HORIZON 2020

EPIC

Report

D3.4 Second Workshop Report

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1 INTRODUCTION

In the frame of the Electric Propulsion Innovation & Competitiveness (EPIC) project, (grant number 640199) and particularly its Work Package 3 "Activity Definition and Master Planning", a Workshop was held in Stockholm, Sweden, as part of Task 3.4 "Roadmap and Master Plan Preparation".

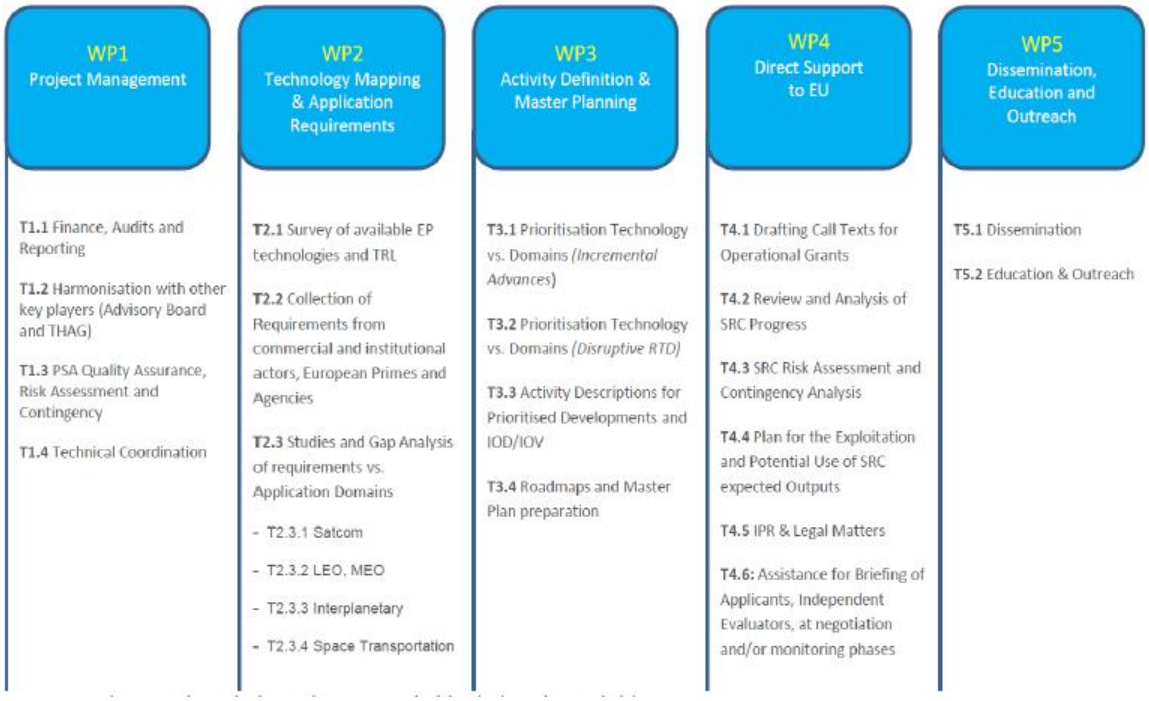

Figure 1-1: Work logic for EPIC

This document provides a report of this second EPIC workshop held in Stockholm City Conference Centre on 11th-12th February 2015. Further information can be found on a dedicated website at the URL: http://www.epic-src.eu/.

2 ACRONYMS & ABBREVIATIONS

Airbus DS: Airbus Defence & Space

CNES: Centre National des Etudes Spatiales

COTS: Commercial of the Shelve

EC: European Commission

EP: Electric Propulsion

EPIC: Electric Propulsion Innovation and Competitiveness

EPS: Electric Propulsion System

ESA: European Space Agency

EU: European Union

FEEP: Field Emission Electric Propulsion

FPGA: Field Programmable Gate Array

GEO: Geostationary Earth Orbit

GIE: Gridded Ion Engine

HEMPT: High Efficiency Multistage Plasma Thruster

HET: Hall Effect Thruster

H/W: Hardware

IOV: In-Orbit Verification

Isp: Specific Impulse

ISS: International Space Station

LEO: Low Earth Orbit

MPD: MagnetoPlasmaDynamic

NASA: National Aeronautics and Space Administration (USA)

PPT: Pulsed Plasma Thruster

PPU: Power Processing Unit

PSA: Programmatic Support Activity

P/L: Payload

RM: Roadmap

SRC: Strategic Research Cluster

SSC: Swedish Space Corporation

S/C: Spacecraft

TAS: Thales Alenia Space

TED: Thales Electron Devices

TRL: Technology Readiness Level

TWT: Travelling Wave Tube

UKSA: United Kingdom Space Agency

WP: Work Package

3 SCOPE OF THE WORKSHOP

3.1 Objectives

The 2nd EPIC workshop was held with the objective to present the EPIC Draft Roadmap to the interested public (Primes, academia and institutional organisations) and to collect their views and comments. The draft roadmap has been developed by the European Space Agency and national agencies within the EPIC consortium.

3.2 Programme and Participants

The agenda of the workshop can be found in Annex 1. The workshop was structured in 5 sessions. In session 1 an overview was given of the Horizon 2020 program and of the work, which the EPIC PSA has conducted so far.
In session 2 an overview of the draft roadmap was given, together with a description of the work logic to arrive at a prioritisation of technologies.
In session 3 the roadmap for the development of incremental technologies was presented and discussed extensively.
In session 4 the roadmap for the development of disruptive technologies was presented and discussed intensively.
In the closing session 5 the results were summarized and a way forward was sketched.

The discussions of the roadmaps for incremental and for disruptive technologies were organised as panel discussions. Experts from the European EP community – not participants of the EPIC consortium – were invited to initiate the discussion by statements concerning the presented draft roadmap. Statements and questions from the floor were commented and answered by panellists or by members of the EPIC consortium.
The result of the discussion was summarised in the closing session.

There were 108 participants registered for the workshop, from industry, academia, and space agencies from a number of European countries. The participants list is attached as Annex 2 to this document.
The presentations are available on www.epic-src.eu, linked to the agenda items. The outputs of the discussion are summarised below.

4 WORKSHOP SUMMARY

The workshop was opened by Olle Norberg, Director-General of the Swedish National Space Board. He reminded the audience of the fact, that SSC has been prime for SMART-1, the first lunar mission of ESA and one of the first missions to use electric propulsion.
The main emphasis of the workshop was on discussing the draft roadmap with European stakeholders. This has happened in two extensive panel sessions, one on incremental technologies, the other one on disruptive technologies. The presentations given at the workshop can be found at www.epic-src.eu . This summary mainly tries to catch the content and the spirit of the discussions. The main contributions to the discussions are therefore reported in detail.

4.1 H2020 Space Strategic Clusters (SRCs)

H. Guerrero (European Commission, EC) presented the Horizon 2020 Programme.
The space sector represents 1.42 B€. 102 projects are linked to space technologies, representing 197 M€. in H2020, open competition is the base for the calls. EC promotes the involvement of Small and Medium Enterprises (SMEs) in their projects (20% of the total H2020 funds). H2020 is an international Research and Innovation Programme, fostering cooperation in Europe at transnational level and between different actors, as well as international cooperation.
Competitiveness, non-dependence and innovation are the main topics for H2020. The projects should deal with technologies for space and should aim at excellence.
Mr Guerrero recalled that the EPIC PSA gives advice to the Commission who will then prepare the calls for the operational grants.

4.2 Introduction to the EPIC project

J. Gonzalez Del Amo, as Coordinator, presented the EPIC project. It was clearly stated that the competitiveness of the Telecom market should not be aiming at European level only, but also that worldwide market should be taken into account.
EPIC is dealing with two topics: the incremental and the disruptive technologies, whose aim is to develop technologies to be ready to be used on the market in the 2020-2030 timeframe.

4.3 Overview of the Brussels EPIC Workshop

The outputs gathered from the EPIC workshop held in Brussels at the end of November 2014 were summarised by N. Arcis (CNES, EPIC partner).

4.4 Roadmap for Incremental Technologies

The discussion followed the presentation of the draft roadmap and was guided by N. Arcis (CNES). Panel members were:

- Ernst Bosch, Thales Electronic Systems (TES)
- Alain Demairé, OHB Sweden
- Philippe Garcon, Thales Alenia Space (TAS)
- Vincent Jacod, Airbus Defense and Space (Airbus DS)
- Huw Simpson, Qinetiq
- Gilles Turin, Snecma
- Fernando Pinto, Airbus Defense and Space (Airbus DS)

The discussion was initiated by a round of statements given by the panel members:

- More details about the mission requirements taken into consideration and a better understanding of the way the prioritization results were reported would have been appreciated.
- All the panelists agreed on the fact that the analysis to be performed for the prioritization of the technologies was very difficult. However they insisted on the fact that the Draft Roadmap (RM) which was presented is very general and that the results of the prioritization exercise was not reflected in it.
- Airbus DS stated that the funding for the future SRC shall not be spread on different technologies if a competitive product should be put on the market at the end of the SRC; and TAS emphasized the fact that the SRC should try to cover all the gaps identified.
- It was also stated that the end customer (operators) should have the choice on the technology they want to use on their platforms and as such, the proposed roadmap should not be limited to only one technology (HET).
- PPU high voltage is a good common technology to the three lines (HET, GIE and HEMPT). High voltage components are a big issue today and should be studied in the frame of those SRCs.

Discussion:

A first point of discussion was on the prioritisation of the technologies.
OHB stated that there is no technology without a market. The allocation of the funding should be done properly taking into consideration that up to now the development of a technology takes tens of M€ and about 10 years and that for the future SRCs the budget is limited. The market should be taken into account and today it is mainly the one of Telecommunication. In Europe most of the Primes have made the choice to adopt in the near future the HET technology on their platforms because it has demonstrated a large number of hours of operation, and therefore that this technology should be the one to develop. Also there are gaps in the technology that should be dealt with: the PPU needs to be challenged on cost, and the integration into the S/C is also an issue. Work on pressure regulators (non-dependence issue, no competitive European product) and xenon tanks should be done. As well according to OHB, the focus should be made on the development of the entire EP chain for one technology and then move to the next one, following the market needs.
H. Simpson emphasized that the ion engine with its high Isp and high thrust has also some advantages for future Telecoms market, allowing a broader choice in the launcher choice, as presented during the Brussels workshop by Eutelsat (European operator). And that therefore a broad range of technologies and a competitive situation in Europe should be kept to have an impact of future market perspectives.
M. Andrenucci recalled that historically, it is the GIE technology which has been favoured for full EP platforms and not the HET; GIE has been available for the past 50 years, the same applied for MPDs. He acknowledged the fact that the HET technology should be consolidated to offer appropriate solutions to Primes and operators for the Telecom market, but he also pointed out that today, the Americans got ahead of Europe when Europe was in very similar conditions. It is urgent to recover time addressing the challenges in the right way and looking at more sectors where EP could be introduced (exploration, space transportation, etc.) and make available products with very high Isp for example.

The PSA confirmed that it should look at the whole system (including launcher) and see the market evolution, to be able to focus the efforts in different ways on each technology, depending on the applications. The last statement was agreed by TES giving the HEMPT as example.

The Primes would like to see a top-down approach on the RM, based on the market and applications and not based on technologies. Airbus DS stated that the market is not there yet and that for the coming years the HET will be the dominant technology and all the Primes are going to adopt it, except Boeing. Only about 10% of the market of EP goes to Europe. Therefore this product shall be made competitive funding this technology (HET) in priority.

Another point was raised in the audience: it is correct that science missions need to have propulsion systems with low thrust and very high controllability, but for exploration missions to Mars or to an asteroid high power and very high Isp (MegaHit, FP7 project) will be needed, and this last point was not reported in the slides presented on the prioritisation exercise. However it was confirmed that the PSA took this into account in the RM.

Regarding the gaps and applications identified in the RM, the addition of the Space debris removal (with Clean Space) seems to be missing.
More in details, questions on possible activities were suggested by OHB for the PPU: What are the observables needed inside the PPU? Where should the autonomous telemetry be located, PPU or on board computer? This thought should be included in the PPU developments. The investigation in case of failure should be pertinent and quick to give more flexibility to the users (more autonomy). This additional telemetry should not add complexity to the PPU but more accessibility.
Fernando Pinto (Airbus DS) pointed out that 40% of the total price of the EPS is for the PPU. If more autonomy is required by the users, it will add complexity to the equipment. Therefore the primes should decide what they want. With more flexibility one gets more use, but also more complexity and cost.
N. Arcis recalls that the calls will not be so specific. For innovative PPUs, anything can be included. It is up to the proposers to come up with technical solutions. Increase competitiveness means there should be a trade-off between performances and cost.

Another question was addressed to the Primes regarding the new type of competition coming from the US, with the recent announcement by Elon Musk of a future LEO constellation using EP on-board the spacecraft: how do the Primes intent to deal with this new market and do the Primes have already full EP platforms in their portfolio?
The future Neosat and Electra platforms are future all-EP platforms; options with chemical + EP and full chemical platforms are kept by the Primes in order to follow the interests of the clients and to be able to address all opportunities, depending on the launcher evolution. Regarding the LEO constellation issue, Airbus DS acknowledged that the price of the European EP system needs to be reduced (building "reliable Chinese cars") and that big changes are needed to comply with this new market, implying robustness of the technology (low power HET). OHB highlighted that Europe lost the time-to-market for the first GEO satellites and therefore that Europe should not lose that opportunity for the constellations; for such platforms integrators should look at the global functional chain with a simplification of the first generation of low power EP system design to lower the costs.
It was confirmed in the audience that certainly the cost of European EPS must decrease to be able to be embarked for the large constellations market which is appearing today. Elon Musk (SpaceX) has published a price tag of 12500€/thruster for its future internet constellation, which represents about five kilograms of Xenon. Therefore the EP community should start thinking about improvements of an order of magnitude not to lose this new market opportunity: if constellation goes into the US market, then they will have a very big advantage once again. Open competition may exist today for other constellations (OneWeb).

Another point was raised by the audience on the short term and long terms needs. Listening to the Primes it seems that they are preoccupied with the short term perspectives (5 kW EPS), while for a development program it usually takes about 10 years; and, therefore for the RM and the future SRCs the medium and long term needs (10 to 20 years) should be looked at. The Primes confirmed the urgency to have a technology ready very soon (HET) to be able to be on the Telecom market, funding it at an appropriate level and keeping the level of development of the two other technologies responsive when the market develops. But they also recognize that the market is also going to smaller as well as larger payloads, and that the requirements are constantly changing because the market is changing, and, as a consequence, that flexibility is needed in this RM. A proposal was made in the audience to try to find a way to speed up the development cycle of the technologies, which is today very conservative, to achieve more flexibility.
The Primes recalled their offer made at the workshop in Brussels to perform systems studies (including markets and Launchers) to be able to foresee the future markets and their needs in the long time frame (2030), because today they are focussed in the near term market which is Telecom.

N. Arcis recalled the drop of the TRL of a technology when a design change is made. The objective of the SRC is to improve the performances of already existing technologies with dual mode operation, etc. Increasing power might require a long development.
On the dual mode operation, Airbus DS recalled that they have been working on high voltages and that the PPU development should start at the same time as the project activities. F. Pinto also agreed on the fact that several technologies should be developed, because even if the Primes are correct stating that they do not know the future evolution of the market, if the market changes and the HETs are not selected, then the other technologies should be ready to take the lead.

H. Guerrero (EC) reminded of the timeline of the H2020 programme and SRCs. Money will not be paid to the projects before 2017. Therefore it will be difficult to respond to the needs of industry in 2-3 years through this programme. It is important that the EP community looks at the market for the future: 2020 -2030. H2020 is also an instrument for mid and long term research. Competitiveness should also be looked at in the mid and long term. The risk of focusing in only one technology is that Europe may lose competitiveness, capabilities and opportunities. He also suggested to the EP community to be ambitious in the definition of this RM, taking the opportunity to design the future for EP.
Another remark in the same line was made by Mr Romana: it is important that the Primes have a long term vision for the EC to be able to support them. A clearer vision and options that would lead to important changes in term of competitiveness would be appreciated.
The Primes acknowledged the fact that they should look beyond 3 years. And for this they need to analyse in details the markets including the launcher market and perform system studies to be able to provide more precise information. They already provided a few inputs in the first workshop in Stockholm such as cheaper electronics, new material for the tanks, etc.

Several other points and comments were made by the audience:

- There is a critical gap that affects competitiveness. Build a portfolio of EP units that can be offered to customers, who come with a new idea. We have 20 concepts, but the customer wants flight experience. We should encourage the Commission to have tech demonstration missions to provide flight heritage to concepts in development.

- On alternative propellants: the objective seems to be the cost of Xenon. It is, however, much more important to know that Xenon is a limited resources and that it is also used in other non-space areas, most importantly in hospitals. Therefore it is very important to look at other propellants, not only noble gases. Iodine for example is very promising (US has already started looking at this propellant) and easy to handle.

- On cathode development: the PSA confirmed that the RM clearly says that cathode development is needed. There are already several technologies in Europe with high TRL. H. Simpson confirmed stating also that the cathodes are facing the same kind of issue as the thrusters: cost competitiveness, suitability for different operation levels, etc. Operation with alternative propellants to Xenon should also be checked and confirmed.

- Questions about the call texts and the way they will present the topic and the scope of the future activities. EC answered that the proposers can decide which topic they want to address and the budget requested for this. And the selection process will be done by the evaluators.

4.5 Roadmap for Disruptive Technologies

The panel discussion following the presentation of the draft roadmap was guided by Nick Cox (UKSA, EPIC). The panel members were:

- Mariano Andrenucci, University of Pisa
- Steve Gabriel, University of Southampton
- Philippe Lamotte, TAS
- Alexander Reissner, Fotec
- Nicoletta Wagner, Airbus DS

The discussion was initiated by N. Cox who emphasised the difficulty to prioritise the technologies in the disruptive line, and that therefore the choice of the EPIC PSA was to present a general roadmap with a list of technologies. Then it was followed by a round of statements given by the panel members. The main points are summarised hereafter:

- Disruptive Technologies could open the discussion to broader elements when compared to incremental.
- It is important to “think out of the box” for this line of developments in order to disrupt the current state-of-the-art in EP technologies.

- During the past decades many ways to combine all the potential principles of EP have been explored in order to reach thrusters with different characteristics. Finding new ways to make thrusters would be very interesting; among them, lighter systems, cost effective solutions, new solutions for nanosatellites can be possibilities. The budget for the development of disruptive technologies is limited in the upcoming call, therefore it was suggested to direct the choices on already existing solutions which can be effective in the short term on aspects like weight, etc.
- FOTEC highlighted the new interest by a number of small and also by big companies in the emerging market of spacecraft constellations. However today, even though Europe has a large competence in this field (small thrusters for micro and nanosatellites), the institutional market cannot provide short term competitiveness. A disruptive roadmap for micropropulsion is needed.
- The choice of proposing activities in the area of PPUs with radical innovation in the disruptive roadmap was highly appreciated. It was also stated that a low cost, reliable PPU built of functional blocks can be developed, to tackle for instance the constellation challenge. The idea of merging power distribution unit and PPU was found very interesting (a lot of studies are going in this direction in USA).

Discussion:

A first topic of discussion was related to costs reduction and PPUs.
It was said in the audience that there is a clear trend going towards constellations of satellites in the market. The example of microsatellite constellations with radar for Earth Observation purposes was given. A question on the way to achieve cost effective EP systems (therefore including the PPU) to be put on-board those spacecraft was raised.
It was highlighted by the audience that low cost systems should be available in the next 5 years and not later, otherwise Europe will be too late to propose suitable solutions for this new market. Elon Musk (US) with his future constellation plans to buy a thruster for about 12500 €. So, if the thruster is down to material cost, pressure will increase on electronics and on propellant. As a consequence there will be also a need to work on low cost alternative propellant. Airbus DS stated that making cheap PPUs implies taking a bottom-up approach, to be able to determine which functions in the PPU are not necessary for all the technologies and can be removed. It was emphasized that the disruptive call can be a good opportunity to cooperate with new ideas for the related developments. TAS stated that integration and test of new PPU in a new architecture can be implemented in a short term to reduce the costs. A question on the production scale was raised by TAS who also requested a close collaboration with the Primes for any future PPU development. As well FOTEC stated that they have already small and compact PPU for microsatellite/ CubeSats (with no redundancy, no radiation protection, decreased reliability), that consists of COTS components, and that of course are not suitable for telecommunication satellites, but can perfectly be used as starting point for specific applications.
S. Gabriel believes that there is room in the disruptive call for new concepts and not only for optimisation of existing ones. The thrusters themselves will have to be taken into account for the related PPUs. For instance, PPTs are very simple devices; however they need to use very specific high voltage capacitors (need to discharge very quickly and need to sustain several million pulses). M. Andrenucci gave the example of direct drive, which could be a game changer in the future.
It was also stated in the audience that if cost is the main criteria, it should also include costs of integration, and the costs of test. Disruptive means improving a performance by an order of magnitude, and for instance on costs. Cost should be a criterion from the beginning.
It was also emphasised that for the disruptive line as well the EP community should look not only at the European competitors, but worldwide. To save costs is one aspect, but applications are needed and both aspects should be taken into account.

Another point of discussion was the perspective of the next decades and beyond. M. Andrenucci gave the example of men going to Mars, stating that this would be impossible using chemical propulsion. Instead, electric propulsion with high thrust density must be used as main propulsion. HET and GIE do not have a thrust density high enough for this; therefore there is a clear need of other technologies (disruptive). As well he believes that in the future power will be growing, not only for telecom platforms. The example of MPD was given; today it is still far from being useable, but its inclusion in the list is more than justified.

Then the topic of the acceleration of the introduction of new technologies on the market was tackled.
The panel members stated that this can be done with IOD missions, which are today one of the key issues. Other alternatives is to look for rather short term opportunities or less risky innovations such as the use of alternative propellants (iodine for instance, which is not a noble gas but stands next to Xenon in the periodic table of the elements). The example of liquid metals was given and their possible impact on different parts of the spacecraft. A clarification on the non-contamination of optical parts by Caesium on the Lisa PathFinder spacecraft due to the very small amount of propellant in the thruster was given by Mr. Andrenucci.
TAS emphasised that to accelerate the introduction of a thruster and its related system on the market, the EP community should work on competitiveness over the next 5 years, work on the integration into the satellite, look at the level of production and the confidence of the customer: heritage is a "key word".

A discussion on the necessity to develop new or improved cathodes was started.
With future thrusters with dual mode operation, the cathodes shall be able to function adequately as well and be able to cope with the new lifetime requirements.

Several other points and comments were made by the audience:

- The main purpose of H2020 is research. Therefore the suggestion to develop cathode-less thruster was made.
- The necessity of having system studies in the disruptive line was also discussed.
- Disruptive means valuable for the customer in order to change the current situation of the market facing higher development risks.
- A new concept could be extreme thrust vectoring (120 °) in the list for disruptive innovation.
- The EPIC PSA chose not the include thrust orientation mechanisms in the roadmaps as they are very well mastered technologies, are missions specific and no issues have been identified in their use.
- With future thrusters with dual mode operation, the cathodes shall be able to function adequately as well and be able to cope with the new lifetime requirements.
- For the future proposers to the SRC calls, it will be important to explain clearly how the consortium intends to validate the performance of the thruster/equipment to be developed. As well it should be clear in the proposals how the consortium demonstrate that there is an improvement to be expected that is really addressing one of the main needs and what should be the potential impacts of the technology in the future.

4.6 Conclusions of the Panel Discussions

The possibility to comment on the draft EPIC roadmap was used extensively. Some aspects brought forward in the discussions could be implemented into the draft EPIC roadmap. One of the difficulties encountered was the very short time between distributing the draft roadmap information and the workshop itself. The panel members and the other participants had to react to the information provided almost on the spot and with very little lead time for internal discussions and preparation.
The distinction between incremental and disruptive technologies appeared to be received as arbitrary by a number of participants.
High pressure was exerted to prioritise the technology, which currently has the best market position, and to fund its short term development for actually seen market needs. It was also pointed out that the SRC projects start working only 2017 and that the final results are expected by mid of the twenties. For a development to satisfy short term needs other funding sources should be found. However, it is difficult to determine the need of satellite primes and their customers so far into the future. Therefore, system studies were requested, to be performed as soon as possible.
The growing importance of LEO constellations was stressed by some participants.
In the discussion of the disruptive technology line the importance of science applications was mentioned several times. A particular requirement of some science missions is high precision micropropulsion.
Also for the disruptive technology line system studies were requested, it was however also pointed out that system studies have been undertaken and are available in great numbers.
In both the incremental and the disruptive technology lines the development of much simpler and cheaper PPUs and PPU architectures were stipulated.

Also for both incremental and disruptive technology lines the need to have a space qualification at the end was stressed. Dedicated IOV missions were proposed, perhaps on low cost micro satellites.

5 SUMMARY OF ROUND TABLES POINTS, WRAP-UP AND WAY FORWARD

N. Arcis summarized the discussion on the incremental technology line.
Competitiveness was discussed again. There is a market for EP, but it is not clear to what extent. The market is mainly for telecom, and the long term future market is difficult to predict, but telecom will be the precursor for other applications.
The EP community should also prepare itself for future applications like space tugs. Therefore it is important to be ready on technological level, when those new applications come. It was highlighted again that it is very difficult to anticipate future market changes as for instance the announcement of Boeing in 2012. Therefore Europe should prepare the competence in order to be able to react fast.

The discussion on the disruptive technology line was summarised by N. Cox.
EPIC has built caveats into the roadmap to keep the roadmap open. No technology is excluded from it. It was recalled again that prioritisation of disruptive technologies was problematic. Prioritisation may bear the risk to exclude important developments. It was difficult to tie technologies to applications in the disruptive technology case. Flexibility was mentioned as a final aim.

Jose Gonzalez del Amo was in charge of the closure of the workshop.
The Boeing effect is well known. The conservatism of Europe in the EP field as compared to the USA was mentioned and therefore the need to look in the future. It is agreed that system studies are needed for incremental technologies, but not necessarily for disruptive. Proposals for incremental technologies have to be very good, for disruptive perhaps even more so, because the topic is so open. The idea (by M. Andrenucci) of self-evaluation by the proposers was very much appreciated for disruptive line proposals.

ANNEX 1: Workshop Programme

Agenda

DAY 1, WEDNESDAY, 11TH FEBRUARY

09:00 Registration

Session 1

Chair: José Gonzalez del Amo; Secretary: Alexandra Bulit

09:30 Welcome
Olle Norberg (SNSB - Swedish National Space Board)

09:45 Horizon 2020 Space Strategic Research Clusters (SRCs)
Hector Guerrero (EC - European Commission)

10:15 Introduction to the EPIC project
José Gonzalez del Amo (ESA – European Space Agency)

10:45 Overview of Brussels EPIC Workshop
Nicolas Arcis (CNES - Centre national d'études spatiales)

11:15 Coffee Break

Session 2

Chair: Klaus Ruf; Secretary: Inés Alonso

11:45 Overview of the draft EPIC Roadmap for a H2020 SRC
José Gonzalez del Amo (ESA – European Space Agency)

12:00 Results of the Critical review and Gap analysis of requirements vs application domains
Carlos Garcia (CDTI - Centro de Desarrollo Tecnológico Industrial)

12:15 Rational for the prioritization of technologies
Danilo Rubini (ASI - Agenzia Spaziale Italiana)

- **Incremental line**
  Nicolas Arcis (CNES - Centre national d'études spatiales)
- **Disruptive line**
  Nick Cox (UKSA)

13:00 Lunch Break

Session 3

Chair: Nick Cox; Secretary: Carlos Garcia

14:30 Presentation of the EPIC draft Roadmap for the incremental line
José Gonzalez del Amo (ESA – European Space Agency)

14:50 Round Table to identify gaps / improvements on the draft EPIC Roadmap - Incremental line
Moderator: *Nicolas Arcis (CNES)*
Panel: Ernst Bosch (Thales Electronic Systems), Alain Demairé (OHB Sweden), Philippe Garcon (Thales Alenia Space), Vincent Jacod (Airbus Defense and Space), Huw Simpson (Qinetiq), Gilles Turin (Snecma), Fernando Pinto (Airbus Defense and Space)

16:15 Coffee Break

16:45 Continuation: Round Table to identify gaps / improvements on the draft EPIC Roadmap - Incremental line

18:00 End of day 1

DAY 2, THURSDAY, 12TH FEBRUARY

Session 4

Chair: Nicolas Arcis; Secretary: Danilo Rubini

09:00 Presentation of the EPIC draft Roadmap for the disruptive line
José Gonzalez del Amo (ESA – European Space Agency)

09:20 Round Table to identify gaps / improvements on the draft EPIC Roadmap - Disruptive line

Moderator: *Nick Cox (UKSA)*

Panel: Mariano Andrenucci (Pisa University), Stephen Gabriel (University of Southampton), Philippe Lamotte (Thales Alenia Space) , Alexander Reissner (Fotec), Nicoletta Wagner (Airbus Defense and Space)

11:00 Coffee Break

11:30 Continuation: Round Table to identify gaps / improvements on the draft EPIC Roadmap - Disruptive line

13:00 Lunch

Session 5

Chair: Jose Gonzalez del Amo; Secretary: Klaus Ruf

14:00 Summary of Round Tables points:

- **Incremental line**
  Nicolas Arcis (CNES - Centre national d'études spatiales)
- **Disruptive line**
  Nick Cox (UKSA - United Kingdom Space Agency)

14:40 Wrap-up and Way forward

José Gonzalez del Amo (ESA – European Space Agency)

15:00 End of Workshop

ANNEX 2: List of participants

Ane	Aanesland		CNRS, Paris
Eduardo	Ahedo	Professor	UC3M: Universidad Carlos III de Madrid
Ines	Alonso	EPIC Coordination Team	European Space Agency (ESA)
Bjarne	Andersson	Engineer	OHB Sweden
Mariano	Andrenucci		Pisa University
Luigi	Ansalone	Postdoctoral fellow, member of the EPIC consortium	ASI Italian Space Agency
Nicolas	Arcis	Head of the Propulsion Pyrotechnics and Aerothermodynamics section	CNES
Gianluca	Ascanio	System engineer	CGS S.p.A.
Andrew	Bacon	Senior Systems Engineer	Thales Alenia Space UK Ltd
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