratory). Relevant issues not yet fully addressed: PPU design and Measurements of the delivered thrust in a microbalance.

6.13 Disruptive Transversal Technologies (Chair: V. Pulcino, ASI)

- Angel POST, Advanced Thermal Devices (ATD): C12A7:e- ELECTRIDE. A PROMISING MATERIAL FOR IONIC THUSTERS
    - The ATD space technology group, founded in 2013, make research in different fields. Once the research field is identified, ATD looks for partners with higher knowledge in that field. Advanced Thermionic Emission Devices with C12A7 material are one of the projects and research conducted by ATD. The project aims to generate energy from heat and also to be a way to support ionic thrusters (by the production of Plasma).
    - ATD has first synthetized the new material C12A7, then developed a configuration for producing electricity and started to improve the technology with the goal to achieve 15% efficiency in energy conversion; finally they are also working to prevent the electride degradation due to highly aggressive environment.
    - ATD has obtained to put in place devices able to create electricity without mechanical parts (such as turbines or other mechanical elements). An additional result has been the production of plasma that could be eventually used for ionic propulsion.
    - Argon has been used for the tests; plasma generation has occurred at 400°C, first electricity emissions occurred at 600°C and the working temperature is 750°C. Theoretical quantum efficiency is around 15%
    - The technology is potentially usable in the following fields: industrial cogeneration at high temperatures, geothermal energy generation, electric power generation for deep space missions.

- Fabrizio SCORTECCI, AEROSPAZIO Tecnologie s.r.l.: Standardisation and Improvement of EP Diagnostics
    - Aerospazio is actively involved in EPIC (HEMPT) trying to investigate the possibility of standardizing the testing of HEMPT.
    - Additionally in the past years two different grants have been assigned to Aerospazio for developing an Advanced Electric Propulsion Diagnostic system (AEPD) with the aim of qualifying it for EP thruster characterization and the system was tested with a GIE and an HET. For comparison reasons the tests were performed in two different facilities: Aerospazio and University of Giessen. The system measures by the use of different probes, Plume parameters and operational characteristics and geometries.
    - Results are promising and reproducible and this shows that tools can be standardized for different facilities. The future challenge is to standardize the facilities and the procedures.

- Alexander REISSNER, ENPULSION: Industry 4.0 Meets Space - Establishing a production line for 200+ EP thruster per year
    - ENPULSION is a start-up founded in 2016 stemming from FOTEC, a research subsidiary of University of Applied Science in Wiener Neustadt. It makes research and builds FEEP (single spiked or multi spiked). The thruster is named IFM and has different sizes and performances.
    - Additionally, taking example from airplane and automotive industries, and thrusting an increasing trend in the market of Cubesats, ENPULSION is developing a system which is able, with a ramp, to manufacture in house up to 500 FEEP units per year. They are establishing a production line for more than 100 thrusters per years.
    - Main points are the definition of methods and procedures to test this high amount of engines and make it match the strict PA rules for space.

- Marcelo COLLADO, ARQUIMEA: Shape Memory Alloy Technologies for Electric Propulsion Valves
    - ARQUIMEA presented the basis of the Shape Memory Alloy technology, the high temperature SMA (SMARQ), and the advantages and disadvantages to use Shape Memory Alloy valves.
    - The company SMA NC/NO one-shot valve concept and the SMA LATCH valve concept characteristics and TRL were presented, together with other release actuators for deployment mechanisms.

- Stephen GABRIEL, University of Southampton: Electric propulsion activities at the university of Southampton: Incremental and Disruptive
    - The University of Southampton presented the previous work, facilities, current research (heater-less hollow cathode, alternative propellants for GIEs (GIESEPP), Liquid PPTs and spectroscopic diagnostics) and future ideas on electric propulsion.
    - The future working lines are: low current, propellant-less cathodes; novel geometries for heater-less hollow cathodes; new concepts for starting cathodes; high current heater-less cathodes; methods of overcoming ion acoustic instability/plasma instabilities; alternative propellants for EP thrusters; hybrid GIE/HET thruster.

6.14 Workshop Conclusions

- Jorge LÓPEZ REIG, CDTI: EPIC Workshop facts and figures
    - Two full days of intensive work and interactions with: 45 presentations, 47 speakers and 136 participants from 14 countries.

- José GONZÁLEZ DEL AMO, ESA: EPIC Workshop conclusions
    - These were the main conclusions presented at the end of the Workshop:
    - Time to market for constellations: we are already late; 2021-2022 are the expected years for the launch of the first constellations. EPIC needs to have this in consideration for the call, maybe asking the proposers to start with the constellations work in 2020.
    - Satellite Large System Integrators and Satellite Operators are happy to have several technologies, especially in the case of constellations.

- New accelerated Qualification Strategies to save time to market are very important. Special round table during the next EPIC Workshop at London on this subject.
- PPU technologies should be taken into account as they represent the 50% of the cost of the EP system.
- Disruptive technologies are important to reduce cost of the systems.
- High power (>20 kW) EP systems are today for institutional missions (Exploration, interplanetary, etc.).

7 WORKSHOP FACTS AND FIGURES

The EPIC Workshop 2017 was performed in two full days of intensive work and interactions, with 45 presentations and 47 speakers. The Workshop had 136 participants from 14 countries, all from the European electric propulsion community, including the main space stakeholders in Europe. European participants came from: EC, REA, ESA, Space National Agencies, main Satellite Large System Integrators, main Satellite Operators, main Propulsion Subsystem Integrators, equipment industry, research institutions, universities, and industry associations.

Figure 7.1: EPIC Workshop 2017 participation and networking

Figure 7.2: EPIC Workshop 2017 sessions and presentations

Figure 7.3: Round table with Satellite Large System Integrators (primes) and Satellite Operators during the EPIC Workshop 2017

Figure 7.4: EC, REA and EPIC PSA Teams at the EPIC Workshop 2017

The future EPIC Workshops will be organized in 2018 and 2019 in London and ESTEC. The preparation had already started for the one to be held in London in October 2018 in full coordination with REA, EC, and all SRC OGs under the SRC Collaboration Agreement [RD2]. Further details on the EPIC Workshop 2018 will be published soon at: http://epic-src.eu/workshop-2018/

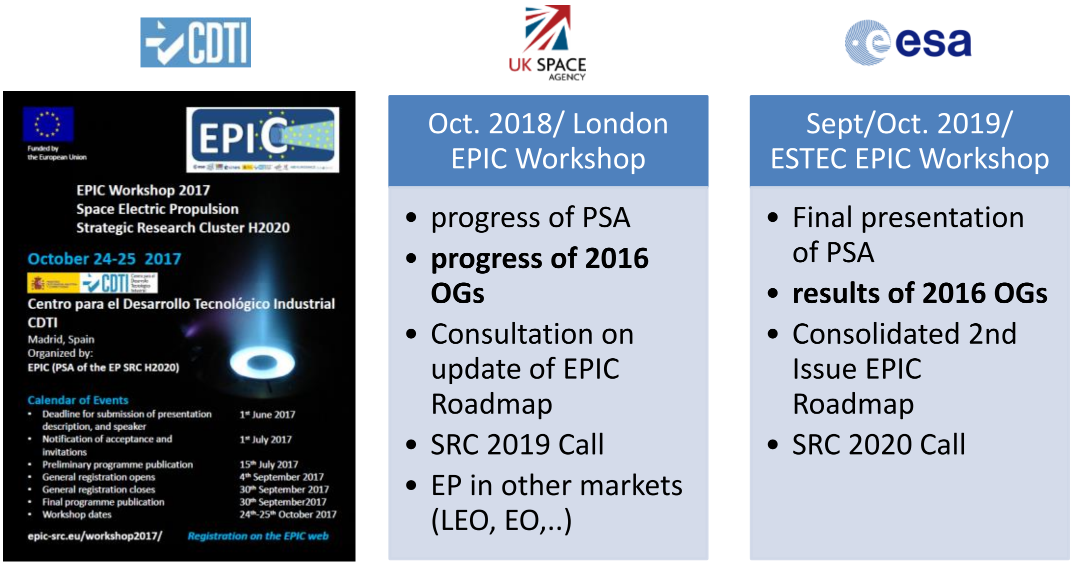

Figure 7.5: 2017 and future EPIC Workshops.

8 CONCLUSIONS

One of the main objectives of the EPIC PSA is to disseminate its progress and results, and to contribute to the dissemination of the SRC results'. The dissemination activities are been implemented following the EPIC PSA Dissemination plan [RD1] in close coordination with all Operational Grants under the SRC Collaboration Agreement (CoA) [RD2], and the most important dissemination activity during the third year was the EPIC Workshop 2017.

This document aims at reporting in detail the organization, results and conclusions of the EPIC Workshop 2017 (Workshop 3) organized by CDTI and held on 24-25 October 2017 in Madrid, at: CDTI (Madrid), Spain; with the active involvement of all PSA Partners: 24-25/10/2017 (http://epic-src.eu/workshop-2017/).

The main objective of the EPIC Workshops is to present the Horizon 2020 Electric Propulsion SRC activities to the electric propulsion community and stakeholders and to collect and assess the latest electric propulsion technology developments in Europe. EPIC Workshops are the fundamental element of the SRC dissemination of SRC activities, and the collection of information for the EPIC SRC Roadmap.

The EPIC Workshop 2017 was performed in two full days of intensive work and interactions, with 45 presentations and 47 speakers. The Workshop had 136 participants from 14 countries, all from the European electric propulsion community, including the main space stakeholders in Europe. European participants came from: EC, REA, ESA, Space National Agencies, main Satellite Large System Integrators, main Satellite Operators, main Propulsion Subsystem Integrators, equipment industry, research institutions, universities, and industry associations.

These were the main conclusions presented at the end of the Workshop:

- Time to market for constellations: we are already late; 2021-2022 are the expected years for the launch of the first constellations. EPIC needs to have this in consideration for the call, maybe asking the proposers to start with the constellations work in 2020.
- Satellite Large System Integrators and Satellite Operators are happy to have several technologies, especially in the case of constellations.
- New accelerated Qualification Strategies to save time to market are very important. Special round table during the next EPIC Workshop at London on this subject.
- PPU technologies should be taken into account as they represent the 50% of the cost of the EP system.
- Disruptive technologies are important to reduce cost of the systems.
- High power (>20 kW) EP systems are today for institutional missions (Exploration, interplanetary, etc.).

9 ANNEX 1: WORKSHOP'S PROGRAMME

EPIC WORKSHOP 2017

Centro para el Desarrollo Tecnológico Industrial - CDTI
Cid, 4. 28001 Madrid

AGENDA / FINAL PROGRAMME: TUESDAY 24TH OCTOBER 2017

08:20-09:00	**Registration**
	Welcome (Chair: J. López Reig, CDTI)
09:00-09:15	Jorge LÓPEZ REIG, CDTI: CDTI Welcome, Inauguration Workshop
09:15-09:30	Jorge LÓPEZ REIG, CDTI: Introduction, and organization logistics
09:30-09:50	José GONZÁLEZ DEL AMO, ESA: PSA Welcome, and EPIC Workshop Objectives
	H2020, EP SRC and PSA (Chair: J. Gonzalez Del Amo, ESA)
9:50-10:10	Tanja ZEGERS, European Commission: SRC & EPIC policy context, H2020 WP 2018-2020
10:10-10:30	Florence BEROUD, REA: Implementation of the SRCs
10:30-10:40	José GONZÁLEZ DEL AMO, ESA: EPIC PSA and activities
10:40-11:15	**Coffee break**
	Incremental SRC Operational Grants (Chair: L. Martin-Perez, DLR)
11:15-11:55	Idris HABBASSI, Safran Aircraft Engines: CHEOPS Consortium for Hall Effect Orbital Propulsion System
11:55-12:35	Farid INFED, ArianeGroup: GIESEPP: GRIDDED ION ENGINE STANDARDISED ELECTRIC PROPULSION PLATFORMS
12:35-13:15	Ernst BOSCH, Thales Deutschland GmbH: HEMPT-NG – Development to provide European competitive EP solutions for future space missions

13:15-14:15	**Lunch break**
	Satellite Large System Integrators (Chair: P. Lionnet, Eurospace)
14:15-14:30	José GONZÁLEZ DEL AMO, ESA: Disruptive thruster technologies for telecom & constellations markets
14:30-14:45	Vincent JACOD, Airbus Defence & Space: Electric Propulsion Market Trend
14:45-15:00	Philippe LAMOTTE, Thales Alenia Space: TAS drivers towards electric propulsion versus satellites applications
15:00-15:15	Birk WOLLENHAUPT, OHB Systems: OHB's reflections about the first study phase
	Satellite Operators (Chair: R. Pavone, SME4S)
15:15-15:30	David MOSTAZA-PRIETO, Hispasat: Hispasat and Electric Propulsion
15:30-15:45	Cosmo CASAREGOLA, Eutelsal: ELECTRIC PROPULSION: EUTELSAT STANDPOINT
15:45-16:00	Eric KRUCH, SES: SES Perspective on Electric Propulsion
16:00-16:45	**Round table with LSI and Satellite Operators "Electric Propulsion in the telecom and constellations markets" (Chair: R. Pavone, SME4S; Rapporteur: J. Gonzalez Del Amo, ESA)** • Vincent JACOD, Airbus Defence & Space • Philippe LAMOTTE, Thales Alenia Space • Markus PEUKERT, OHB Systems • Antonio ABAD, Hispasat • Cosmo CASAREGOLA, Eutelsal • Eric KRUCH, SES
16:45-17:15	**Coffee break**
	Disruptive SRC Operational Grants (Chair: : N. Cox, UKSA)
17:15-17:45	Louis / Eric GRIMAUD / BRIDOT, Safran Electronics & Defense: GANOMIC: Disruptive technologies for PPU cost & volume efficiency
17:45-18:15	John STARK, Queen Mary Univ. of London: HIPERLOC-EP: Development of Electrospray Colloid Electric Propulsion as a low cost disruptive propulsion technology
18:15-18:45	Denis PACKAN , ONERA: MINOTOR H2020 project for ECR thruster development
18:45- 19:45	**Workshop cocktail** Networking light cocktail

HORIZON 2020

EPIC

EPIC WORKSHOP 2017

Centro para el Desarrollo Tecnológico Industrial - CDTI
Cid, 4. 28001 Madrid

AGENDA / FINAL PROGRAMME: WEDNESDAY 25TH OCTOBER 2017

08:30-09:00	**Registration**
09:00-09:15	**Welcome of the day** Jorge LÓPEZ REIG, CDTI: Introduction, and organization logistics
	Incremental Technologies PPUs (Chair: J. López Reig, CDTI)
09:15- 9:30	Fernando PINTÓ, Airbus Defence & Space: PPU activities in Airbus DS Space Equipment
09:30-9:45	Guillaume / Javier / Nicoletta GLORIEUX / PALENCIA / WAGNER, Airbus Defence & Space (FR / ES / DE): PPU developments for Incremental Technologies (HET / GIE / HEMPT) and common building blocks
09:45-10:00	Frédéric VARASTET, Safran Electronics & Defense: Safran PPU roadmap
10:00-10:15	Eric BOURGUIGNON, Thales Alenia Space Belgium: GEO Dual Mode PPU and LEO HEMPT PPU
10:15-10:45	**Coffee break**
	Incremental Technologies (Chair: F.-X. Thibaut, BELSPO)
10:45-11:00	Farid INFED, ArianeGroup: Shape Memory Alloy Valve – New Technology for Telecom Satellite Applications
11:00-11:15	Michel POUCET, Bradford Engineering BV: Development of the Next-Generation Fluid Management Technologies for LEO, GEO & Navigation Satellites
11:15-11:30	Kevin HALL, QinetiQ: Development of a Ring Cusp high power thruster
11:30-11:45	Mariano ANDRENUCCI, SITAEL S.p.A.: DEVELOPMENT OF A 20 kW CLASS HALL THRUSTER FOR SPACE TRANSPORTATION AND EXPLORATION
11:45-12:00	Daniele PAVARIN, University of Padua: Helicon research at University of Padua and T4i
12:00-12:15	Pablo FAJARDO, Universidad Carlos III Madrid: An advanced simulation code for Hall effect thrusters
12:15-12:30	Jochen SCHEIN, Universität der Bundeswehr/Transmit: RIT technology for space debris removal
12:30-13:15	**Round table "Trends in Power Processing Units" (Chair: : M. Gollor, ESA)** • Eric BOURGUIGNON, Thales Alenia Space Belgium • Luca BENETTI, SITAEL S.p.A. • Fernando PINTÓ, Airbus Defence & Space

	• Alain DEMAIRÉ, OHB Sweden • Matthias GOLLOR, ESA
13:15-14:15	**Lunch break**
	Disruptive Thruster Technologies I (Chair: F. Castanet & C. Boniface, CNES)
14:15-14:30	Franz Georg HEY, Airbus Defence & Space: Electric Propulsion Opportunities for Future Scientific Explorations Missions
14:30-14:45	Alberto GARBAYO, AVS Added Value Solutions: Disruptive EP technologies at AVS
14:45-15:00	Georg HERDRICH, Baylor University/ Institut für Raumfahrtsysteme (IRS): Overview on IRS electric and advanced electric propulsion activities
15:00-15:15	Luc HERRERO, COMAT: Vacuum arc thruster development
15:15-15:30	Jean-Luc MARIA, EXOTRAIL: Exotrail miniature HET for CubeSats
	Disruptive Thruster Technologies II (Chair: J. López Reig, CDTI)
15:30-15:45	Christophe KOPPEL, KopooS Consulting Ind: Liquid PPT for attitude and orbit control of space vehicles
15:45-16:00	Francesco GUARDUCCI, Mars Space Ltd: EP Technologies Development at Mars Space Ltd
16:00-16:15	Mercedes RUIZ HARO, SENER: Development and tests of HPT-05
16:15-16:30	Ane AANESLAND, ThrustMe: Next generation ion thruster with imbedded neutralizaiton and propellant
16:30-16:45	Luis CONDE, Universidad Politécnica de Madrid: Development and current status of the ALPHIE (Alternative Low Power Ion Engine) plasma thruster
16:45-17:15	**Coffee break**
	Disruptive Transversal Technologies (Chair: V. Pulcino, ASI)
17:15-17:30	Angel POST, Advanced Thermal Devices (ATD): C12A7:e- ELECTRIDE. A PROMISING MATERIAL FOR IONIC THUSTERS
17:30-17:45	Fabrizio SCORTECCI, AEROSPAZIO Tecnologie s.r.l.: Standardisation and Improvement of EP Diagnostics
17:45-18:00	Alexander REISSNER, ENPULSION: Industry 4.0 Meets Space - Establishing a production line for 100+ EP thruster per year
18:00-18:15	Marcelo COLLADO, ARQUIMEA: Shape Memory Alloy Technologies for Electric Propulsion Valves
18:15-18:30	Stephen GABRIEL, University of Southampton: Electric propulsion activities at the university of Southampton: Incremental and Disruptive
18:30- 18:50	**Workshop Conclusions** Jorge LÓPEZ REIG, CDTI: EPIC Workshop facts and figures José GONZÁLEZ DEL AMO, ESA: EPIC Workshop conclusions

10 ANNEX 2: LIST OF PARTICIPANTS

Final list of participants as registered (136 from 14 countries):

First name	Last name	Organization	Position	Country
Ane	Aanesland	ThrustMe	Founder and CEO	FR
ANTONIO	ABAD	HISPASAT	CTO	ES
EDUARDO	AHEDO	UNIVERSIDAD CARLOS III DE MADRID	PROFESSOR	ES
Jesus	Aivar	LIDAX	BDM	ES
DOMINIQUE	ANCEL	SAFRAN ELECTRONICS & DEFENSE	PROGRAMME MANAGER	FR
Bernard	ANDRAU	Airbus Defence & Space - Space Systems	Head of Technical Strategy France	FR
Mariano	Andrenucci	SITAEL, Italy	Head Propulsion Division	IT
Yacine	Babou	UC3M		ES
Rafael José	Badell Fabelo	Universidad Carlos III de Madrid - School of Engineering	degree seeking student	ES
ANGEL	BARRASA	EMPRESARIOS AGRUPADOS	PROPULSION SIMULATION ENGINEER	ES
Olaf	Behrens	Thales Deutschland GmbH		DE
Johan	Bejhed	NanoSpace	Integration and Test Manager	SE
Luca	Benetti	Sitael SpA		IT
Chloe	Berenguer	DEDALOS Ltd	Project manager	GR
Florence	Beroud	REA	Research Programme Officer	BE
Antoine	BLANCHET	COMAT	Space propulsion engineer	FR
Richard	Blott	Richard Blott	Sole Trader	GB
Claude	BONIFACE	CNES	Electric propulsion engineer	FR
Ernst	Bosch	Thales Germany GmbH	Senior Expert&technical adviser Space Products	DE
Eric	BOURGUIGNON	Thales Alenia Space Belgium	PPU Product Line Manager	BE
Eric	Bridot	Safran Electronics & defense	R&T program	FR
Gautier	Brunet	ThrustMe	COO	FR
Miguel	Carrera	AVS Added Value Solutions	CEO	ES
Angel	Carretero	CRISA	Power Equipments Programmes	ES
Javier	Casado	Aernnova		ES
Cosmo	Casaregola	EUTELSAT	PROPULSION, THERMAL and MECHANICAL SYSTEMS PROCUREMENT	FR
Fabien	CASTANET	CNES	CNES representative for the EPIC PSA	FR
Miguel	Castillo Acero	Aernnova	VP Technology Development	ES
Giovanni	Cesaretti	SITAEL SpA	Marketing and Sales, Propulsion Division	IT
Marcelo	Collado	Arquimea Ingeniería	Head of Mechanisms Group	ES
Luis	Conde López	ETSIA Universidad Politecnica de Madrid	Professor	ES
Susana	Cortes-Borgmeyer	ArianeGroup GmbH		DE

Nick	Cox	UK Space Agency	Head of Technology Strategy	GB
Julius	Damba	ETSIA Universidad Politécnica de Madrid	PhD Student	ES
Käthe	Dannenmayer	European Space Agency	Electric Propulsion Engineer	NL
Ludovic	Daudois	COMAT		FR
Ignacio	Deleuze	Airbus DS Space Equipment Crisa	KAM CDTI & ESA	ES
Alain	Demairé	OHB Sweden AB	Head of propulsion department	SE
Andreas	Derntl	RUAG Space	Business Development Manager	AT
ALESSIO	DI IORIO	ALMA SISTEMI SAS	CEO	IT
Juan Luis	Domenech Garret	ETSIA Espacio Universidad Politécnica de Madrid	Professor	ES
José Manuel	Donoso	ETSIA Universidad Politécnica de Madrid	Professor	ES
Farid	Dr. Infed	ArianeGroup GmbH	Business Development & Sales Manager	DE
GUILBAUD	ERIC	AIR LIQUIDE		FR
Pablo	Fajardo	Universidad Carlos III de Madrid	Associate Professor	ES
Pablo	Fernandez	ESA	Electrical Power Management Engineer	NL
Andreas	Franke	ESA		NL
Stephen	Gabriel	University of Southampton	Professor of Aeronautics and Astronautics	GB
Alberto	Garbayo	AVS UK	Business Development Manager	GB
Ausias	Garrigos	Miguel Hernandez University of Elche	Associate professor	ES
Vittorio	Giannetti	Airbus DS UK		UK
Domenico	Giordano	ETSIA-UPM + ESA (retired)	research professor	ES
Guillaume	Glorieux	Airbus DS		FR
Matthias	Gollor	European Space Agency	Principal Engineer	NL
Victor	Gomez	Sener Ingeniería y Sistemas SA	Electric Propulsion System Engineer	ES
Jorge	Gonzalez	ETSIA Universidad Politecnica de Madrid	Researcher	ES
Jose Antonio	Gonzalez del Amo	European Space Agency	Head of the Electric propulsion Section	NL
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Francisco	Gutiérrez	ARQUIMEA Ingeniería	General Manager	ES
Idris	Habbassi	Safran Aircraft Engines	Program Manager	FR
Kevin	Hall	QinetiQ		GB
Georg	Herdrich	IRS	Head Plasma Wind Tunnels and Electric Propulsion	DE
Luc	Herrero	COMAT	Head Of Propulsion Dpt	FR
Franz Georg	Hey	Airbus	Propulsion Architect	DE
Marco	Invigorito	CIRA - Italian Aerospace Research Centre		IT
Vincent	JACOD	Airbus Defence & Space	Head of Electric Propulsion Department	FR
Kerstin	Jonsson	NanoSpace		SE
Konstantinos	Katsonis	DEDALOS Ltd	Director	GR
Christophe	Koppel	KopooS Consulting Ind.	CEO	FR
Eric	Kruch	SES	Senior Propulsion and ADCS	FR

			Engineer	
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Pierre	Lionnet	Eurospace	Research Director	FR
Eric	LOPEZ	Airbus Defence and Space		FR
Jorge	Lopez Reig	CDTI	EPIC Proyect manager at CDTI (PSA)	ES
Andrea	Lucca Fabris	Surrey Space Centre	Lecturer in Electric Propulsion	GB
Pablo	Maldonado	Delft University of Technology	Master Student in Aerospace Engineering	DE
Noëlle	MANESSE	Safran Aircraft Engines	Program, Contracts & Sales Director	FR
Massimiliano	Marcozzi	Thales Alenia Space	Space Segment Product Line Manager	IT
FREDERIC	MARCHANDISE	SAFRAN AIRCRAFT ENGINES	Electric Propulsion new design & technologies Technical Responsible	FR
Jean-Luc	Maria	EXOTRAIL	CTO	FR
Lisa	Martin Perez	DLR Raumfahrtmanagement	Scientist	DE
Jevgenijs	Martjanovs	Rovsing A/S	Master Thesis Student	DK
Luca	Massotti	RHEA BV for ESA	EO System Engineer	NL
Mario	Merino	Universidad Carlos III de Madrid	Assistant Professor	ES
Poucet	Michel	Bradford Engineering BV		NL
Tommaso	Misuri	SITAEL S.p.a.		IT
Marco	Molina	Leonardo Spa	CTO	IT
DAVID	MOSTAZA	HISPASAT, S.A.	OPERATIONS ENGINEER	ES
Navin	Nayak	Airbus DS UK		UK
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Cristina	Ortega	AVS Added Value Solutions	Head of Space Area	ES
Denis	Packan	ONERA	Scientist	FR
Javier	Palencia	Crisa		ES
F. Javier	Palomares	Instituto de Ciencia de Materiales de Madrid (CSIC)	Researcher	ES
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Tiago	Pardal	Omnidea		PT
Andrea	Passaro	ESA		NL
daniele	pavarin	Univeristy of Padua	Associate Professor	IT
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Jaime	Perez Luna	QinetiQ		GB
Mario	Pessana	Thales Alenia Space	Expert Advanced Propulsion	IT
Markus	Peukert	OHB System	Head of Propulsion Systems	DE
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			Programme Manager (Strategy)	
Javier	Rodriguez	CDTI	Aerospace Programmes department	ES
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MANUEL JULIÁN	SANSEGUND O	HISPASAT, S.A.	Head of Space Segment Engineering & Programs Development	ES
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