Information Society

# Technologies for Product Design and Virtualisation

## Final Report on the FP7 Consultation Workshop, 30-31 March 2006, Brussels

# Contents

# Executive Summary

A distinctive European approach should drive the research and development agenda for ICT in the area of technologies for product design and virtualisation. However, radical innovation is needed, not incremental development of the present generation of virtualisation and design technologies. A human-centred approach should be developed, building on Europe's humanistic traditions, which implies that the research agenda is not just purely technological. A strategy based on development of a human-centred design and development method, with human-centred technologies, is needed, and the challenge will be to operationalise the meaning of human-centred within the context of technologies for product design and virtualisation.

Virtualisation is considered to be a critical area for future competitiveness and needs to be applied in all manufacturing sectors, and across the whole product lifecycle. Management of the whole lifecycle is a key issue for handling all the product and service properties through multidimensional simulations that are able to evolve and grow across the whole lifecycle, and to retain knowledge about descriptions and results for future use. Management of the lifecycle is also important to deliver better coupling between different stages (design, manufacturing, modification, disposal).

Collaboration is a basic requirement for product design and development, but this is more than just exchanging information; it also involves thinking processes, and networking between people dealing with a wide range of issues and systems. More needs to be done to improve collaboration, while avoiding a simple continuation of past work. Importantly however, collaboration also needs to be extended to include new disciplines that are becoming increasingly important.

Research efforts need to be directed at the front-end stages in design, to address early concept simulation and evaluation, and to transform the knowledge-time curve, ensuring greater acquisition of knowledge earlier so that better informed design decisions can be taken. The handling of uncertainty in design is also a crucial area. Ways need to be found of keeping design options open for longer, without incurring time and cost penalties, to understand the impacts of different design options in terms of cost, quality, performance, etc.

It is now also necessary to deal with new circumstances. Examples of these are those brought about by entirely new product technologies and concepts such as nano materials and technologies, embedded systems, creation of service elements, etc.

More virtualisation across the whole lifecycle is the way forward, but mixed reality is still important, in particular the notion of *living labs*, for the purpose of idea generation and idea evaluation. This concept will be particularly important to SMEs, providing a means of accessing tools for designing with customers, and testing new product concepts. The development a Europe-wide *living-lab* infrastructure should also be addressed.

Improvements to the models used in design are needed, and new models addressing new technology areas such as nano should be integrated into design environments. This will require identifying solutions for obtaining true multidimensional representations as well as making links at a meta-level between all models to create multidisciplinary simulations.

# Introduction

As part of the very early preparatory consultations for FP7 back at the beginning of 2005, product design in manufacturing was discussed at a workshop held in Brussels in February of that year[1]. Then, as now, there is concern among researchers and industry communities that more needs to be done to improve product design and development capabilities since these have significant potential to help achieve sustainable European competitiveness. In addition to addressing design, this previous workshop also considered several other areas of relevance to product design: innovation networks; human factors; and ICT infrastructures.

Manufacturing is an industry where Europe has strengths in many sectors, and ICT has been identified as an important enabler of both improved productivity and increased competitiveness in manufacturing[2]. Several important ICTs have been identified in this respect, among them technologies to support product design and virtualisation in the design process.

Now proposed for the ICT workprogramme in FP7 is research in the area of *ICT for manufacturing* as part of the application pole, *ICT supporting business and industry*. In relation to product design, integrated environments for modelling, simulation, presentation and virtual production have been identified as one of several possible topic areas to be addressed.

In this context, a further workshop was held in Brussels on 30-31 March 2006, to consult with relevant stakeholders concerning the RTD agenda in the area of technologies for product design and virtualisation. This workshop considered discrete-parts manufacturing, the process industries, and the construction sector.

# Strategic Motivation

## *ICT as an Enabler of Improved Competitiveness*

European manufacturing industries operate in an increasingly difficult competitive environment. In such circumstances improvements to all aspects of a manufacturing enterprise's activities are needed to enhance competitiveness. However there are some activities that provide more opportunities for radical innovation and which are more critical than others are, and product design and development is one of these. In particular, there is tremendous scope for the application of ICT in this specific area, to support both virtualisation through the use of models and simulation, and for the application of other novel ICTs in different stages of the design and development process.

Significant benefits have already been achieved through the application of ICT in the area of virtualisation. The automotive and aerospace industries are both pioneers of the use of these technologies and their main focus has been on using virtualisation to avoid the costs and time associated with constructing physical prototypes. Key to achieving this has been the development and use of models with predictive

[1] Strategies for the Design and Manufacturing of New Products, February 2005, http://www.ims-noe.org/FP7.asp
[2] ISTAG Report on Shaping Europe's Future Through ICT, March 2006, http://www.cordis.lu/ist/istag-reports.htm

capabilities. Simulation has of course played a role in these developments. The process industries have also applied virtualisation, for example to the design of process plants, and other industry sectors, such as construction have begun exploring the potential of this approach. However, in all cases there is wide agreement on the need to extend the use of virtualisation across the whole product lifecycle, from conception, though use, to final disposal.

Using virtualisation in the whole product lifecycle has to be seen in the light of other needed enhancements to the product design and development process. For example, development of tools to support the early feasibility and concept stages of design has largely been ignored, in comparison to the effort devoted to tools for the later more detailed stages of design.

Consequently it is evident that there is significant potential for improvements through the use of ICT in product design and development. However, there is one fundamental issue that needs to be resolved before investing in research and development: defining an appropriate strategy for ICT research and application in this domain.

### *Research Strategy*

Increasingly ICT and many other technologies are no longer limited to a few rich industrialised nations. Traditional entry barriers, such as restricted access to technologies, do not provide the degree of protection against competitors and new market entrants that they once did. Continuing innovation in technologies is therefore needed, but this alone is not enough. Europe needs to develop a distinctive European approach to product design and development: one that competitors in other regions, in particular the United States and the Asia-Pacific region, will find hard to copy. Europe’s long-standing humanistic tradition, manifesting itself in such areas as concern for people and for the environment, may provide a basis for achieving this goal. This humanistic tradition could be Europe’s way towards achieving sustainable competitive advantage. It could also help to enable the interdisciplinary research and design work that will be a characteristic of the future.

Brought-up in a culture where social concerns are evident in just about every aspect of daily life, Europe’s designers and engineers are, relative to their counterparts in the United States and elsewhere, potentially better able to deal with a broader range of issues in the product design and development process. These cultural characteristics are an inherent asset and the challenge, in the context of product design, is how to exploit and to build on this strength for Europe’s benefit, to help differentiate Europe from other regions. The important message is that culture matters, and just following the same avenues that the Americans or Asians are pursuing is not a recipe for success in the longer term.

To move forward it will be necessary to enhance product design and development capability, bearing in mind that it will be crucially important that European manufacturing industries avoid, where possible, the development of circumstances where competition is based on price alone. But it will not be enough to respond by just adding more functionality to products, since in a world where product design and development capability is no longer confined to the advanced industrialised nations, all Europe’s competitors will be doing this. In these circumstances it is necessary to find novel ways to add value to products.

This can be achieved by moving closer to customers, by understanding their needs and aspirations, and by understanding the emotions and other user related responses to product designs and their use, for it is services, functionality, aesthetics, product features, etc. which customer's value that delivers commercial success. Moreover, ways need to be found to involve the customer, either in person or through the use of models, depending upon the context, to address various issues such as cognitive and behavioural aspects. However, Europe's manufacturing enterprises should do this in a way that is different from that which might reasonably be expected by firms in other regions. Otherwise Europe will be caught up in a game of copying other nations' and cultures' best practices, as has been the case over the past few decades, for example with the American inspired computer-aided technologies in the 1980s, and Japanese enterprise practices in the 1990s. Europe needs to take such ideas and modify and improve them in the context of a unique European perspective.

### *A Human-centred Approach*

People, as just about everyone would agree, are central to the success of product design and development, for they bring skills, creativity, knowledge, judgement, insights, emotions, understandings, experiences, etc. to the process of bringing new and improved products to market. But this sentiment has been expressed many times before, and now actions are needed that fully reflect this philosophy; actions that will involve re-appraising some fundamental and taken for granted assumptions about design, and the development of radically new and different product design and development processes.

Key to achieving this goal and operationalising the above perspective will be three people-oriented principles:

- Users, customers, citizens, and others need to be brought into the product development process. This should not just be based on using people as subjects for testing out ideas, concepts, and designs. It is of course important to validate product ideas from a user perspective, but users can bring more than just their views on a particular idea. People are a rich source of information about emotions, values, biases, etc. that can matter when designing products, and they are also a source of ideas. Design by, with and for users is the way forward, but in different ways depending on the context.

- Human-centred technologies for products. In many circumstances people as users of technology-based products are expected to adapt to the needs of the technology, but now, with increasing use of embedded intelligence, it is feasible to conceive and implement a new relationship where the technologies adapt to the people who use them. Additionally, there should be sufficient freedom to explore different ways of using the technologies for those inclined in this direction.

- Human-centred technologies for designing products. To address the complexities of the emerging and, to some extent, as yet unknown future product design and development requirements, human-centred technologies are also needed by designers and engineers involved in this field of activity. These people too are users, and must be treated as human beings with needs, emotions, and so forth.

### *The Need for Enhanced Product Design and Development Capabilities*

It is also evident that enhancement of product design and development capability is needed to better deal with the increased complexity of the product-use environment. This complexity comes from several sources, including regulation, user requirements, changing social conditions, new technologies, sustainable development, the growing importance of services, etc. But, fundamentally, product design and development is an important part of the innovation process. Thus improved innovation capabilities in enterprises can be achieved through enhancements of product design and development capability, proving a basis for: continuing improvement of established product concepts; bringing new product concepts to market; and creation of new markets and new opportunities.

Evidently the research agenda therefore must not solely be concerned with technology, as social, organisational, and human issues need to be considered in an interdisciplinary manner: technology alone will not be enough[3].

## The Present Circumstances

The workshop identified a number of limitations in product design and virtualisation:

- Virtualisation has been pioneered in the automotive and aerospace industries to reduce the time and cost involved in producing physical prototypes. However, virtualisation is still not widely and routinely used in all manufacturing sectors, and tends to be limited to larger enterprises. SMEs are not significant users of the technologies.

- There is a heavy focus, especially in the engineering communities, on models, but these often have their main role in the back-end of the design process. There is insufficient awareness that designing is not modelling.

- The current base models are still limited, particularly as a result of the digital representations that are fundamental to computer-aided design tools. There is insufficient intelligence in models; for example they lack information about the important design intent.

- Models used in design, generally, do not encompass the human being.

- There are also only a limited number of so-called *living labs*, and insufficient appreciation that they can serve a dual purpose: idea generation and idea evaluation.

- There are no ambient intelligence based design facilities for designers.

- There is still only a limited theoretical and philosophical foundation for design.

- The hardware used in design is still too complex. This applies to human-machine, interfaces, human-computer interfaces, and virtual reality systems.

[3] ISTAG Report on Strategic Orientations for Information and Communications Technologies Research in Europe, September 2004, http://www.cordis.lu/ist/istag-reports.htm

- The assumption behind many design tools is that they are black boxes, and that all that is necessary is to enter data and collect the results; this is often an inappropriate assumption.

- Tools used in design are fragmented with little consistency of data, information and knowledge across the different stages of design.

- There are limited tools available to evaluate lifecycle scenarios in the early design stages. Generally, there are few tools and methods to support the early phases of design (both generative and evaluative tools).

- Capabilities to evaluate and accommodate, in the early stages, diversity in its multiple manifestations, as well as handling uncertainties, are very limited.

- Collaboration is fundamental to design, but many issues still remain to be addressed.

## Major Trends Impacting Product Design, Development and Virtualisation

There are a number of major trends impacting product design, development and virtualisation:

- There are greater expectations from customers for products and services that better match their needs and aspirations.

- The emotional dimension of products is assuming greater significance and there is evidence that forward thinking companies are hiring a more diverse range of disciplines to work on product design and development, for example, psychologists, sociologists, and anthropologists.

- Other market regions continue to exert competitive pressure to perform better in all aspects of business operations, including customer focus, which is very important in the context of product design and development.

- With this globalisation comes the wider spread of product design and development capabilities, and a rush to add more functionality to products. In these circumstances, adding functionality alone will not enough to compete.

- Standards are also an important driver with a trend towards development of global standards. There is also growing appreciation of the need for standardisation processes that will enable standards to evolve through use, rather than through the old formal time-consuming way of setting up committees.

- Developments in software engineering such as model-driven software architecture, software factories etc., may offer some insights and useful approaches than can be applied more widely in other design contexts.

- Several considerations are placing additional demands on designers and engineers:

- New product concepts are continually emerging and this is starting to create some novel difficulties, such as asking customers about new product concepts that they have no conception or experience of.

- Future products may not be fully defined at purchase, but will evolve with users as needs change and new developments emerge.

- Increasingly, breakthrough technologies, such as nanotechnologies, mechatronics, and others, are being used in products.

- The need to address such issues as product disassembly, component re-use, design for the creation of services, etc. are further elements in the complexity equation.

- ICT is set to become a fundamental component of products and services.

- The emergence of a new (younger) generation of people already accustomed to digital technologies means customers will be more capable of exercising judgements about the perceived quality of digital products, and are likely to be a source of ideas that can be used to create commercially successful products.

# Desired Circumstances in 2015 – The Vision

By 2015 many of the deficiencies and problems identified in the above sections should have been resolved, and the trends accommodated.

### *A Distinctive European Approach*

It will be important in the available time, to have more fully defined a distinctive European approach to product design and development. The different professions involved in design should be much more aware of the whole process and of the issues involved, and that, as a creative process, design is more than a purely rational scientific activity. However, having said this, the foundations of design, in terms of theory, philosophy, tools, and models should have been significantly improved by 2015.

### *Enhanced Models*

With regard to models, these should be better and more intelligent, and provide details of design intent. They should provide more predictive capabilities to help reduce the need to produce expensive and time consuming physical prototypes. Models for breakthrough technologies, such as nanotechnologies and embedded systems, should be much improved and be in wide use by 2015. Modelling should also better encompass material and component properties and variations in these, and help to identify hidden impacts such as increased stresses, temperatures, etc. Importantly, models and tools to address service creation, environmental impacts, safe disposal, recycling etc. should be part of the design environment. These models should be capable of supporting simulations and be based on common approaches. All the different types of models in use for different purposes should also be linked together at the meta-level and support multidisciplinary simulations. Models should support interaction with users, both real, simulated and through virtual environments.

Enhanced context aware and multidimensional models of humans are a key factor, and should provide accurate prediction of human behaviour during interactions with simulated systems and services. Models should also be easier to use.

### *Involvement of People*

Involvement of people as users, customers, critics of products should be extensive and routine by 2015. So-called *living labs* should have advanced to a high level of sophistication and be used for both idea generation and idea evaluation. In addition, ambient intelligence based design facilities for designers should have been developed and widely deployed. These design facilities should also assist with the non-intrusive collection of information about human behaviour. Tools should provide the means of capturing the various uses of products as well as the diverse characteristics of users. Novel knowledge-based design tools that will allow vague and fuzzy user requirements to be translated into specific design requirements should be available. Simulation and mixed reality tools should also be provided to support this activity.

### *Design Tools*

Interaction with computer-based models should also have moved forward significantly from the mouse, keyboard, screen, glove, helmet and visor of the present day, to more natural, easy to use and realistic means of interaction. Interaction with design environments should be based on all senses, as well as brain-computer interfaces. Three-dimensional modelling should be less complex and should be widely used by SMEs. Designers should have full control over the tools that they use. Tools should no longer be black boxes and it should be possible to interface with them in depth. There should be a seamless interplay between traditional and new devices, and mobile devices should provide visualisation, communication, and easy access to information. Easy and intuitive set-up of virtual environments by non-experts is another capability that needs to be achieved.

### *Interoperability*

The fragmentation associated with today’s models and tools should have been overcome. Interoperability, and consistency of data, information and knowledge, across the different stages of design, needs to have become a taken for granted aspect of design environments. There should be user-driven, shared, and selected access to information. Nomadic environments and self organising architectures need to be in place to overcome the bottleneck of resource, service provision and information management for *ad-hoc*, collaborative and interoperable information sharing.

### *Front-end Focus*

Early evaluation of lifecycle scenarios, and capabilities to evaluate and accommodate, in the early stages, diversity in its multiple manifestations, as well as handling uncertainties, should have become advanced and provide real competitive advantage. Simulation tools to support concept evaluation should also have been developed and should help designers to find optimal solutions at an early stage. Tools and methods to support the early phases of design (both generative and evaluative tools) should be as widespread and accepted by 2015, as the corresponding tools for the later stages of design and development, are today. These front-end tools should result in a reduced need for redesign during later stages of the design process.

### *Design Environments*

Design environments need to be self-organising and able to adapt to different sectors and industries. Collaborative design environments should also provide facilities for modelling, decision-making, and client-oriented simulation. These design environments should also be location and context aware. Filters that direct selected information and knowledge to different groups depending upon their needs and activities should be provided. It should be possible to add new tools and devices in a simple plug-and-play manner. Collaboration should have moved forward beyond the videoconference mindset of today, and should be the means by which it becomes possible to work together on product and process representations, across organisational and enterprise boundaries. Collaboration needs to be based on virtual co-location, and multi-user, multidiscipline and immersive environments. Tools to help collaborative teams to reach compromise solutions, or to resolve disagreements between competing ideas, should have been developed. The problems of how to protect information in circumstances when a supplier works for competing customers should have been resolved. IPR protection should be built into design environments.

### *Lifecycle Management*

Full lifecycle management should be possible by 2015. In addition to the technical data management perspective, product lifecycle management for all design information and analysis results should be possible. New tools are needed to manage both the product architecture and the process architecture, and to manage the interaction between the different teams involved in the design process. Tools for multiple views of single representations should be available along with models to support the program management of the different teams; models that address schedule, time, costs, and balanced workload between teams.

### *Knowledge and Analysis*

Knowledge capture needs to be more widespread, including knowledge transfer to other teams and projects, and also across the lifecycle, for example from use to design. Extraction and inter-linking of knowledge from different simulation results and domains, for example new insights into product behaviour, that is to say, implicit knowledge, need to be implemented.

Simulation frameworks should have evolved into analysis frameworks that also encompass simulation, but in a more comprehensive way. These analysis frameworks should cover areas such as cost analysis, scheduling and feasibility. Comprehensive engineering platforms should have been developed that enable sharing of information between disciplines. Knowledge sharing and decision-making between experts and customers should also be supported.

## Conclusions and Recommendations

The workshop concluded that technologies for product design and virtualisation are strategically important for European competitiveness. However, a radical transformation of product design and development is needed, based upon a distinctive European approach, with ICT providing the key technologies to enable this innovation. The key conclusions are:

- The above will be very challenging and implies addressing a larger ICT research agenda, involving contributions from the humanities.

- Design tools should not be developed as black boxes.

- Design models and tools should provide a much more accurate representation of the behaviour of the product.

- The fundamental limitations of computer-based representations need to be recognised and improvements made by addressing basic issues such as computer representation of real numbers and the uncertainties of geometric computation.

- A multi-sector approach that can identify common issues, requirements and solutions would seem to be appropriate.

- Perceptual engineering needs to be addressed as a multidisciplinary challenge, and design, engineering and customer-driven tasks have to accommodate both technological requirements and human aspects such as cognitive, perceptual, psychological and social issues in relation to areas such multi-modality, knowledge, etc.

- Given the numerous areas and issues that need to be tackled, the use of an Integrated Project, supported by some focused STREPS would probably be the best way forward.

- SMEs should not be forgotten. Efforts need to be directed at improving the design and development capabilities of such firms, as well as developing a Europe-wide infrastructure to assist SMEs to use emerging research results and to adopt good practices. SMEs are unlikely to want to develop their own *living labs*, so such facilities need to be provided as a service.

- As part of the research and development, there should be an effort to explore further the concept of a distinctive European approach to product design and development, with ideas such as human-centred technologies and processes being operationalised within the context of different design and product scenarios.

In terms of research priorities the workshop identified the following:

- Methods and tools to support customer involvement in the design process should be covered by the first call.

- Within the first call (and also later calls) multidisciplinary consortia must be fostered, and both multidisciplinary and interdisciplinary research undertaken involving the traditional engineering domains and the human sciences.

- In the first call there should be a focus on the early feasibility and conceptual stages of design, and tools to support these stages. Examples might be tools to evaluate lifecycle scenarios at the early stages. Generative tools are also needed for the early stages of design.

- Evaluation of diversity, in its multiple manifestations, in the early stages of design, and the development of capabilities to handling uncertainty, for example by enabling design freedom to be maintained longer by keeping options open, without time and cost penalties, are both priority requirement that need to be addressed in a first call.

- Improvements to models and their linking at the meta-level and the capability to use all models to generate multidisciplinary and more accurate simulations should be addressed. This area could be addressed in a second call.

- The fragmentation between tools, between models, and the consistency of data, information and knowledge across the lifecycle is also an important issue to address in a second call.

- Physical devices used in design need to be improved and new interaction technologies developed and deployed. This includes the development of ambient intelligence design facilities for designers. The development a Europe-wide *living-lab* infrastructure should also be addressed. Interoperability between all design and development tools needs to be ensured so that data generated by one tool and can be used in other tools. All these topics can be covered in a second call.

- Lessons learned from software engineering, from the application of model-driven architectures and software factories, should be assessed for their possible relevance in wider design contexts. This aspect could be addressed much later in FP7 to allow time for good practices in the area to become more stable and widely disseminated.

# Appendix 1 – Workshop Agenda

**Venue** Avenue de Beaulieu 24,
Day 1 in room 0/84 and 0/70**,** Day 2 in room 0/83 and 0/70

**DAY 1**

*Day 1 Chair: Georgios Tselentis, INFSO/F4*

13.00 Registration & sandwich lunch (BU24) (room 0/70)

14.30 Why this Workshop?
*Ulf Dahlsten, INFSO Director, Emerging Technologies and Infrastructures (tbc)*

14.45 ICT for Manufacturing in FP7
*Erastos Filos, INFSO, Components and Systems Directorate*

15.00 Keynote speeches (1) - Set the scene

*Prof. Marco Taisch, Politecnico Milano*

Conclusions of the workshop "Strategies for the design and manufacturing of new products"

*Prof. Dimitris Kiritsis, EPFL*

"R&D Challenges for Product Design and Virtualization"

15.30 Keynote speeches (2) - Industrial Prospectives

Aerospace –
*Dr. Yves Baudier, EADS*

Automotive –
*Dr. Giuseppe Varalda, CRF and member of EUCAR*

Construction -
*Dr. Souheil Soubra, CSTB*

Process Industry -
*Dr. Martin Ollus, VTT*

16.15 Tour de table: presentations of other participants

16.30 Coffee Break

16.45 Participants Brainstorming in **Parallel Groups A and B** (rooms BU24 0/84 and 0/70)
*- Where do we stand today*
*- Major trends that may impact the field*
*- Where do we want to be in 2015*

18.15 End of Day 1

20.00 Dinner

**DAY 2**

*Day 2 Chair: Teresa De Martino, INFSO/F4*

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|---|---|
| 09.30 | **Group A Reporting** |
| 09.50 | Discussions: comments and **constructive criticism from Group B** |
| 10.30 | **Group B Reporting** |
| 10.50 | Discussions: comments and **constructive criticism from Group A** |
| 11.30 | Coffee break |
| 11.45 | Consolidation discussion*, Paul T. Kidd, Rapporteur* |
| 12.30 | Sandwiches lunch |
| 14.00 | Wrap-up, Report structure, *Paul T. Kidd, Rapporteur* |
| 15.00 | Close |

# Appendix 2 – Workshop Participants

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|---|---|---|
| Jamil Appa | | BAE |
| Yves Baudier | | EADS |
| P-Henri Cros | | CERFACS |
| Holger Graf | | Fraunhofer IGD |
| Paul Hekkert | | Technical University Delft |
| Ioannis Karaseitanidis | | NTUA |
| Dimitris Kiritsis | | EPFL |
| Patrick Martin | | AIP-Primeca |
| Alain Massabo | | Think3 |
| Martin Ollus | | VTT |
| Jivka Ovtcharova | | University Karlsruhe |
| Christophe Ramshorn | | |
| Souheil Soubra | | CSTB |
| Stephan Rudolph | | Uni Stuttgart |
| Marco Taisch | | Politecnico di Milano |
| Giuseppe Varalda | | CRF & EUCAR |
| Teresa de Martino | | European Commission |
| Georgios Tselentis | | European Commission |
| Erastos Filos | | European Commission |
| Paul Kidd | Rapporteur | Cheshire Henbury |