

Decision Engineering Report Series

# Industrial Product-Service Systems

## THINK TANK

11 July 2011

*Cranfield*  
UNIVERSITY



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**Decision Engineering Report Series**

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**INDUSTRIAL PRODUCT – SERVICE SYSTEMS (IPS<sup>2</sup>): THINK TANK**

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## Executive Summary

Cranfield University and Rolls-Royce plc designed and developed a one-day 'Think-Tank' international workshop to establish the future research direction for Industrial Product-Service Systems (IPS<sup>2</sup>). The workshop was held at Cranfield University, UK, by invitation only to visionary academics across the globe, senior industrialists and funding organisations.

The workshop aimed to trigger discussions on high impact challenges involved in IPS<sup>2</sup>. The research directions from the workshop could inform IPS<sup>2</sup> researchers and research funding decisions in the future. The overall objectives were to:

- Engage multi-disciplinary academics and practitioners in a deeper discussion to identify major research directions for the future.
- Identify the unique challenges faced in IPS<sup>2</sup> and also any country specific requirements.
- Prioritise the research directions into mid-term and long-term categories.
- Identify major industry and public procurement trends across different countries.

The workshop design has gone through two main phases. Prior to commencing the event, the participants submitted their thoughts on either "IPS<sup>2</sup> Research Directions" or "Industrial requirements for IPS<sup>2</sup>" and these were thoroughly analysed. During the event, the analysed results were presented and followed by capturing strengths, weaknesses, opportunities and threats (SWOT analysis) to IPS<sup>2</sup> research across different countries. One of the main strengths of the research area is that IPS<sup>2</sup> research is maturing in international profile and creating wide awareness of its importance among stakeholders. How the bigger picture of IPS<sup>2</sup> was described and the immaturity of models, tools and techniques developed for real industrial applications were major weaknesses of IPS<sup>2</sup> research. To develop an enhanced understanding of IPS<sup>2</sup> research results across countries, wider opportunities to establish a common case studying pool is suggested. Finally, prolonged research funding for analysing real impact on industry is a major threat widely discussed.

Every delegate had to express his/her views on potentially high-impact in their countries. Combined grouping analysis of these answers gave ten common themes within them. Examples of these common themes are cost, skills, design and manufacturing, society, and case studies. These themes underwent a rigorous prioritization process by the delegates to identify high impact challenges. From the prioritization of grouped challenges, the themes - Design and Manufacturing, Case studies, Business capability, Cost and Complexity, all emerged as the foremost areas on which to concentrate.

## **ACKNOWLEDGMENTS**

Cranfield University would like to thank all delegates for giving their time to attend the workshop and for their willingness to engage in constructive and stimulating discussion during the day. We hope that every delegate found the day to be a worthwhile activity, and that the contacts made will be fruitful for the future.

We would to thank the Cranfield Secretaries Mrs Teresa Bandee and Miss Kayleigh Brennan for providing support to the workshop.

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## **1. Background**

The research areas in industrial product-service systems (IPS<sup>2</sup>) are diverging and producing valuable insights for creating novel systems that are delivering sustained value outcomes. There is a need to consolidate and facilitate research directions for future research to impact industrial and societal requirements. To elicit and stir these research directions, active discussion among academics and practitioners across various countries is required.

Cranfield University and Rolls-Royce plc organized a one-day 'Think-Tank' international workshop to establish the future research direction for Industrial Product-Service Systems (IPS<sup>2</sup>). The workshop aimed to trigger such discussions among renowned IPS<sup>2</sup> researchers and industrialists. This is a well planned event to set the IPS<sup>2</sup> scene in a global context. High impact challenges involved in IPS<sup>2</sup> were brought forward, discussed and summarized. Largely the list of research directions from the workshop could inform IPS<sup>2</sup> researchers and research funding decisions in the future.

The IPS<sup>2</sup> Think-Tank workshop was held on Monday 11 July, 2011 at Cranfield University, UK.

## **2. Objectives**

The industrial product-service systems 'Think-Tank' workshop was planned with the following core objectives:

- Engage multi-disciplinary academics and practitioners in a deeper discussion to identify major research directions for the future.
- Identify the unique challenges faced in IPS<sup>2</sup> and also any country specific requirements.
- Prioritisation of the research directions into mid-term and long-term categories.
- Identify major industry and public procurement trends across different countries.

## **3. Attendees**

The workshop was a one-day event by invitation only. The most research active and visionary academics from multiple disciplines around the world and senior leaders in engineering services and related areas from industry were invited. National and international funding bodies were also represented and involved in the discussion.

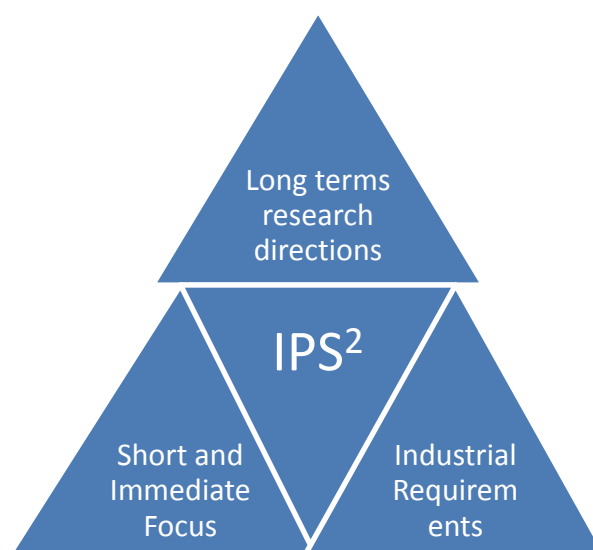
27 academics / industrialists participated in the workshop and a full list of attendees has been given in Annex 1.



Workshop Delegates

#### 4. Strategic Context

Before the start of this event, all the interested attendees were requested to write a single page on either “Industrial Product-Service Systems (IPS<sup>2</sup>) Research Directions – mid (3 years) and long terms (5-10 years)” or “Industrial requirements for IPS<sup>2</sup>”. It had been agreed that these one page inputs would be shared with other participants during the workshop and assist in developing this report. The one page write-ups set the scene for the workshop and were used to facilitate all of the workshop discussions.



The key focus areas emerging from these initial write-ups were summarized and presented in the workshop. In the mid term IPS<sup>2</sup> research directions, the focus areas commonly discussed were customer behaviour profiling, the trade-off between availability and cost, risk analysis, contractual issues, design of service, obsolescence management, co-creation of value, design and innovation, multi-disciplinary interaction modelling, cost modelling, life cycle maintenance planning and IPS<sup>2</sup> deployment approaches.



For long term research directions, real time modelling and optimization for agile service delivery, engineering services automation, validation of IPS<sup>2</sup> designs, IPS<sup>2</sup> delivery, standardization, and lean engineering services were mentioned. This initial summary laid a foundation for the workshop and discussions.

The industrial requirements were summarized and presented by Rolls-Royce. The key issues are summarized in the areas of requirements setting, design optimization, managing risk, predicting outcomes, managing operational efficiency, and learning from experience.

Annex 2 provides a complete summary, which was derived from the one page write ups.

## **5. Workshop Outputs – Community Analysis**

Attendees were divided into two groups with equal composition of academics and practitioners from industry in each group. Strengths, weaknesses, opportunities and threats (SWOT analysis) to IPS<sup>2</sup> research across different countries were captured. The complete list of outputs from this session is presented in Annex 3.

### **Strengths**

It has been commonly highlighted that IPS<sup>2</sup> research is maturing in international profile and creating wide awareness of its importance among stakeholders. The time is right for establishing stronger roots for IPS<sup>2</sup> research. The IPS<sup>2</sup> research community is leading the way in thinking and vision for long term benefits. Innovations brought about by the IPS<sup>2</sup> outcomes are distinguished. There is a stronger industrial pull for IPS<sup>2</sup> research. Integrated research with some of the companies is largely appreciated. The complexity of IPS<sup>2</sup> has created collaborative multi-disciplinary community from engineering, science and management. Well established industry participation in IPS<sup>2</sup> research is noted.

### **Weaknesses**

Describing the bigger picture of IPS<sup>2</sup> is considered as an immediate issue to be resolved. Difficulties have been observed in cross research community communications. It was highlighted that there are challenges in collaboration between academia and industry which need to be addressed. Immaturity of models, tools and techniques developed for real industrial applications is also a concern. The deterministic structure mostly adopted in research framework for generating IPS<sup>2</sup> may not always hold true. Discussion has focussed on either a broad or specified scope of research, which leads to difficulty in IPS<sup>2</sup> adaptation in industries. Integration between manufacture and service is highlighted to be poor. Identified

access to the correct business data is difficult, and too late in some cases. Benefits attributed to IPS<sup>2</sup> solutions need to be presented with evidence e.g. profitability.



Two Groups of Delegates Working on the SWOT Analysis Session

### **Opportunities**

For developing the enhanced understanding of IPS<sup>2</sup> research results across countries, wider opportunities to develop a common case study pool is suggested. Inputs have been provided to infer research results from other disciplines. Wider possibilities for developing engagement methods between industry and academia are proposed, which includes trust building. Demonstrating the value of IPS<sup>2</sup> models using new paradigms is emphasized. The time is currently right for considering environmental factors in IPS<sup>2</sup>.

### **Threats**

The lack of prolonged research funding for analysing real impact on industry is a major threat that is widely discussed. A short term view for return on investment is perceived as a hindrance for developing highly valued IPS<sup>2</sup> theories. Cultural issues especially related to the mindset of employee's impacts the wider penetration of IPS<sup>2</sup> concepts in industry. Furthermore, industry views of difficulties to change for adopting IPS<sup>2</sup> concepts impedes real case demonstration. Confidentiality issues for industrial data are noted, so as barriers to building wider trust between academia and industry.

## **6. Workshop Outputs – Identifying High Impact Challenges**

Following a wider discussion on the SWOT session, thinking time was provided to each delegate to reflect on their views on the critical challenges to be addressed. The questions each person needed to consider were:

1. What are the potentially high-impact (e.g. national/core capability or a potential threat) industrial and social challenges in your country?

2. What efforts are undertaken in each country/names of researchers/research groups?
3. Why is the challenge not solved yet, or what barriers exist?

Delegates used variety of post-it notes to express their answers. Grouping of these answers highlighted ten common themes within them. The common themes along with highlighted points of challenge are listed below. A complete list of challenges is presented in Annex 4.

### **Cost**

- Unsustainable increase in cost for IPS<sup>2</sup>, e.g. military aircraft and health care
- Reduce whole life cost of engineering system
- Short term benefits compared to sustained long term relationships

### **Skills**

- Skill change in work force
- Changing social networks
- Major growth in Asia (United States of America (USA))
- Inability to transfer national skills in innovation/invention from product domain to service domain – threat to our ability to compete in the world (UK)
- Education and training is not producing enough people with the right skills to embrace IPS<sup>2</sup> thinking and respond to challenges

### **R & D**

- Moving from theoretical to technological research (UK)
- Lack of funding (industry do not want to fund research that easily can be shared e.g. by competitors (Sweden))
- Gap between proof of concept and development (UK)

### **Business Capability**

- Technology in life extension for systems and coping with the information explosion and for so many years! (UK)
- Moving from an overhead heavy business to a 'lean' overhead service business (UK)
- Maturity shifting gear from largely 'bespoke' services to commoditized services with bespoke 'feel' in defence services (UK)
- Growing needs in understanding global consumers. Extend life cycle of product in the global contrast (USA)

### **Society**

- Society gets older (low birth rate, baby boom, hitting 50+, long living expectation).
- Major challenges to provide engineering workforce in sufficient time.
- Getting the best out of older people – intelligence
- Integrating the social needs and technical demonstration

### **Culture**

- Shifting a legacy design and manufacturing mindset business to a service mindset (UK)
- Corporate and government short-term ROI mindset is inimical to full-life PSS optimization and exploitation (UK)
- How to convince the people of the effectiveness of PSS approaches and to drive them to step in the direction of PSS business (Japan)

### **Competition**

- Competition from low cost economies (UK)
- Competition for materials, energy and water (UK)
- Key performance indicators for measuring the performance of PSS (Sweden)

### **Case Studies**

- Lack of studies that really show the industry the real potential (pros and cons) of PSS (Sweden)
- How to gain (search, learn and find) experience in times where turnaround time of events shortens? (Sweden)
- Research initiatives in IPS<sup>2</sup> have not yet found a way to engage all stakeholders in an inclusive fashion and in a way that enables open collaboration.

### **Environment**

- Environmental sustainability
- Meeting environmental targets (UK)
- New thinking models for PSS and sustainable manufacturing value creation solutions

### **Design and Manufacturing**

- Real time modelling and optimization of agile services (UK)
- Integrating service performance feedback in product manufacturing
- Design for reliability not solved. Reliability loss comes from improbable events. Hard to get bulk of population to think about statistical universe
- Service knowledge management not solved. Extreme complexity. Data to wisdom compacting issues. Delivery at point of need. Push not pull.

## **Complexity**

- Dependence on supply – energy and logistics. Lack of resilience
- Solving of tomorrows problems today
- Complexity of systems – interactions between components/sub-systems

After grouping the challenges identified in ten major themes, each delegate was provided with ten dots to prioritize their high impact challenges themes. Delegates attached as many dots as they wished to any single theme without limitations.

Figure 1 represents the priority challenges as identified by delegates. From the prioritization of grouped challenges, the themes - Design and Manufacturing, Case studies, Business capability, Cost and Complexity emerged as foremost areas on which to concentrate.

These themes were chosen for further in-depth discussion to elicit further insights and are presented in section (7).

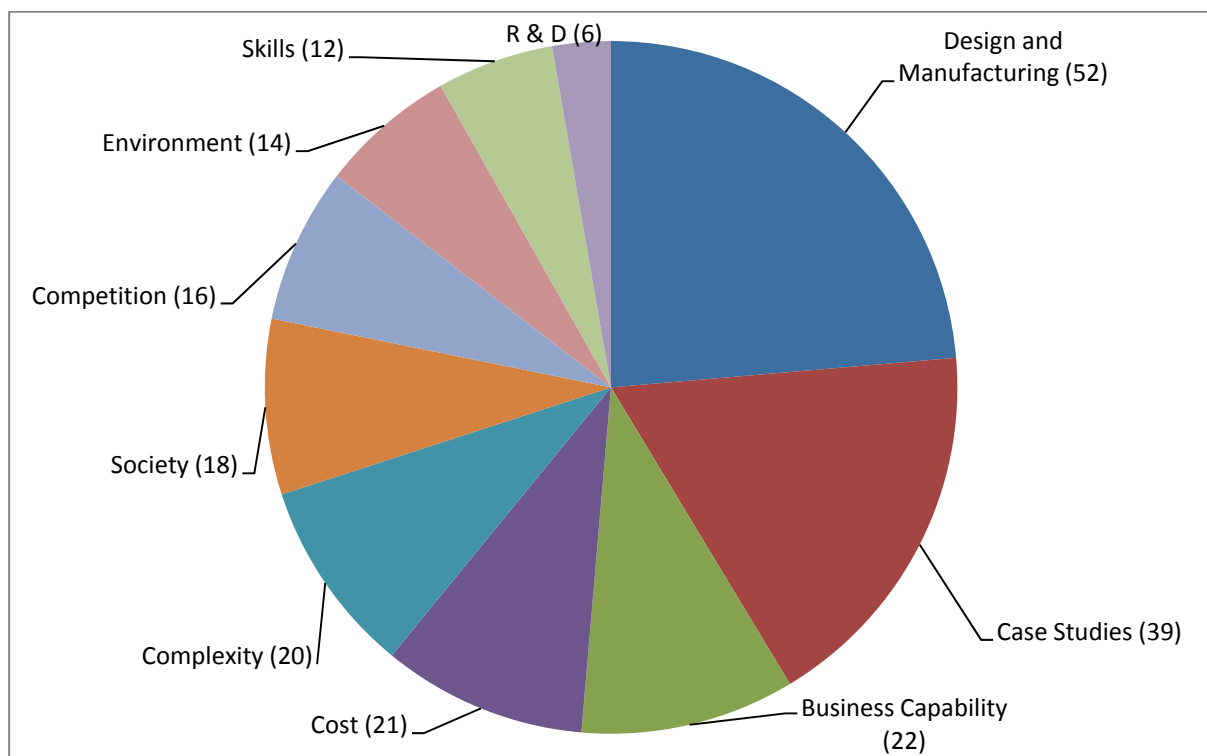


Figure 1 High Impact Challenges within Grouped Themes



Grouping of High Impact Challenges and Prioritizing Individually

## 7. Workshop Outputs – Focused Group Discussion

The final session was structured around the top four chosen themes namely: Design and Manufacturing, Case Studies, Business Capability, Cost and Complexity. The delegates were grouped into three teams and each discussed one theme in-detail. To summarize the discussion one member from each group presented a 'one minute' elevator pitch on the IPS<sup>2</sup> research directions required to solve the high impact challenge.

The discussion was structured to answer following questions:

- What is the nature of the challenge to be tackled? Generic/Specific?
- What are the potential IPS<sup>2</sup> research directions to solve the challenge?
- What would the solution/idea entail?

The discussion around the themes is summarized as follows. A complete list of points noted is presented in Annex 5.

### **Design and Manufacturing**

To develop sustained IPS<sup>2</sup> solutions, the importance of generating modularized configuration of products and services is stressed. Modularization could be visualized through framing architectural models of the holistic system. The holistic system should depict all the stakeholders involved in the development and their respective business and operations processes. Importantly representation of the holistic system should stress the integration and relationships definitions between system parameters. The integration aspects could highlight the dependency network between stakeholders and increase important aspects of visibility. To create understandable and efficient architectural models standardization of terminologies is paramount. Even though various representation standards are emerging, commonly accepted IPS<sup>2</sup> language is needed. In the evaluation process of IPS<sup>2</sup> development, crucially dynamic and hidden cost and risk modelling are noted, which includes implications for satisfying surprise technology changes. Also notably, agility of the infrastructure, changes in human behaviour and measures of robustness for



specifying system readiness level are stressed to be focused upon in the evaluation process.

### **Business Capability**

It has been argued that business capability should be underpinned by the process of IPS<sup>2</sup> delivery. The understanding and implications of the IPS<sup>2</sup> delivery process within industry and academic researchers is questioned. The importance of establishing links between business capability and co-creation of value is highlighted. Strategies are needed to explore and create business models such as revenue split/risk share with reference to the co-creation of value. The industrial delegates raised a query about whether know-how knowledge is protected better using complexity involved in IPS<sup>2</sup>. Learning from cross sector case studies is considered as a key tool for enhancing business capability.

### **Case Studies**

The group felt that progress in understanding of IPS<sup>2</sup> issues; conveying benefits of IPS<sup>2</sup> to industry and government leaders; and identifying key research areas, would be enhanced by a set of comprehensive case studies. The first and foremost step necessary in case studies is to define the fundamentals of IPS<sup>2</sup> compared to ordinary product oriented and service offerings. The next step is to highlight the representative case studies which were successful or not. The key elements that need to be specified for each case study are: value proposition, stakeholder set up, necessary culture and mind set change, critical skill set, bottom line results and new PSS offerings developed. Emphasis has been made for both industry oriented and community driven case studies. Constraints involved in the degree of openness towards innovation are highlighted. Suggestions have been provided to build a case study: start small, test and mature; increase scale as is reasonable; create a trust level first and provide capability for value analysis with the academic partners and research centres.

### **Cost and Complexity**

IPS<sup>2</sup> complexity is explained by the fact that it is difficult to: understand, communicate, predict, define, be paid for, divide work among a network of suppliers, share knowledge developed in a network and formation of network changes. The units of analysis to define complexity are structured around formulating partners, contracts and activities involved in geographic delivery. Managing changing customer requirements, each value chain boundary change, uncertainty and dynamic behavioural variation of the outcomes in the life cycle of IPS<sup>2</sup> are noted as exacerbating the complexity.

## **8. Conclusions**

A fruitful IPS<sup>2</sup> Think-Tank workshop generated intensified discussion among most research active and visionary academics from multiple disciplines around the world and senior leaders in engineering services and related areas from industry. The workshop achieved the intended aim to establish the future research direction for Industrial Product-Service Systems (IPS<sup>2</sup>).

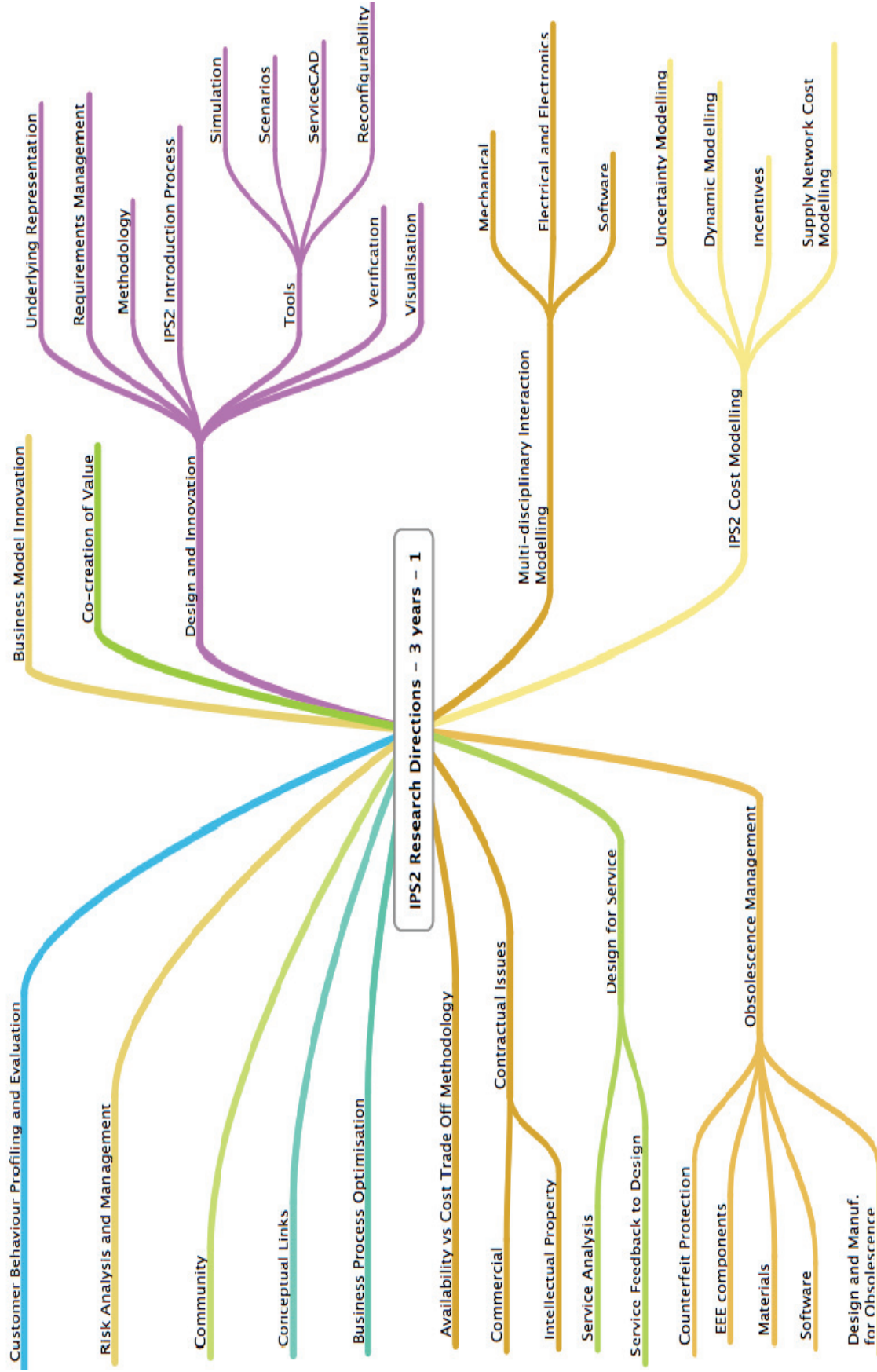
The outcomes identified the unique challenges faced in IPS<sup>2</sup> and also highlighted country specific requirements. Grouping of challenges yielded ten common themes to be addressed. Prioritisation of these themes indicated that attention has to be focused on the following four themes: Design and Manufacturing, Case Studies, Business Capability and Complexity.

The wider research community delegates' participation from across countries generated various joint collaboration approaches to solve the identified issues and challenges. The initiative triggered by this workshop will be sustained through joint meetings in the IPS<sup>2</sup> conferences and other workshops organized in the community.

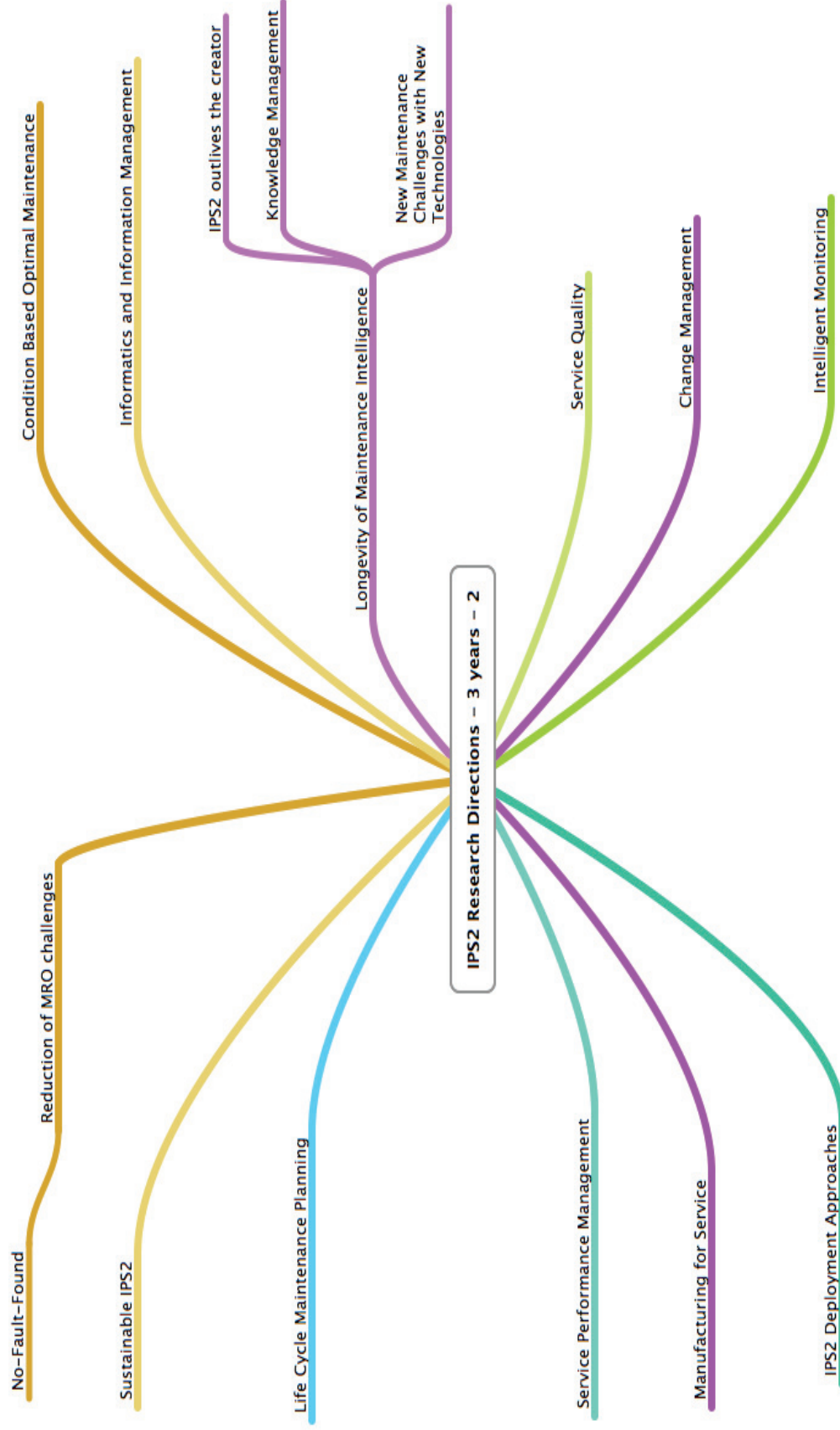
## Annex I Workshop Attendees

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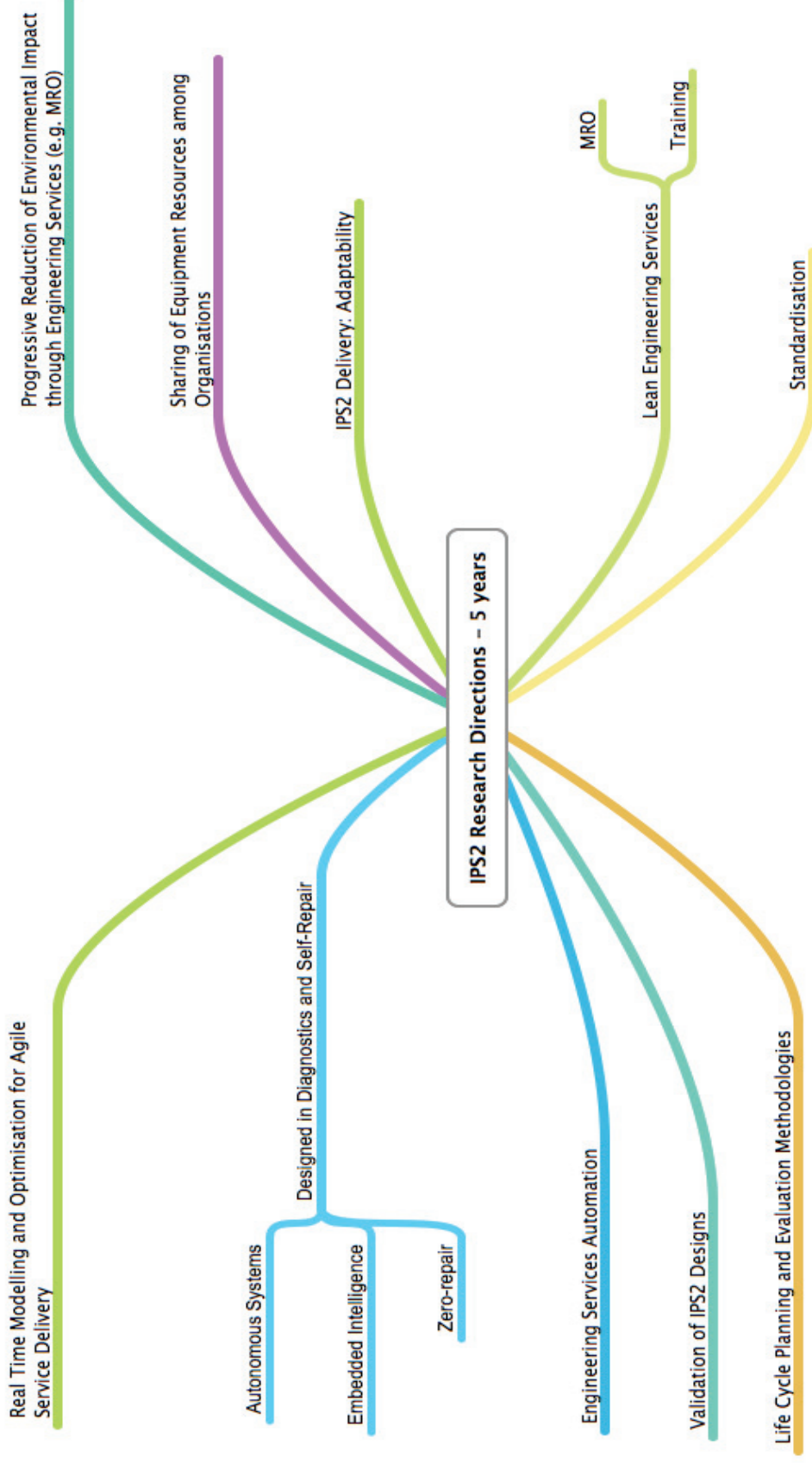
## Annex 2 Summary of Industrial Product-Service Systems (IPS<sup>2</sup>) Research Directions – mid (3 years)



**Annex 2 Summary of Industrial Product-Service Systems (IPS<sup>2</sup>) Research Directions – mid (3 years)**



**Annex 2 Summary of Industrial Product-Service Systems (IPS<sup>2</sup>) Research Directions long terms (5-10 years)**





## Annex 2 Summary of Industrial Product-Service Systems (IPS<sup>2</sup>) Research Directions Industrial requirements for IPS<sup>2</sup>

<b>Factors to be focused on Design for Service</b>	<b>Industry needs a holistic set of the following PSS capabilities</b>
24/7/365?	Requirements Capture and Dissemination
Key Performance Indicators	Design Optimization and Risk Management
People factors in customer satisfaction	Service Delivery and Support
Service Knowledge Feedback	Knowledge Capture, Modelling and Sharing
Customer Operational Data Security	Networks, Supply Chains and Partnerships
Responsiveness versus lean efficiency	Who will we work with
Aligning to customer value	What type of relationships
Lower Rework	What contract types
Increased and Predicted Reliability – Reduced Inventory	Lines of communication
Reduced Costs – Improved Maintainability and Cost of Ownership	Risk and Revenue Splits
Increasing Quality of Decision in Less Time to Make	Length of Relationship
	Integration

### **Annex 3 Strengths, weaknesses, opportunities and threats to IPS<sup>2</sup> research across different countries**

#### **Strengths**

- Research is funded
- Good contact/interaction with industry
- Real industry need
- Industry led/supported
- Strong industry incentives
- Robust supply chain design/MGMT
- Remanufacturing operations management
- Ability to contribute to sustainability
- Research demand is recognized in academic and industries
- New methods for product engineering are in development
- Formalized modelling
- Modelling and evaluation
- Maintenance cost modelling – Cranfield and Southampton
- Reliability models
- Systems thinking
- Framework for creating PSS
- Created awareness of PSS benefits to SMEs.
- Definitions of terminology
- In UK – Good understanding of co creation of value
- Advanced search – Sheffield UK
- In UK – Significant research already completed by obsolescence management and concepts for open standards in sharing obsolescence data
- On an international basis, SAE standards organization already researching responses to management
- Cross sectoral industrial contacts
- Interest from both industry of academia
- Level of UK research activity
- Several fields of research involved to address the large field IPS<sup>2</sup>
- Research in various aspects in underway
- 10+ years of industry /universities collaboration in the area
- We have people in a community
- Multi disciplinary
- Environment for company collaboration
- Potential for improving other goals e.g. sustainability
- International collaboration opportunities
- Ability to leave conventional business constraints – liberty of new ideas
- Capability to develop new theoretical models across scientific disciplines
- National network between research groups
- Attractive state of research – awareness, incentives and still forming
- Good exemplars in industry
- Government interest and support

**Weaknesses**

- Interface between disciplines
- Lack of visibility/popularity of IPS<sup>2</sup> Research
- Dispersed body of knowledge
- Established research predominately within domains – strong paradigms
- Benefits are 10 years in future – difficult to justify
- REF impact driver is 15 years for impact too short?
- Time and timing – effect takes time and expectation on short term effect
- Too much focus on immediate applications
- Lower levels of supply chain not yet engaged
- Haven't yet achieved concurrent design of products and services
- Not yet able to visualize complex IPS<sup>2</sup> systems to inform design optimization
- Demonstrating tangible benefits
- Current research dominated by small number of sectors
- Prototyping of the new researched approaches. No engineering sandbox with industry set up yet
- Availability of experimental platform, benchmarks, exemplars for cross – comparison of results
- Methodology – invention and discovery
- Actual industrial practice not described
- IPS<sup>2</sup> development process not enough detail
- Too generic not tailed to industrial branch specialties – makes transfer difficult
- Many business models prevailing in current practice
- Education e.g. PSS, Master
- Selling methods for PSS
- Abstraction not welcome
- PSS required holistic (user value focus) thinking
- Guts based (non-scientific) service design
- Ownership of data & sharing an issue
- Risks are poorly understood and shared
- Tools and methods immature in PSS
- Cannot predict long-term costs with certainty
- Lack of standard tools/techniques
- Method distance from practice
- Modelling and simulation predictive methods not good enough
- Research results not yet enough predictive with good data
- Human/service models harder to validate than physical models
- Complexity – long-term forecast and design use affect performance and life
- Lack of fundamental models appropriate for PSS
- Awareness and competence weak and good examples/facts
- Few strong engagements
- Inter-community communication
- Research community has not yet come up with a complete end to end approach (too many specific methods)
- No shared understanding of boundary of IPS<sup>2</sup>
- PSS require a shift on paradigm
- Engineering research vs management research incompatible approaches
- No common shared PSS landscape
- Uncertainty management in PSS

Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

- Industry ahead of academia in any aspects or PSS
- Gap business v engineering
- Topic – product/science
- Either very broader or narrow approach
- The breadth of the problem is very wide
- Coordination and activities are limited
- Fragmented mono disciplinary approaches
- Difficulties in working effectively between disciplines
- The problem is real to addressing is with generate (contribute to gain of wealth)

**Opportunities**

- Strong network possibilities
- True multi-disciplinary work
- Application of multiple sectors
- Involve developing countries in this transformation
- International collaboration
- Build on global PSS community – create an identity
- Research Map/directory
- Secondments into industry
- Work with industry to identify new opportunities for industry and academia
- Reference scenarios to compare methods and tools
- How to identify business cases
- Tools to help the designer feel the service needs
- Common neutral test case. E.g. new paradigm for military and commercial market?
- Learning lessons from the past
- Customization of PSS
- Research validation across countries and environment
- Certification auditing of service (level)
- Experience and standardise effort exist. Can be used and expanded.
- Capability to model simulates complexity maturing. Can attach PSS
- Opportunity for novel research that solves a current problem
- Define architecture of IPS<sup>2</sup>
- Holistic package services
- Exploit open standards for exchange of data
- We can frame the research landscape
- IPS<sup>2</sup> is a too difficult term; If renamed it will be consumable for a wider expert group and for public
- Investigate modelling techniques based on architecture frameworks. E.g. TOGAF
- New business models e.g. social enterprises
- Business is there – theory and research can help explain and support and develop means
- There is real problem to solve
- Youth generation like context feedback and quick feedback suitable PSS developers
- Change expected communities such as this can help coordinate and facilitate

Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

- IPS<sup>2</sup> still has major potentials to provide new engineers hands on and management solutions
- Industrial pull
- Investigate better commercial arrangements. E.g. terms and conditions. Contract incentivisation performance measurement
- New research funds initiatives in green/sustainable MFG
- Build modelling system of IPS<sup>2</sup> - verification
- IPS<sup>2</sup> A core strategy for sustainable product design/MFG/use
- Benefits based incentives for research outcomes
- IPS<sup>2</sup> has the potential to deliver the core of the future value creation model for sustainability
- Potential to contribute to general purpose underpinnings
- Model the different parts of the IPS<sup>2</sup>
- Common community view of PSS – architecture from different perspectives

**Threats**

- No method to take theory to practice – industry adoption
- Validation and proving effect of new research results
- Using learning in new PSS that has short term benefits but longer term unanticipated costs
- Industry demands prediction of ROI before committing resources to research – difficult to achieve
- Quantification of real benefits
- Lack of underlying science
- Methodical weaknesses
- Engineering lack of prestige for research in IPS<sup>2</sup> – related areas e.g. Maintenance
- Fail establishing the PSS ecology
- We only create a bunch of useful bits and elements
- Not enough data from architecture – model
- Verification and validation
- Needs for means of cross-comparing models and results e.g. wireframe, surface, BREP, CSG
- Industry will close the information for academia
- Not enough industry value chains involved
- Don't fix the problems
- IP/commercial, confidentiality. Prevents collaboration
- Business an integral part of IPS<sup>2</sup> = IPR becomes too sensitive
- Serious engagement to solve needed issues
- Politicians demand instant knee-jerk quick fixes to difficult service delivery challenges, e.g. UK NHS
- Faster and more faster outcomes
- Disruptive societal change – unanticipated
- No true community engagement
- Lack of educated workforce for IPS<sup>2</sup>
- Self-satisfaction no international comparison
- Funding for basic research decreasing?
- Failure to deliver industrial impact
- Lack of funding?

Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

- Research funds vanishing prior to have reached full industrial impact
- Lack of funding (sort manufacturing)
- Culture eats good ideas and theories for breakfast
- Big m/c specific
- Processes/tools we're working on not saleable to small IPS<sup>2</sup>
- Specific to big companies

**Highlighted Summary Points of SWOT Analysis****Strengths**

- Industrial pull
- Existing multi disciplinary community – with strong industry participation
- The time is right
- Opportunity to be innovative
- Packets of research strength
- Integration – in some companies
- Diversification, agility
- Enthusiasm (students)
- Leading thinking and long term
- Diversity – multi sector
- Maturity of PSS Research in international profile and awareness

**Weakness**

- No means to describe the big picture of PSS
- Research methodology issues (reflective vs developing solutions)
- Challenges in academic/industry research collaboration
- Difficulties In cross research community communications
- Immaturity of models, tools and techniques
- Ability to cope with complexity of PSS
- Structure: Deterministic is not always true.
- Short-termism
- Research too contextual – too specialized
- Access to core business data
- Mixed views on profitability – evidence?
- Information come too late
- Manufacture and service poorly integrated
- Research lags industry
- Service is designed like a product

**Opportunities**

- The time is right – environmental factors
- Big picture model development
- Engagement methods between industry/academia
- Common case studying pool
- Driving, directions from customers
- Spot context from patterns in business
- Focus on specific sectors
- Need transformation process structure for PSS
- Draw research from other disciplines



Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

- Relationship building for trust
- Early information for standards checkers
- NEW paradigms for use. Demonstrate value
- Shift mindset for service

**Threats**

- Funding challenges
- Confidentiality issues for industry data
- Risks for methodological problems/lack of theory/science
- Faster, faster
- Return on investment
- Applicable only to big companies
- Cultural issues and workforce issues
- Mindset
  - Conversation
  - Cost
  - Legacy/baggage
- Lack of visibility of impact
- PSS: Serious events no longer happen – Visibility.
- Companies think they can't change

## **Annex 4 Identifying High Impact Challenges and Grouping**

### **Society - Culture**

- Shifting a legacy D+M mindset business to a service mindset (SLEVS, UK)
- Corporate and government short-term ROI mindset is inimical to full-life PSS optimization and exploitation (UK)
- Deeply embedded emphasis on manufacturing status quo with priority on social job presentation rather than business transformation to PSS (FRANCE)
- Making services 'sexy' – attracting the right calibre of graduates etc into the services world (SLEB, UK)
- How to convince the people of the effectiveness of PSS approaches and to drive them to step in the direction of PSS business. (Japan)
- Cultural change
- Change the mind set to 'service focused' (NL)

### **Cost**

- Reduce whole life cost of Engineering System
- Costing services
- Unsustainable increase in Cost for IPS<sup>2</sup>, military aircraft, health care (no moore's law)
- Driven by price, nothing else
- Predicting cost of service provision – trace cost
- Economic sustainability
- Short terms benefits compared to sustained long term relationships
- Poorly written contract terms
- PSS pricing/cost modules
- Unsustainable cost increases cited by U.S. Defense Advanced Research Projects Agency (DARPA): <http://www.darpa.mil/AVM.aspx>
- Need new product/service development strategy that borrows from semiconductor module/rules approach (INTEL)

### **Skills**

- 1. Skill change in work force 2. Changing social networks 3. Major growth in Asia Mailouts (USA)
- Balance between 'continuous export driven strong industry output' v 'new ways of ICT enabled sustainable manufacturing' (LER)
- Continuous learning becomes more important than deep skills?
- Creating good quality jobs
- Skills gap (UK)
- Young people put off early - smaller pool of talent (UK)
- Inability to transfer national skills in innovation/invention from product domain to service domain – threat to our ability to compete in the world (UK PJWI)
- Higher mobility of staff between countries, companies – greater need to get staff to be productive quicker and capture knowledge
- Education and training is not producing enough people with the right skill to embrace IPS<sup>2</sup> thinking and respond to challenges
- Mobility of workforce – adaptability of systems

Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

- Promoting industry to schools and media
- People – skills, capabilities and education (lifelong)
- Lack of staff (researchers)

**R & D**

- National funding focusing functional products/PSS (threat) Sweden
- Interaction between industry and academia (UK)
- Moving from theoretical to technological research (UK)
- Lack of funding (industry don't want to fund research that easily can be shared e.g. By competitors (Sweden)
- Loss of R+D capability in advanced MFG
- Balance between applied and blue sky research (UK)
- Gap between proof of concept and development (UK)
- Reducing funding for research
- Increase of research funds and incentive models for wind and solar energy solutions and micro energy solutions & e-mobility grid solutions (GER)
- Initiated to work with many academics to develop common PSS ontology
- Few opportunities for blue sky research in this area (UK)
- Off-shoring and loss of R+D: Tax policy, trade policy & lack of skilled workforce (USA)
- National big picture initiative missing, EU and global research collaboration limited too (GER)
- Lack of funding

**Business Capability**

- Several industry companies are interested in Functional Products/PSS (Capability, Sweden)
- Technology for Life Extension for Systems
- Irrelevant demands from the customers
- Coping with the information explosion and for so many years! (UK)
- No end to quality improvement (Kaizen) (NL)
- Complete supply network development (UK)
- Defence acquisition model is broken – what replaces it? (..for services) (UK)
- Business transformation needs visionary individuals in decision making roles – e.g. R-R Des Evans at MAN trucks, not the norm even where PSS makes sense (UK)
- Moving from an overhead heavy business to a 'lean' overhead service business (SLEVS UK)
- Multi-platform engineering service. New business sector?
- Good examples to prove advantages of PSS may not be enough (Threat Sweden)
- Acting in the global context, not resource independent (Knowledge into material energy) Sweden
- Long-standing historic views on asset ownership and maintenance responsibility inhibit radical changes toward integrated PSS delivery.
- Mindset in industry (Sweden)
- SMEs in the supply chain highly Impacted

Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

- Off-shoring of manufacturing – loss of high-wage middle class jobs (threatens health/SME of middle class (USA)
- Ownership outside country: Global – general (UK)
- Too much focus on large companies (Sweden)
- Maturity shifting gear from largely ‘bespoke’ services to commoditized services with bespoke ‘feel’ in defence services (UK)
- Increasing Media scrutiny – individual service events attract disproportionate media coverage. Reliability must be exceptional to avoid adverse publicity (UK)
- Analyzing (with confidence) service properties with surety of outcome (eg safety security agility etc) as well as ROI (UK)
- Growing needs in understanding Global consumers. Extend Life Cycle of product in the global contrast (USA)
- Transferring risk to industry for long-term sustainment of equipments
- Low customer appreciation of PSS models
- What does the exploitation path look like for service research – crossing the ‘valley of death’ (UK)
- Decline of basic capacity and capability (UK)
- Global and universe local culture essential
- Such big changes were already revised twice. No continuity, limited understanding of the challenge.
- Single countries too small to maintain key capabilities

**Society**

- Longevity of product – working life of people
- Aging population – support/caring for
- Integrating the social and technical
- Demographic change – Assisted living, medicine technologies & new work systems
- Increasing needs in alternative energy and low-carbon products. Changing needs on service.
- New energy mix without nuclear power. Sharp increase of renewable energy and major infrastructure update/upgrade
- Society gets older (low birth rate, baby boom, hitting 50+, long living expectation) Major challenges to provide engineering workforce in sufficient time
- Getting the best out of older people – intelligence
- Incentive models and funding not sufficient. Politicians are over whelmed with the challenge.
- Blaming game rather than solving issues
- Seriously considering new on the job academic education programs to maintain skill set mix

**Competitiveness**

- NL competitiveness
- Competition from low cost economies (UK)
- Competition for materials, energy and water (UK)
- Key performance indicators for measure the performance of PSS (SWEDEN)

- PSS Sale techniques

### **Case Studies**

- Sweden has a good portal to do deep PSS Studies e.g. access data (SWEDEN)
- Acceptance of PSS (UK)
- Lack of studies that really show the industry the real potential (pros and cons) of PSS (SWEDEN)
- Companies are sometimes to reveal what they are dying to e.g. Their competitors (SWEDEN)
- Lack of time from the industry partners to join projects. Works 100% to run ongoing projects
- How to gain (search, learn and find) EXPERIENCE in times where turnaround time of events shortens? (SWEDEN)
- Many case studies undertaken to understand issues and creating awareness (UK)
- Quantitative case studies of industrial PSS examples
- Research initiatives in IPS<sup>2</sup> haven't yet found a way to engage all stakeholders in an inclusive fashion and in a way that enables open collaboration.
- Combined case studies within academic community

### **Environment**

- Renewable energy (GERMANY)
- Keeping materials in loops, critical materials
- Environmental sustainability
- Meeting environmental targets (UK)
- Sustainability
- New thinking models for PSS and sustainable manufacturing value creation solutions
- Sustainability may cost more now

### **Design and Manufacturing**

- Maintaining high value manufacturing
- Producing tools and techniques that uses engineering skills and social science analysis
- Designing products and associated services for optimal results
- How to balance value focus and cost focus
- Digital inclusion
- Predicting availability at this early design stage
- Real time modelling and optimization of agile services (UK)
- Service feedback to design and manufacturing
- Integrating service performance feedback in product manufacturing
- Integrating service performance product in design and feedback concept
- Re-newel/innovation in established businesses – balance exploitation and exploration
- Optimization of business processes that deliver services

- Digital economy hubs – Dundee/Newcastle and Nottingham. Aberdeen?
- Media scrutiny – ultra reliability. Design for service – Rolls-Royce (Global)
- Mobility – service knowledge. Capture and delivery research. Cranfield/Rolls Royce. Advanced search for industrial global deployment. Rolls-Royce/Sheffield University
- Multidisciplinary design/design science.
- Design for reliability not solved. Reliability loss comes from improbable events. Hard to get bulk of population to think about statistical universe
- Service knowledge management not solved. Extreme complexity. Data to wisdom compacting issues. Delivery at point of need. Push not pull.

### **Complexity**

- Increasing PSS complexity
- Solving of tomorrows problems today
- Increasing complexity of service offerings
- Dependence on supply – energy and logistics. Lack of resilience
- Complexity is hard to analyse for real examples and demonstrators
- Complexity of systems – interactions between components/sub-systems
- Created frame work to consider important features step by step

### **Not classified**

- End users are not bothered
- Information 'overflow' – how to make use of information & experience generated
- Stressing on tools rather than science
- Integrated Business and product and service dev – solutions development
- Tools for designing sustainable IPS<sup>2</sup>
- Lack of data by which a realistic can be created. Sectionalism both in companies and research communities (JAPAN)
- Tools for optimization of agile service delivery
- Lack of systematic methodology in service systems engineering (USA)
- Manufacturing for service, coupled whole system focus
- Lack of Funding from government. Service research is defined by the traditional OR/CE disciplines. Lack of care for education (USA)
- Not enough understanding and collaboration between difficult subject areas (SWEDEN)
- Lack of technology for PSS
- Unification of what IPS<sup>2</sup> is on architecture level
- Case studies to link business process optimization to service delivery
- Lack of technology for self repair
- Lack of vacancy modelling
- Change national mindset on environmental targets
- Education and training in IPS<sup>2</sup> related subjects still not mature enough to produce people capable of solving real-world challenges (UK)
- Lack of awareness, no recognition (NL)
- Lack of automation in Engineering Services
- Less engagement & support from industry



- (Related to Government short-term week) uneasy standing with whole EU edifice inhibits strategic change nationally
- Lack of strategic foresight. UK elements of global corporations only a small part of the whole government horizons are short/near-term (and ministers are short-lived) (UK)
- Lack of government funding (NL)
- Not enough efforts concerning funding from collaborative projects (SWEDEN)
- Not deep enough knowledge (research) in all parts of PSS/FP (Sweden)
- User involvement and validation of solutions
- An integrated PSS design tool
- Who will be the PSS design system vendors and what will they sell?
- Availability of researchers who can work across disciplinary boundaries
- Refocus engineering education on through life support
- Relatively high cost/lower output results from multi-disciplinary working
- Barriers – industry added cost perceptions. Cultural.
- Barriers – lack of tools for industry – strategic framework and migration strategic
- NL: Existing production, capacity.
- NL: Produce/business easier
- Being a trusted service provider – what does it mean and how can you tell? (SLEVS UK)
- What's the proposition of PSS? (SLEVS UK)
- Image (poor) of MFG for professional and skilled workers
- UK Groups – Southampton, Aston, QUB and Nottingham
- Knowledge sharing / M.Bertoni et al Lutea (Sue)
- Functional product development
- Visualization of PSS & Value / FPD & LTU
- Attempts to influence schools to teach appropriate skills/knowledge through national curriculum, universities follow STEM initiatives in higher education (UK PJW2)
- MSc programme in Through Life Services
- Low Cost Competition: Cranfield, German Universities and Danish Universities
- Environmental targets: Cranfield (Steve Evans). Scandinavian PSS Community and Mont and McAlone
- Sustainable PSS
- Methods for fleet, management & monitoring
- Cambridge IFM (UK)
- PSS Business models in building
- Cranfield EPSRC – Through-life engineering services
- EPSRC Centre for Sustainability Cranfield/Cambridge
- TSB Funding EPSRC & Industry collaboration
- Cost Engineering research at Cranfield in PSS – Cost and obsolescence
- Socio-technical centre. Clegg et al (LEEDS UK)
- Methods for handling issues in a PSS offering
- Research groups – Cranfield and IVHM
- PSS Research
- UK Groups – Cranfield, Cambridge, Exeter & Leeds
- Through life engineering Services Centre @ Cranfield
- Supply chain research in services. Service design tools.

Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

- EPSRC Centre in through life engineering services
- PSS Network in research in SWE, LIU, LTU, KTA and BTH
- Business process mining and modelling and optimization research at Cranfield (EPSRC funded)
- Discrete event simulation of engineering services
- PSS Design – Cranfield and TU Delft
- Working with multi-industries across countries to validate the proposed framework (USA)
- MFG Image: The manufacturing institute (National Association of MFGRS – Emily De Rocco)
- Virtual Product Realization
- Models and methods for integrated development of physical products and services (SWEDEN)
- Enabling Engineering Support for PSS LTU
- Spread out knowledge by teaching. Eg students and industry projects
- Cambridge Service Alliance
- Developing tools for supporting PSS design and evaluation such as service C4D and life cycle simulation (Japan)
- Models for implementing PSS
- Visualisation of PSS offerings (SWEDEN)
- Sustainable product development and innovation
- Gout influences research to start national capacity in service as well as products
- EPSRC – KT Box, tool development, Cranfield, Cambridge, Exeter, Nottingham & Bristol
- EPSRC Centre in Industrial Sustainability
- Team based innovation and networked innovation

## **Annex 5 Focused Group Discussions on Identified Key Themes**

### **Complexity**

Why complexity is a problem?

1. Network of suppliers
2. Difficult to understand
3. Difficult to communicate
4. Difficult to predict
5. Difficult to define
6. Difficult to be paid for
7. Difficult to divide work
8. Knowledge is developed in a network. Difficult to share and network changes

Complexity issues

1. Dimensions of complexity
  - a. Interaction between dimensions
2. Systems engineering approach to design
  - a. Tools and techniques - trade offs
3. What is the unit of analysis?
  - Partners
  - Sustainability
  - Contracts – nature of resource
  - Activities - geography of delivery
4. Study of dynamic behavior
  - a. Life cycle analysis
5. How to manage changing customer requirements?
6. Modeling uncertainty and complexity
7. Predictability of a system during life time
8. Standardization – open std, supply chain, obsolescence mgt, less easy to standardize
9. Mapping between Use view and org view
10. Innovation and complexity – diff divers of competitiveness
11. IPS<sup>2</sup> innovation and customer insight
12. How to find use phase feedback for IPS<sup>2</sup>
13. Technology insertion plan dev
14. Value chain – each boundary changes introduce complexity
15. Emergent behavior modeling
16. Incentivisation of supply chain. Avoid loss/lose
17. Relation between Business models of complexity
  - Co creation
  - IP
  - Constraints

### **Design and Manufacturing**

1. Standardization
2. Modularization/architecture/configure
3. Modeling hidden costs – co creation

Industrial Product-Service Systems (IPS<sup>2</sup>): *THINK TANK*

4. True cost modeling with better confidence
5. Concurrent design and products of services – service evaluation is different/trade space not well understood
  - How do you link me to service offers? - Emotional mapping
6. Dynamic cost modeling – complexity input
7. Study of complexity and cost
8. Study of link. Manufacturing processes/tech – service performance (degradation)
  - Service attributes
  - Processes
9. Scheduling and process planning
10. Product and service trade off. During design
11. System integration: Relationships definitions
12. Cost implications for satisfying surprises technology change
13. Human behavior + change
14. Data mining
15. Attitudes of people
16. Longevity of people
17. Capabilities for providing services
18. Understanding risks and costs
19. Legacy for hardware and software
20. Infrastructure – agility
21. State of readiness/measure robustness
22. Information and knowledge capture based on context

Solutions

1. Service simulators: CAVE
2. Training for long terms
3. Gaming for scenarios: GAMES
4. Global architecture development: Boundary OFPSS
5. Capture cost elements
6. Standards development
7. Forecast possible future scenarios

**Business capability**

1. Participating in sys and complexity
2. Can we protect know better using IPS<sup>2</sup> complexity?
3. Revenue split/risk share – co creation of value
4. How many people in comp understand IPS<sup>2</sup> delivery
5. IPS<sup>2</sup> delivery evolution and changing complexity
6. Modular service for customization – complexity mgt
7. Leaving from cross sector case studies

**Test case research approach/case studies**

1. IPS<sup>2</sup>/PSS in a nutshell introduction (2-3 pages to describe the fundamentals of IPS<sup>2</sup> compared to ordinary PO + service)

2. Description of representative case studies which were successful or not! If necessary, disguise the specific names

#### Key elements

1. Distinguish between provider & customer!
2. Capability set per PSS stage or process step (usable for benchmark)
3. Driving value proposition behind the example
4. Stakeholder set up
5. Necessary culture and mind set change
6. Critical skill set
7. Bottom line results
8. New PSS offering

Description of synthetic test case/case studies to reach out to the new borders. Make it possible for all enterprises to participate in these case study discussion

#### Representation types:

1. Document template (by elements or process)
2. Inclusion of media
3. e-learning type out documentation

#### Who should be the main customer of the case study description?

1. Industry management
2. Tech expert
3. Researchers
4. Funding organizations
5. Politicians

#### How to tackle it?

##### 2 possibilities

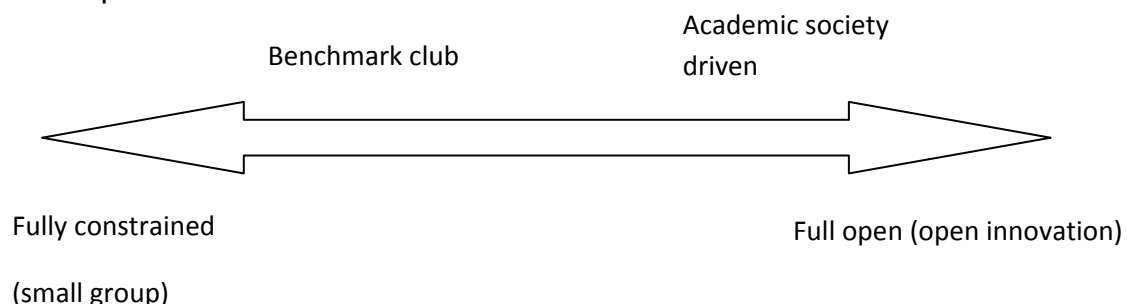
1. Real case study (inc the capability set-up) – industry oriented
2. Synthetic / virtual case study (community driven)

Include industry partners as they are known by the academic groups. Web feedback.

#### Issues/concerns

1. IP & patent differences between the regions
2. Avoid compelling advantages
3. Show cultural sensitivity
4. Who is the face-off body?

#### How open should/could it be?



### Approach A

1. Start small, test and mature.
2. Scale bigger as reasonable.
3. Create a trust level first.
4. Provide capability for value analysis with the academic partners and research centers



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