ISTAG Report on Experience and Application Research

"Involving Users in the Development of Ambient Intelligence"

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"Involving Users in the Development of Ambient Intelligence"

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1 Executive Summary

Realising the vision of ambient intelligence poses challenges for Europe's research and development (R&D) community. Successful R&D in ambient intelligence needs a new approach based on the involvement of those that will be affected by the presence of such systems. This observation also applies to the later activity of developing and introducing new commercial ambient intelligence products and services.

There is a belief that ambient intelligence will not be widely accepted and used, unless users are deeply involved in the shaping of these technologies. Developers need to do more than just bring new technologies to users to ask them what they think. A novel two-way relationship needs to be established between those that develop new technologies and those that use them. Users should be integrated into the processes of R&D, and new product creation and introduction. Users should be part of the innovation process, a source of ideas, and not just a resource to evaluate ideas generated by professionals.

Experience and Application Research has been proposed as a means of addressing the challenge of creating a human-centred approach to R&D in ambient intelligence. Experience and Application Research involves research, development and design by, with and for users. It also covers research into methods and tools to enable this. A novel aspect of Experience and Application Research is that it involves users in all stages of R&D and all stages of the product development lifecycle, not just at the end phases as, for example, in more classical field trials or user testing of products.

Experience and Application Research can involve:

- *user-related research* in interaction technologies for ambient intelligence. Research on design processes for ambient intelligence. Development of methods for usability testing;
- *development of prototypes* for ambient intelligence, based on the results of basic research. Integration of these prototypes and of existing prototypes into quasi-realistic user environments (for example, laboratories for living or work);
- *usability tests* of ambient intelligence components in quasi-realistic environments;
- *feasibility tests and validation* of ambient intelligence solutions in field environments (field trials).

The research can be undertaken in physical or virtual centres, via co-operative networks, or through field trials. There are three possible types of centre. The first is Science and Technology Centres, where basic research is conducted on component technologies for ambient intelligence. The second is Feasibility and Usability Centres, where basic research is conducted with users on component technologies and systems for ambient intelligence and where components are integrated into real user environments on a small scale and usability is investigated. The third type of centre is Demonstration and Evaluation Centres, where promising prototypes are fully integrated into large-scale demonstration facilities and shown to a large number of users. Emphasis is placed on involving users in new and different ways to that which is now perceived as best practice in user involvement.

This research can provide the infrastructure to enable the involvement of users in turning the vision of ambient intelligence into reality. Importantly, the research can also provide an opportunity to develop a distinctive European approach: one that competitors in other regions, in particular the United States and the Asia-Pacific region, will find hard to copy.

Experience and Application Research can therefore be seen as a means of furthering the development of and for realising the vision of ambient intelligence. The requirements for realising the vision are multidisciplinary approaches and research, and evaluation and demonstration activities involving the people who will use ambient intelligence systems. Experience and Application Research would be based on such requirements, and would also provide a structure for existing activities, and support to enable these activities to develop.

The proposed research has a number of potential benefits for European industry and Europe's citizens. The research can help to reduce the barriers to the development and take-up of ambient intelligence. Importantly, it can also help to improve industrial competitiveness and provide support for emerging industrial practices. Experience and Application Research can be a platform for enabling developments in new ways of undertaking research. It can also provide a service to industry, by supporting small and medium size enterprises (SMEs) and delivering improved education and training to the European workforce. The nature of the activities will also contribute towards standardisation and assist with technology integration. Last, but not least, the research can provide a means for involving Europe's citizens in R&D.

Experience and Application Research has the potential to considerably develop the activities of the IST programme in a number of ways. It will enhance the systems approach, reinforcing consideration of an aspect of information and communications systems, namely users, which is often not given sufficient attention. Furthermore, Experience and Application Research, being based on the involvement of users, will help to improve research focus, because poor ideas and those that have limited market value will be more quickly identified and eliminated. Finally, Experience and Application Research will help SMEs by providing opportunities for small firms to integrate their products with others, within an existing infrastructure. Centres of excellence in Experience and Application Research could also form hubs around which larger firms could build a network of innovative smaller companies.

Experience and Application Research is a bridge between the world of researchers, developers and designers on the one side, and the world of users on the other. The proposed work is founded on the understanding that users vary, both across Europe, and across the globe. Furthermore, Experience and Application Research provides the means of developing closer relationships with customers, and applying emerging industrial practices such as customisation and co-creation with customers. Location is therefore critical to success. To understand European users and to create closer links with European customers, Experience and Application Research needs to be undertaken in Europe: it cannot be done in China or India or other such countries.

The proposed Experience and Application Research will create opportunities to develop centres of excellence in user-related ambient intelligence research, development, and design activities.

Experience and Application Research would be multidisciplinary and offer significant opportunities to develop superior ambient intelligent systems: world-class products for a global marketplace. Experience and Application Research will also be interdisciplinary and

thus offer the potential to open up entirely new avenues of research in ambient intelligence, for example, human-centred ambient intelligence based on human-computer co-operation and intelligent relationships between people and computers.

This is the potential for Experience and Application Research. It can provide a multidisciplinary environment for the development of ambient intelligence products and systems, with all the benefits that multidisciplinary brings. But it can also be interdisciplinary research, creating and exploring new visions and undertaking pioneering research.

Collectively, therefore, these novel and exciting aspects will help to make Experience and Application Research a field where people will want to contribute, thus increasing the attractiveness of Europe to young researchers as a place to pursue a career in information and communication technologies (ICT)-related research.

Experience and Application Research should be undertaken with support from the IST Programme. There are 11 specific recommendations about Experience and Application Research.

Recommendation 1: support Experience and Application Research through centres and field trials

Experience and Application Research should be undertaken within the context of centres and field trials. Field trials can be either small or large-scale. There should be two types of centre: Feasibility and Usability Centres, and Demonstration and Evaluation Centres. The focus of Feasibility and Usability Centres should be on advanced concepts, technologies and prototypes that are typically five or more years away from the market, and these centres should undertake studies with small numbers of people using one-to-one data collection, directed at identifying patterns, relationships, etc. The focus of Demonstration and Evaluation Centres should be on technologies and prototypes that are close to market, and these centres should address many people in less depth using mass data collection techniques to identify trends.

Recommendation 2: create synergies

It is fundamentally important that the centres and field trials work together to create synergies. These can be achieved through common use of standards for integration, sharing methods and tools, exchanging best practices, sharing data, working together to create common platforms, exchanging people, having common working groups, sharing tasks, and undertaking cross-border studies etc.

Recommendation 3: ensure the wide community has access to results

To ensure wider take-up of the results of Experience and Application Research, access by a wider community to results, methods and tools, background data etc, must be an obligation for projects. A database containing methods and tools, background data, and other results, should be created, with open access guaranteed.

Recommendation 4: support mobility of researchers

Europe has an established tradition of working with users, especially in the Scandinavian countries, although the skills and knowledge base is fragmented and under-used. Experience and Application Research will enable this existing expertise to be developed and disseminated more widely. To facilitate this, opportunities for transferring expertise through mobility of researchers should be provided.

Recommendation 5: use additional criteria for proposal evaluations

The success of Experience and Application Research depends upon a number of features. These are related to user involvement, interdisciplinary approaches, use of appropriate methods and tools, adopting a new approach to research, wider impact, availability of infrastructure, and coherence with other aspects of the research. Thus there is a need to apply additional criteria beyond the standard ones used for proposal evaluation.

Recommendation 6: provide funding within the context of Work Programme 2005-06

In the short-term, Experience and Application Research should be addressed within a few selected Strategic Objectives in the context of Work Programme 2005-06. If the work is successful, Experience and Application Research should be extended to a broader range of research in Framework Programme Seven. In the short term, the Strategic Objectives *Applications and Services for the Mobile User and Worker*, and *eInclusion*, provide the best platform for developing Experience and Application Research within the IST Programme.

Recommendation 7: build on existing centres and expertise

Most existing centres and skills are based on the home or office of the future. Projects should tap into this existing infrastructure and expertise and build on it, but in the context of Work Programme 2005-06 there should also be an effort to expand beyond home and office applications, for example, into areas such as consumer electronic systems for cars and for the home.

Recommendation 8: use funded projects to build a bridge to Framework Programme Seven

Funded Experience and Application Research projects in Framework Programme Six should undertake feasibility studies and road mapping exercises to establish what should be addressed in Framework Programme Seven.

Recommendation 9: address interdisciplinary issues

Experience and Application Research is a long-term activity which is focused on interdisciplinary work. Given the importance of the interdisciplinary aspects of Experience and Application Research, there is a need to consider Experience and Application Research from this perspective and how this can be developed in Framework Programme Seven.

Recommendation 10: research user-related methods and tools for ambient intelligence

Ambient intelligence provides a new set of circumstances for the use of user-related methods and tools. Research into user-related methods and tools for ambient intelligence therefore needs to be undertaken. A number of ambient intelligence applications should be investigated and research work undertaken to determine and test the most appropriate methods and tools. This will also help to identify which methods and tools are missing.

Recommendation 11: develop centres of excellence

Centres of excellence in Experience and Application Research should be developed. These will help to maintain and to improve the attractiveness of Europe as a place to undertake ICT-related research.

2 Introduction

Experience and Application Research involves research, development and design by, with and for users. It also covers research into methods and tools to enable this. Experience and Application Research can be undertaken in physical or virtual centres, via co-operative networks, or through field trials. An important novel feature of Experience and Application Research is that it involves users in all stages of R&D.

Experience and Application Research is a means of furthering the development of and for realising the vision of ambient intelligence. The requirements for realising the vision are multidisciplinary approaches, and research, evaluation and demonstration activities involving people who will have to use ambient intelligence systems. Experience and Application Research will also help to provide a structure for existing activities, and the means to enable these activities to develop.

Successful R&D in ambient intelligence needs a new approach based on the involvement of those that will be affected by the presence of such systems. This observation also applies to the later activity of developing and introducing new commercial ambient intelligence products and services.

In the language of developers, those affected by the presence of ambient intelligence are commonly referred to as users. However, it should not be forgotten that these users are human beings. And humans are complex. They have needs and preferences, fears and worries, likes and dislikes. They can behave in both rational and irrational ways. They have physical and mental characteristics, and emotions. People are both individuals and members of larger groups. And the point is that all the above vary among individuals, groups, nations and cultures. There is no standard user.

The age of the mass-produced standardised product or service has already passed. While many commodity items will continue to be produced in large quantities, the future will see a greater focus on customisation of products and services. This point alone could serve as a justification for bringing potential users into the process of R&D and new product creation. But there is more at stake than businesses getting closer to their customers and producing better products.

Some people have expressed the view that ambient intelligence will not be widely accepted and used, unless users are deeply involved in the shaping of these technologies. And this is not just a matter of *show and tell*. Developers need to do more than just bring new technologies to users to ask them what they think. A novel two-way relationship needs to be established between those that develop new technologies and those that have to use them. Users should be integrated into the processes of R&D, and new product creation and introduction. Users should be part of the innovation process, a source of ideas, and not just a resource to evaluate ideas generated by professionals. This is a novel and challenging task.

The above implies a profound change in the processes used by researchers and developers. Industry will need to adopt new ways of working and also to deal with culture change. The challenges are significant, but so is the potential payback measured by competitive advantage in global markets and the social acceptance of ambient intelligence.

Experience and Application Research has been proposed as one means of addressing the challenge of creating a human-centred approach to R&D in ambient intelligence. The Information Society Technologies Advisory Group (ISTAG) first highlighted the need for Experience and Application Research in September 2003. The concept emerged as a recommendation (see Appendix 1) from a working group that was tasked with defining future strategic research directions for the European Commission's Information Society Technologies (IST) research programme [1]. As a result, the ISTAG set up a new working group to examine and define in more detail the concept of Experience and Application Research. The mission of the working group was to:

- elaborate further the concept of Experience and Application Research including objectives, approach, topics that could be covered and who should be involved, including which users;
- consider existing initiatives or pilots for Experience and Application Research and lessons to be learnt from them;
- analyse the structuring aspects of Experience and Application Research (within the European Research Area and Enlargement context), for example, Experience and Application Research achieved through *distributed centres* or *single centres*;
- examine the means to support Experience and Application Research, including the potential instruments to be used at the Community level (links with Integrated Projects, Networks of Excellence, other instruments);
- consider the criteria to select Experience and Application Research projects (for European Union funding).

The report is organised as follows. The first section, *Opportunities and Benefits*, deals with the matter of the justification for Experience and Application Research. This addresses the benefits for European industry as well as Europe's citizens. The second section, *Experience and Application Research*, provides some details about the concepts. Examples are presented, along with a description of experience prototyping that forms a central component of the approach to user involvement. The third section, *Detailed Proposals*, describes the methods and tools that can be used within Experience and Application Research, and details the suggestions for organisation, field research, application domains, funding options, selection criteria for evaluation, methods and tools, and software and interface requirements. In the final section, conclusions and recommendations are presented.

3 Opportunities and Benefits

European industries operate in an increasingly difficult competitive environment. There are greater expectations from customers for products and services that better match their needs and aspirations. Other market regions continue to exert competitive pressure to perform better in all aspects of business operations, including customer focus. Furthermore, new product concepts are continually emerging and this creates some novel difficulties. Applying tried and tested market research techniques to customers who lack any knowledge of proposed new product concepts is not easy. Moreover, there is a developing view that future products will not be fully defined at purchase, but will evolve with users as their needs change and new developments emerge.

One aspect of the vision of ambient intelligence is the focus on placing users at the centre of technology and product development. Interaction with ambient intelligence will be through natural and intuitive interfaces. This vision provides an opportunity for European industries to become much more customer focused.

It is true that the subject of user involvement in technology development is not a new idea. It has been advocated many times in the past in several different contexts. However, never before has there been such an imperative to involve users in all stages of research, development and design of new technologies, products and services. The moment seems to have arrived for this approach to become a normal business practice. Business and social needs point to this as a new requirement. The time and the circumstances appear to be right for a concerted effort in Europe to help industry to adopt a human-centred approach to researching and developing ambient intelligence, and the products and services that will be based on the emerging technologies.

Experience and Application Research is a means of achieving this user participation. There will be a number of benefits to Europe from undertaking this type of user driven research:

- reducing the barriers to the development and take-up of ambient intelligence;
- improving industrial competitiveness;
- supporting emerging industrial practices;
- developing new ways of undertaking research;
- supporting SMEs;
- delivering improved education and training to the European workforce;
- contributing towards standardisation activities;
- assisting technology integration;
- involving citizens in R&D.

3.1 Reducing the barriers to the development and take-up of ambient intelligence

Not everyone is an early adopter of new technologies. Some people like new gadgets or having the latest technologies in their cars, homes and workplaces. However, many people are either suspicious of new technology, or in some cases frightened by it. Concerns about security, safety and privacy are widespread. Europeans in particular seem less inclined to accept new technologies that their counterparts in the United States and the Asia-Pacific region.

Furthermore, some groups in society have special needs, for example, profoundly deaf people, elderly people and so on. The understanding of these special needs is still limited, and design that takes these needs into account is not as widespread as it should be.

Something needs to be done about all these problems. There is a danger that they will become barriers to the adoption of ambient intelligence in Europe. At best these barriers may appear in the form of reluctance of people to buy and use products and services based on ambient intelligence. Other market regions may then see this as an opportunity to develop better products and thus take the lead in the development and implementation of ambient intelligence. At worst, people may become actively disposed against the concept of ambient intelligence, as happened with genetically modified crops, and then seek to have developments stopped.

To help resolve these potential problems, activities that will enable people *to live in their own future, today,* are required. These activities will not only have the benefit of bringing R&D closer to the needs of citizens and businesses, but also provide the means of helping people and researchers to deal with fears and concerns, rational or irrational. Experience and Application Research has the potential to be a vital tool in this process.

3.2 Improving industrial competitiveness

The view has often been expressed that technology, and the ownership of the associated intellectual property, does not generally provide the basis for sustainable competitive advantage. Why is this so? The reason is that technologies are often in the public domain, so they can be analysed. Once understood, alternative technology can be developed. Competition often ensures technological progress, but also often brings about competing solutions.

Recognition of this fact has led many enterprises to seek competitive advantage in areas that are harder to copy. Examples are organisational design, company culture, and business processes. Often there are intangible aspects to these. Usually they are less visible to competitors, and the difficulties of achieving a good fit between organisation, culture, and processes and the business environment makes copying hard.

Research, development and design processes involving users can become a source of sustainable competitive advantage, because user involvement is hard to bring about and hard to copy. Involving users in these processes requires knowledge about how to successfully achieve this. Know-how is intangible, and the intangible is a source of wealth in a knowledge-based economy. Experience and Application Research can therefore serve an important role in helping European enterprises to develop these processes, thus contributing to the development of sustainable competitive advantage.

3.3 Supporting emerging industrial practices

Since the early 1990s there has been an increasing emphasis in European companies on customer focus. Japanese practices in this respect have been studied and copied. New product development processes have been redesigned, both to reduce time-to-market and to improve the definition of customer requirements. Techniques such as quality function deployment have been introduced to complement more traditional techniques such as customer questionnaires and focus groups.

There has also been growing interest in a number of other areas related to customer focus. One of the better known of these is mass customisation. This seeks to offer customised products and services at mass production costs. But there are other techniques that look to create a different relationship between companies and customers.

One of these is known as expeditionary marketing. This technique is aimed at minimising the risks associated with opening up markets for novel products, especially those where customers have no notion of the proposed product concept. The aim is to determine the precise configuration of product functionality that customers will value and to establish the hurdles that need to be overcome to achieve the combination of price and performance that will open up the market for the new product.

The technique involves an iterative approach to product design and launch. A product is quickly created and then launched into the market. Testing of its reception and establishing what needs to change to achieve the right combination of features, price and performance then follows. The product is then quickly redesigned and re-launched. The process continues until the right combination has been achieved or until it is judged that the product is unlikely to succeed.

The process requires close working with groups of customers, or users, but another technique, called co-creation, has even more profound implications for relationships with customers.

The problem with market research is that it limits firms to addressing customers' existing frames of reference. Co-creation with customers addresses this fundamental problem. Co-creation seeks to develop a continuing and intertwined relationship between a firm and its customers. It works to define not only short-term customer requirements, but also the exploration of new opportunities using customers' perceptions of future requirements. It also seeks to collect from customers their own ideas about how products can be redesigned or improved. An important underlying tenet is that it is not always possible to establish fully, in advance of product design, customer needs. Instead, needs and solutions emerge together rather than one following logically on from the other.

Experience and Application Research will be able to provide opportunities to European firms to support these novel practices and assistance to ensure their wider adoption in Europe.

3.4 Assisting small and medium size enterprises (SMEs)

Everyone knows that Europe is a region with many SMEs. But these companies, no matter how innovative, suffer from one or more resource constraints: shortages of time, money or expertise. If the future lies in human-centred ambient intelligence products, in user involvement in new product creation, in processes such as co-creation with customers, then how will SMEs cope with this new future? The answer is probably that many will not cope very well. The priority in small firms is usually to deal with current customer orders and to ensure that they are delivered on time. But there are a myriad of other things that also need their attention: keeping abreast of changes in regulations, implementing new internet-based technologies and techniques, finding new customers, managing cash flows, and so on. Ambient intelligence and customer involvement may just be seen as another burden, something that, in the day-to-day prioritising that has to take place when resources are limited, will just be put to one side.

Experience and Application Research facilities would provide opportunities for small firms to integrate their products with others, within an existing infrastructure. Organisations undertaking Experience and Application Research would also provide a useful service for SMEs, helping them to deal with the complexities of ambient intelligence. There also exists the possibility that centres of excellence in Experience and Application Research could form hubs around which larger firms may build networks of innovative smaller companies.

Experience and Application Research is therefore needed to help SMEs deal with ambient intelligence and the many issues that it raises.

3.5 Developing new ways of undertaking research

An important characteristic of modern research, development and new product creation is its multidisciplinary nature. An essential ingredient in most projects is a multidisciplinary team.

Multidisciplinary approaches are concerned with using ideas from a range of disciplines and the application of these ideas to the solution of design problems, or technology developments. This provides valuable information flow among different professions, new insights and usually better results. Multidisciplinary approaches however, largely maintain the existing divisions between knowledge domains.

An increasing amount of research is, however, adopting an interdisciplinary approach, and this usually opens up entirely new perspectives and research topics.

Interdisciplinary activities are concerned with the areas between disciplines, and applying insights from these areas to solve design problems and to create new visions, new ideas and new opportunities. Interdisciplinary work has the potential to create new research domains.

Multidisciplinary approaches offer significant opportunities to develop superior ambient intelligent systems: world-class products for a global marketplace. Interdisciplinary approaches have the potential to open up entirely new avenues of research in ambient intelligence, for example, human-centred ambient intelligence based on human-computer co-operation and intelligent relationships between people and computers.

This is the potential for Experience and Application Research. It can provide a multidisciplinary environment for the development of ambient intelligence products and systems, with all the benefits that multidisciplinary brings. But it can also be interdisciplinary research, creating and exploring new visions and undertaking pioneering research in novel and unexplored areas.

3.6 Delivering improved education and training to the European workforce

Experience and Application Research will provide an opportunity to develop and deliver, to industry, education and training for the European workforce. There will also be opportunities to contribute to the education of undergraduate and postgraduate students.

Most of the education and training that will be delivered by organisations participating in Experience and Application Research will be related to how to work with users. However, this will need to be related to processes. In addition to learning about methods and tools and techniques, usability, human-computer interaction, interface technologies etc, the education and training activities will also address design method, R&D methods, and new product development processes. Inherently therefore, education and training activities focused on user aspects will also lead to improved awareness and knowledge of these methods and processes.

An important spin-off from these education and training activities will be increased awareness of ambient intelligence in general, and the importance of placing people at the centre of developments. Armed with these insights and knowledge, new graduates will also be better equipped for roles as both developers and users of ambient intelligence.

3.7 Contributing towards standardisation activities

Experience and Application Research has the potential to make a significant contribution towards the development of standards, particularly open standards. This will happen if there is a requirement placed on organisations undertaking Experience and Application Research to make use of, promote and contribute to the development of standards. An alliance between industry and research centres could form a powerful European force, speaking with one voice, within international standardisation activities and bodies.

A focus on open standards and open-source software will also help to counter the domination of markets by North American companies and their proprietary *de facto* standards.

The contribution to standards will not just be limited to technical ones, but will also encompass those related to users.

3.8 Assisting technology integration

Integration of components and systems continues to be a difficult task. This is a challenge that will need to be addressed by Experience and Application Research. Creating realistic user environments, where ambient intelligence technologies and systems can be tested, validated and demonstrated, will require integration of technologies from different suppliers. New technologies and prototypes will also need to be integrated into established infrastructures within research centres.

Experience and Application Research will therefore be a driver for technology integration. This will be an important secondary benefit from the activities of the organisations involved. Their work with users will also act as a driver for greater co-operation among European firms in the area of technology integration.

3.9 Involving citizens in Research and Development (R&D)

Involving citizens in European R&D programmes and bringing technology closer to citizens has emerged as an important issue that will need to be addressed in the years ahead. Experience and Application Research, by the nature of the topic and remit, can form an important component in future plans to increase citizen involvement in European R&D programmes.

4 Experience and Application Research

4.1 Introduction to Experience and Application Research

Experience and Application Research involves research, development and design, by, with and for users. It also covers research into methods and tools to enable this. This approach is crucial to the development of human-centred ambient intelligence systems.

Ambient intelligence refers to a digital environment that is sensitive, adaptive and responsive to the presence of people [2]. Ambient intelligence will encompass the home, car, clothing, work and public places.

Ambient intelligence will support people in their daily life in a non-intrusive way. ICT will become part of the environment in which people fulfil their tasks and in which people live. User interfaces will disappear [3,4] and interaction will be with a federation of devices like sensors, actuators and microcomputers. The communication in these intelligent surroundings will be based on conversational interaction technologies such as speech, gesture and emotions. In such an environment human-computer interaction will be transformed into human-computer co-operation.

Ambient intelligence is mainly based on three technological fields:

- *ubiquitous computing*, which consists of integrating microcomputers, sensors and actuators into everyday objects;
- *ubiquitous communications*, which enable objects to communicate with one another. *Ad hoc* networking, self-organisation, personalisation, and context awareness play an important role;
- *human-computer co-operation*, which means interacting with devices in a human-like way. The main technologies are speech, gesture, emotions, artificial skins, and multimodal interaction.

One of the aims of involving users in ambient intelligence R&D processes is to create useful and successful products. Researchers and developers increasingly recognise the need to cross the barriers of disciplines to create products that match the future demands of users. A more multidisciplinary approach to the development process opens up to new possibilities, perspectives and methods. The possibilities and constraints of ambient intelligence are dependent on user evaluations in the context of their everyday lives. Experience and Application Research must also consider relevance to social and cultural practices. This calls for application of user-related research results, and further research in the context of ambient intelligence. For instance, Experience and Application Research may provide a frame for cross-European studies of variations in user needs and evaluations of ambient intelligence applications.

Communication between users and ambient intelligent systems has not been sufficiently investigated. Furthermore, a better understanding is needed of the perceptual and cognitive elements that play an important role in the interaction between users and the ICT environment. To be successful in the marketplace for ambient intelligence, European companies need to understand users' needs. This means that there is a requirement to establish a human-centred design process that involves the user from the very beginning of activities. This will enable users' requirements to be derived in a systematic way. Therefore, Experience and Application Research needs to focus on all aspects of human-computer co-operation in ambient intelligent systems.

Experience and Application Research can involve:

- *user-related research* in interaction technologies for ambient intelligence; research on design processes for ambient intelligence; development of methods for usability testing;

- *development of prototypes* for ambient intelligence, based on the results of basic research. Integration of these prototypes and of existing prototypes into quasi-realistic user environments (for example, laboratories for living or work);
- *usability tests* of ambient intelligence components in quasi-realistic environments;
- *feasibility tests and validation* of ambient intelligence solutions in field environments (field trials).

The use of Experience and Application Research for testing is grounded in economic, as well as practical and technological, considerations. Experience and Application Research can be undertaken in:

- Science and Technology Centres: where basic research is conducted on component technologies for ambient intelligence;
- Feasibility and Usability Centres: where basic research is conducted with users on component technologies and systems for ambient intelligence and where components are integrated into real user environments on a small scale and usability is investigated;
- Demonstration and Evaluation Centres: where promising prototypes are fully integrated into large-scale demonstration facilities and shown to a large number of users;
- Field Trials: small and large-scale longer-term studies of technologies and systems undertaken with users in private as well as public places (airports, hospitals, etc.).

Centres can be physical or virtual, or based on co-operative networks. The centres, be they physical or virtual, can be organised around applications. For example some can specialise in the home of the future, others in the office of the future. Other possible areas are the hospital of the future, the car of the future, nomadic working of the future, and so on. Whatever their focus however, sharing of data and results, collaboration among centres, and ensuring access by a wider community to data and results are key factors for success.

4.2 A brief history of user involvement in design

The idea of involving users in development activities is of course not entirely new. The issue of user involvement and participation has arisen in different contexts over many years: organisational design, architectural design, software engineering, town planning, and so on.

In organisation and job design, the socio-technical school of thinking, which arose in the United Kingdom after World War Two, advocates the involvement of employees in organisational design. Participation helps designers to understand the work that employees undertake and can produce emotional commitment to the new design. Participation is therefore considered important to the design of successful socio-technical systems. In Scandinavian countries there have been many examples of the participation of employees in both organisational design and new technology development projects.

Software development is another field where much has been written about user participation. As far back as 1977, Gane and Sarson [5] were advocating the need to improve involvement of users in software development. They proposed a spiral method for this purpose. Similar ideas then reappeared in later years (Floyd and Keil [6] in 1983 and Boehm [7] in 1988).

In the area of human-computer interaction, an approach called user-centred design regards the early involvement of users as a basic principle. The focus is generally on early testing and evaluation with users to ensure that a system is designed to meet their needs.

The problem of understanding and defining user needs and expectations is at the centre of design, and the difficulties of this are discussed in the design literature. Various tools have been devised to assist designers, such as quality function deployment. But there are also others, and direct involvement of users is one of these. Novel design processes have been developed to deal with this.

Most people are aware of stage-based sequential design methods, where one phase follows on from the preceding one, with iterations between steps. For some design problems a stage-based sequential process is satisfactory. But there are circumstances where they are not, and for these, other approaches such as incremental or adaptive design methods can be used. The spiral software development methods mentioned above are examples of adaptive design methods.

An important tool in many of these methods is prototyping.

4.3 Experience prototyping

Prototyping has played an important role in most examples of user involvement in design. Prototypes provide a tool for classical evaluation of users' reactions to systems and their satisfaction, and they can be a useful way to measure the effectiveness and efficiency of users' tasks. Prototypes can further be used to observe cognitive tasks, such as users' attention and perception. They allow developers to test new ideas either in a laboratory setting or in more realistic contexts.

Prototypes come in different forms. First there are full prototypes that contain complete functionality, but provide less performance than a completed system. Second there are horizontal prototypes that demonstrate operational aspects but do not provide full functionality. Finally there are vertical prototypes that contain full functionality for a restricted part of the system.

There are also different types of prototyping methods. Requirement animation prototyping uses tools that assist designers to demonstrate design possibilities to users. Rapid or throwaway prototyping focuses on collecting information on requirements, recognising that initial requirements may be inaccurate and therefore need to be checked with users. Prototypes, once finished with, are then discarded. Evolutionary prototyping seeks to build a system in an evolutionary way, with refinements being added over time. In this way the final design emerges over a period of time. This should be contrasted with incremental prototyping, where the system is built one step at a time, but to a design established at the beginning.

Developers have to choose which prototyping methods and tools to use, and how much time and money can be invested in prototype development, based upon the objectives of constructing the prototypes.

Prototypes enable an approach called experience prototyping. This provides the opportunity for design team members, users and other interested groups to gain first-hand appreciation of existing or future conditions. Experience prototyping can be used to understand existing user experiences and their contexts, analyse and evaluate new designs, and communicate ideas to designers and stakeholders.

Experience prototyping tests user interaction with technology. It involves users actively engaging with a prototype and examines how they use it. There is emphasis on the way people communicate in the presence of the prototype in a natural environment. A key aspect of experience prototyping is the way user group behaviour is observed with tangible interfaces, perhaps supported by *props*, so users can reflect on the design and improvise.

Experience prototyping places emphasis on the quality of users' interactions and experience, and less on the pure functionality and technology of the solution. Therefore the approach is well suited to the goal in ambient intelligence of addressing users' needs in the context of socio-economic problems and activities.

As ambient intelligence scenarios become more complex, it is also possible to see how further development of the experience prototyping approach can make an important contribution to making highly innovative, yet complex and abstract, ideas both physical and understandable.

Nevertheless, a number of research challenges must also be addressed for experience prototyping to fulfil its promise. In particular there is a need to:

- integrate prototypes with model-based user interface design, thus satisfying both users and developers;
- develop a lifecycle for prototypes supporting different abstraction levels and fidelities;
- annotate prototypes with higher level information such as the results of performances, user testing, expert evaluation and participatory evaluation;
- develop exploration and evaluation methods of prototypes that integrate cognitive processing, system tasks and the interaction between them.

Experience and Application Research can provide the means of implementing experience prototyping, and further developing the concept, in the context of ambient intelligence R&D.

4.4 Facilities for experience prototyping

To solve a problem in a particular domain, there is a need to build a system that will be introduced into the domain. The system may replace some work already performed in the domain by other systems or manually, or the system introduces new tasks that were not possible to perform previously.

To understand what problem is to be solved, skills and tools are needed to quickly understand the application domain, that is to say, *analysis* tools. These tools abstract the problems and yet describe contextual or situated details. Tools will help developers define the scope of the problem. Different types of contexts are considered: temporal, spatial, social (actors), technological, organisational, etc., and in each case the scope within each context is examined. Some problems are already obvious, but others need to be detected to create innovation. Part of the problem definition is analysing the criteria according to which solution will be validated.

Knowledge management and elicitation tools are needed. Either existing knowledge resources are built upon, or knowledge is elicited through observations, interviews, surveys, and questionnaires that produce qualitative and quantitative data. Tools are needed that help do

this more automatically than before. For example, pattern detection of behaviours, eye tracking, sensors, etc. Tools are also needed to transform the qualitative and quantitative knowledge into more formal domain or problem models.

Traditionally, analysts extract this knowledge from the domain, but Experience and Application Research can also enable users to suggest problems that need to be solved: pushing problems to designers. This can be organised as a problem library, much like a science web that accepts questions about science and technology.

When the new system is introduced to the domain, it will interact with the domain, for example, receive input and produce output.

To understand how other actors (systems or humans) in the domain will activate the new system, and react to it, tools and techniques are needed to understand the interaction. Examples of interacting systems are computing, mechanical, electrical, natural etc, and there is a need to understand how they behave in response to the new system. These tools should allow communication protocols and interfaces between the new system and external systems to be described. Behaviours of the interacting systems can help with the understanding of their interaction with the new system.

Available tools are interaction models, for example Goals Operators Methods Selection (GOMS) models, state, interaction and collaborative models.

When a new system is built to solve the problem, it needs to be built based on current science and technology. However, it is also necessary to look ahead and see how the new system can advance knowledge, increase effectiveness, efficiency or satisfaction.

To sketch a solution for a problem, abstract ideas of what information it will use, what information it produces and what goals it has, will be produced. These are conceptual ideas of the new system. Experience prototypes have been used to test ideas by asking actors to execute the tasks. Props are used for artefacts and can indeed be very abstract in the beginning and then evolve to more detailed ones at the design stage. To build the system *synthesis* tools are needed, for example, models of the new systems. The models need to be capable of being validated.

Prototypes are one type of a model. Scenarios or storyboards are another type. Models of entities, navigation or contexts are yet another. There will be several types of models to describe different aspects of the system.

When the system is installed into the domain there is a need to validate a previously built model. To install the system *validation* tools are need. The validation tools need to record the actions of the system and reactions of the interacting systems. The validation tools need to feed data to the models for comparison. The inconsistencies between the expected behaviour of the models and the actual ones will either stimulate updates of the models or the interacting systems. Thus the feedback in the validation phase is a problem that needs to be worked on more heavily.

The output of validation (or testing) tools is usability problems, but can also be positive experiences. More generally a validation tool should help developers decide whether the criteria for the design have been met. The input of validation is the design and the criteria to

be tested against. There is a range of usability testing tools, for example, observation with think-aloud protocol, heuristics analysis etc.

Not much is known about validation of early phase models. Much research is focused on, for example, usability testing of products or high fidelity prototypes.

There has been continuing work at Fraunhofer (Center Maryland and Europe) on Experience Factory that attempts to capture experiences for Software Development organisations [8]. Experience Factory was introduced well before Knowledge Management became popular. The same concept can be used for exploiting the experiences of introducing a new system into a domain (for example, its interaction to the domain) or on a meta-level to learn from the experience of creating (for example, what processes to use) a new system for ambient intelligence.

In Experience and Application Research it will be possible to build on experience created in the past and to capture experiences for the future. Learning from experience should be emphasised in Experience and Application Research. Digital libraries and validated web resources in general will be an important tool.

The scope of the design will be different in Experience and Application Research than previously, because it will enable *collaborative* design among groups and this will also span interdisciplinary teams. This calls for collaborative intelligence (one of the seven layers from Knowledge Management).

The tools of Experience and Application Research will be different because intelligent processing of empirical data will be needed, and the aim should be to use this as a basis for automatic design and validation.

Experience and Application Research will also emphasise strong *visualisation* of experiences. More complex criteria will require tools that can evaluate different design solutions to meet many and sometimes, conflicting, criteria. Also, action research will be used and this will turn industrial partners into a laboratory. Activity theory will also be important, placing the emphasis on the artefact.

4.5 Examples

Examples of Experience and Application Research are presented in Appendix 2. These cover research projects, field trials (for example, those undertaken by Telenor), and examples of Feasibility and Usability Centres (for example the Philips HomeLab) and Demonstration and Evaluation Centres (for example, Living Tomorrow). The key lessons learnt from the examples described in Appendix 2, are:

1. *Location*: The location of facilities can be important, depending upon the purpose. Facilities that are located in a campus type environment are not a natural setting for longer-term studies. It is better if facilities devoted to longer-term studies are located in the centre of town or in a residential area. Facilities that are located in campus type environments are only suited to short-term studies or experiments;

2. *Research focus*:

- Facilities like the *Philips HomeLab* need a coherent research programme. This should contribute towards the build-up of the infrastructure. Projects that just use the facility and then remove all their equipment at the end should be avoided: projects should leave something behind. The development of a coherent research programme requires planning and also people to support the emerging infrastructure;
- Facilities like the *Philips HomeLab* are suitable for experience prototyping and do not support other types of prototyping used for specification development. These other types of prototyping approaches also need to be integrated into the approach;
- Facilities like *Living Tomorrow* are best suited to addressing many people in less depth using mass data collection techniques to identify trends. Facilities like *HomeLab* are best suited to undertaking studies with a small number of people using one-to-one data collection, focussed on identifying patterns, relationships, etc.;
- House of the future facilities can provide a focus for research activities and help to enable interdisciplinary working, collaboration and communications;

3. *Research data*: The data generated from experiments should be stored in a database and researchers from across a company need to be able to access this data to undertake analysis;

4. *Pitfalls*:

- It is possible to devote too much resource to maintaining the observation infrastructure, rather than maintaining the infrastructure of the environment (home, office, etc.);
- The question of how to make observations when concepts, technologies and products are not fully developed needs to be better addressed. Experiments with incomplete systems can lead to rejection or poor user acceptance;
- Care needs to be exercised when designing the facilities that users will experience, especially in Demonstrations and Evaluation centres: it is all too easy to create a technologically centred environment, which is far from human-centred, and where the technology is the dominant message;
- Many of the German examples have a significant application component, and the user experience aspects are less well addressed, even though most of the developments involve user groups, development of user requirements, and undertaking testing with users. Thus the outcome is product results and marketing of the results. Presenting the use of the results in an appropriate environment is not strong. Involvement of users therefore has to be strongly developed in projects and activities. It is not sufficient just to have users participate in some way: there has to be significant focus on users and political and emotional commitment to working with users;

5. *Costs*:

- Prototyping can be an expensive activity and finding the financial resources can also be problematic. Problems are likely to arise where agreement is required from company divisions or senior executives. However, examples such as the *Telenor House of the Future* show that it is possible to do much, even with a limited budget. Facilities such as *Living Tomorrow* are however expensive;
- Owing to rapid changes in technology and rapid product renewal in the marketplace, centres have a limited life, and after a few years of operation (possibly a maximum of four or five years) facilities need to be rebuilt;

6. *Field research*:

- Special facilities are not the only way to work with users; small and large-scale scale pilot field trails can also be used;
- Longitudinal field research (three years) can capture changes in patterns of usage, discrepancies between attitude to usage expressed in interviews and surveys, and data from computer logs of actual use, and usage changes as pilot services move from being free to being subject to a charge;
- Field research can provided contradictory results to those previously obtained from focus group research, and provide more valid results about the attractiveness of new applications;
- Field trials can provide insight into user creativity in the use of technology (making the technology their own) and create an opportunity to test stability of technological solutions;
- Experience of field trials shows that users want to be actively participate in trials, can contribute to adjustments in applications, and can provide useful feedback for product development;

7. *General*:

- Research and demonstration facilities of the type described can create a lot of media exposure, which generates wider interest, thus helping to bring research into the public sphere.

4.6 Challenges

If user involvement in research, development and design is recognised as being important, then why is it not widespread industrial practice?

One reason suggested for this is the cost and effort argument. User involvement adds costs and effort to the process. But is this true? Or is it the case that user involvement changes the cost-effort profile over the lifecycle of a product? Perhaps it shifts cost and effort that arise in after sales activities such as customer services, maintenance, etc. up-front to the research, development and design departments? Perhaps it increases costs and effort up-front, but reduces them across the full lifecycle of the product?

Another suggestion is that involvement of users has never been institutionalised into the education system and the values of society. As a result, the idea has never taken root.

Industrial society is founded on specialisation and division of labour. There are many of these: managers and workers, business executives and technical experts, strategist and implementers, technologists and social scientists, and so on. The separation of designer and user is just one of these divisions. It is possible therefore that until the integration of users and designers is institutionalised, the matter of user involvement will continue to be discussed into the future.

Whatever the reasons for user involvement not being a widespread industrial practice in the way envisioned, there is certainly a barrier to acceptance that needs to be addressed. This implies dealing with important but challenging matters such as culture, norms and values, departmental budgets, and cross-departmental working.

5 Detailed Proposals

5.1 Organisation

As previously stated, Experience and Application Research can be undertaken in: Science and Technology Centres; Feasibility and Usability Centres; Demonstration and Evaluation Centres; and Field Trials.

While the first three represent centres, field trials are also another means of reaching out to and interacting with users, and should therefore be part of Experience and Application Research. Moreover, it is appropriate and desirable that Feasibility and Usability Centres should undertake leading edge research and not just be places for component integration to enable information to be extracted from users. Thus, work that would normally be undertaken in Science and Technology Centres could be undertaken in Feasibility and Usability Centres with the added advantage that users would be integrated into this basic research work.

Consequently, since Science and Technology Centres exist already they should not be subject to further consideration in Experience and Application Research, as aspects of their work can be undertaken in Feasibility and Usability Centres. Furthermore, the distinction between Feasibility and Usability Centres and Demonstration and Evaluation Centres is important.

Feasibility and Usability Centres should only deal with advanced concepts and should not address products that are already on the market or that are close to market. The focus should be on basic research undertaken with users on component technologies and systems for ambient intelligence and the integration of components into real user environments on a small scale, with usability investigations.

Demonstration and Evaluation Centres should be more robust environments and focus on: partnering; educating users about new technology; and obtaining feedback from a large population of users. They should largely be based (about 80%) on technologies that are close to market. Promising prototypes should fully integrated into large-scale demonstration facilities and shown to a large number of users.

Field Trials, both small and large-scale, should address longer-term studies of technologies and systems undertaken with users in private and public places (airports, hospitals, etc.).

Four levels of activities are considered to be important, all of which should be coherent and integrated from a user perspective:

- the individual's interaction with a product, service, environment or system; this is the traditional domain of user interface design or human-computer interaction;
- the level of the group, or community which involves a multi-user locale with links to a distributed network: examples are the home, the school, the business, the hospital;
- the level of the individual's movement across places and through time. In this scenario the focus is on time rather than place, and design needs to reflect the individual or group's experience across locales and activities.
- individuals moving between groups, for example people moving between home and work, or between work sites, etc.

Demonstration and Evaluation Centres will probably be very expensive to set-up. As the cost of Feasibility and Usability Centres will be significantly less than the cost of Demonstration and Evaluation Centres, there could potentially be many of former types of centres, spread across Europe, and a small number of the latter type of centre.

Demonstration and Evaluation Centres should focus on addressing many people in less depth using mass data collection techniques to identify trends. Feasibility and Usability Centres should focus on undertaking studies with small number of people using one-to-one data collection, directed at on identifying patterns, relationships, etc.

However, it is fundamentally important that the centres work together. Synergy among Experience and Application Research Centres needs to be developed. This can be achieved through common use of standards for integration, sharing methods and tools, exchanging best practices, sharing data, and working together to create common platforms. The centres must clearly show an advantage for Europe. One way they can achieve this is by adopting open-source approaches and avoiding dependencies on proprietary systems. All the Feasibility and Usability Centres need to be connected. They can achieve this by exchanging people, having common working groups, sharing tasks, and undertaking cross-border studies, etc. There should also be links with the emerging European Technology Platforms. Furthermore, some of the Feasibility and Usability Centres may develop in time to become Demonstration and Evaluation Centres. However, at the beginning these two types of centres should be kept apart and their distinctions maintained.

To ensure the industrial take-up of the results of Experience and Application Research, access by a wide community to the results, background data, and methods and tools should be ensured. Also, Experience and Application Research would enable existing expertise in this field to be developed and would contribute towards mobility of researchers within Europe. This would provide opportunities for transferring expertise from those parts of Europe where user involvement has been more widely practised, to those parts where it is less developed.

5.2 Field research

Field research in real user environments may be carried out on a large or on a small scale, depending on resources available and the scope of the research involved. The strength of large-scale studies lies in the ability to cover many aspects and a greater potential for quantification and generalisation. Working with complete social systems, or communities of practices [9] such as a local community, a household, a school or a hospital, to a larger extent produces a critical mass for applications and thereby gives a fair test, especially for communication technology, and lasting impact. In addition it drives market penetration and innovation. On the other hand, larger and more complex field trials are time consuming, and especially for new media and ambient technologies, there are risks that the technology and solutions involved will be outdated by the time the study produces results.

Field research investigates a phenomenon in its actual life setting, and can be a pilot study of a new technology or a case study of an organisational unit. Pilot studies refer to exploratory research in which the technological, methodological, or the theoretical approach to a problem lacks sufficient data and publications, but whose successful outcome would make a significant contribution to a scientific area or field. Case studies are useful for studying a limited unit, in depth, particularly with a qualitative emphasis, such as individuals, groups or organisations.

The case approach may typically use less formally structured methods than the survey or experiment. They are also highly flexible, and may freely mix quantitative and qualitative approaches and seek triangulation of findings [10].

Field research is highly influenced by context, cultural and social, and produces knowledge of users and uses of technologies within that particular context. For this reason it will be interesting to study how field research in different regions of Europe show diverging or converging results. Knowledge of such cultural fits may feedback to transfer of technology and contribute to successful product development and implementation, and reduce time-to-market for new products in different European regions.

5.3 Application domains

The ISTAG report on IST Research Content [1] defined nine ambient intelligence application areas:

- Civil security applications relevant to: counter-terrorism, policing and security, responses to natural disasters and global epidemics, etc.;
- Community building and new social groupings applications relevant to: creating social networks, creating a sense of community, maintaining contacts with friends and family, etc.;
- Home in a networked society applications relevant to: at home entertainment, home automation, learning, working from home, etc.;
- Environment applications relevant to: provision of information to citizens, pollution monitoring and control, resource management, etc.;
- Governance and public services applications relevant to: online voting, delivery of public services; consultation and participation, etc.;
- Healthcare and social support applications relevant to: care of elderly people, monitoring of patients, tracking the location of children outside the home, systems to support disabled people, etc.;
- Improvement of business process applications relevant to designing, manufacturing, delivering and supporting products and services;
- Mobility and transport applications relevant to: use of public transport, in-car systems, integrated vehicle-highway systems, cross-border travel, etc.;
- Sustainability applications relevant to: all aspects of the design, production and consumption of goods and services, with particular reference to predicting and minimising environmental impacts.

The above application areas should not be seen as prescriptive and other applications should not be excluded. Industry and other organisation should be free to propose further areas.

While it is possible to consider that Experience and Application Research should be undertaken in all nine areas, this may be too simplistic. A number of issues need to be considered.

First there are already many examples of centres that are devoted to the home-of-the-future and, to a lesser extent, the office-of-the-future. This is not an argument for ignoring these application areas. What needs to be done is to use funding to better structure that which already exits and to fill any gaps.

Second, many of the nine areas are broad and multi-dimensional. For example, mobility and transport covers cars, aeroplanes, buses, trains, and so on, as well as the infrastructure like roads, airports, stations, etc. Business processes cover many different industrial and commercial activities, such as finance, manufacturing, retailing, etc. and all these can be sub-divided into sectors. People however tend to identify with what they know or that which is important to them. Focus may therefore be needed, especially in Feasibility and Usability Centres, which suggests centres devoted to specific industries, or applications and so on. Demonstration and Evaluation centres however, can be more generic.

Third, many of the nine application areas involve two distinct types of users; there are employees who will use ambient intelligence systems to support their work and there are customers who will experience ambient intelligence in the delivery and use of products and services. Potentially, the case of employees is more complex to deal with because matters of work organisation, business process redesign, change management, motivation, reward systems, etc. will need to be considered. This suggests that some centres may need to specialise in specific types of user.

Fourth, there is the matter of feasibility. Some application areas are safety critical, for example, air traffic control, administering drugs, etc. Moreover, in some environments experiments that lead to disruption will not be tolerated, for example, in operating theatres, intensive care facilities, classrooms, etc. Furthermore, staff in hospitals, schools, airports, etc. may be overworked. Also, how interested will a stressed traveller or someone who is unwell be in participating in experiments, trials, etc.? In all these applications, how will it be possible to involve users, be they employees or customers? Clearly some applications are more suited to Experience and Application Research than others.

Finally, there is a matter of horizontal issues. Civil security is relevant to mobility and transport, public services, etc. Sustainability is relevant to business processes, the home, mobility and transport, etc. There are other horizontal issues such as: security, trust and confidence, and organisational change. Some application issues therefore seem to need to be addressed as horizontal elements that cut across several application areas.

In the short-term there should be a focus on tapping into and building on existing expertise and facilities, which are mainly devoted to home and office applications. However, there should also be some expansions beyond these applications, for example into areas such as consumer electronic systems for cars and for the home. The matter of the application domains to address within the context of work-programme 2005-06 is further addressed in the next section.

5.4 Funding options

In the short-term, Experience and Application Research should be addressed within a few selected Strategic Objectives within the context of work-programme 2005-06, and if the work is successful, Experience and Application Research should be extended in Framework Programme Seven. Experience and Application Research is a long-term activity: its continuation within Framework Programme Seven is therefore important. The interdisciplinary aspects of Experience and Application Research are also important and there is a need to consider Experience and Application Research from this perspective and how this can be developed in Framework Programme Seven.

In relation to work-programme 2005-06, Experience and Application Research appears to be relevant to several Strategic Objectives. These are: *Multimodal Interfaces, Advanced Displays*, *eHealth*, *eSafety for Road and Air Transport*, *Semantic-based Knowledge Systems*, *Networked Audovisual Systems and Home Platforms*, *Applications and Services for the Mobile User and Worker*, *eInclusion*, and *Cognitive Systems*. However, in the short-term, the Strategic Objectives *Applications and Services for the Mobile User and Worker*, and *eInclusion*, provide the best platform for developing Experience and Application Research within the IST Programme.

Within the timeframe of work-programme 2005-06 the emphasis should be on projects to undertake research into methods and tools for use with ambient intelligence systems, and to test and evaluate these methods in actual circumstances. This could involve working in collaboration with projects funded under the first two IST calls, thus creating synergies with these existing projects. The proposed new projects could also undertake preparatory work on the establishment of a network of centres across Europe, as well as road-mapping activities in the context of user-related research for ambient intelligence, thus proving a lead into further research within the context of Framework Programme Seven.

A project, such an accompanying measure, to ensure the sharing of results and experiences across Experience and Application Research projects, and to foster the dissemination of results to a wider community, may also be required.

5.5 Selection and evaluation criteria

The first point to note is that Experience and Application Research is partly a strategic investment in research infrastructure. Ideally therefore, selection should have a strong strategic dimension.

There are three main strategic approaches that can be used:

- Technical importance;
- Current business importance;
- Longer-term competitive advantage.

Technical importance: With this method a strategic view of Experience and Application Research is based on its importance in relation to the enabling of objectives. In other words, desired ends will not be attained unless there is an investment in this research. Thus, when evaluating proposals under the heading of technical importance, the implication is that proposed projects must demonstrate that the work to be undertaken is a prerequisite for future activities. Hence, desirable and advantageous future activities will not be implemented without the work that will be undertaken in a specific Experience and Application Research Project.

Current business importance: The assessment of proposals in relation to current business importance is based on the contribution that will be made towards achieving current business goals. For example, a proposal may lead to significant improvements in customer responsiveness through user involvement in research. Customer responsiveness is often a key business objective.

Long-term competitive advantage: This assessment approach recognises that some activities need to be undertaken because they provide opportunities for companies to gain significant competitive advantages over competitors. Proposed projects may be addressing areas that are not necessarily directly relevant to current business goals, but the achievement of the results may provide the opportunity to create competitive advantage in the future.

Given the requirements of Experience and Application Research, there is a need to apply additional criteria, beyond the standard ones used for proposal evaluation. Possible additional criteria are:

- *user involvement*: recognition of its importance, the impact on technology and users, closing the loop between the two, ensuring that developers do not work in isolation; demonstrating how emotional commitment to working with users will be achieved; demonstrating experience of working with users;
- *interdisciplinary aspects*; demonstrating how interdisciplinary work will be achieved;
- *methods and tools*: a structured approach based on relevant methods, and the soundness of these for the applications; approach to working with users in circumstances where products and concepts are incomplete (for example, how methods and tools will be adapted for this type of circumstance); demonstrating experience of applying user-based methods and tools;
- *wider impact*: co-operation, sharing and plans for this; openness and access by a wider community to results, etc.; exchange of experiences; mobility of researchers; wider impact on disciplines and the user perspective;
- demonstrating that the infrastructure (buildings, equipment, etc.) is available to undertake the work, or that plans are presented about how this will be put in place;
- coherence of the user-related aspects and approach, with the other parts of the proposed R&D;
- demonstrating new methods of undertaking research.

In terms of assessing the success of Experience and Application Research, many of the benefits will be longer term and will be intangible. They will also be enablers of other things, like development of skills and new ways of doing research. Thus longer term measures of success, could be related to the expected benefits:

- reducing the barriers to the development and take-up of ambient intelligence;
- improving industrial competitiveness;
- supporting emerging industrial practices;
- developing new ways of undertaking research;
- supporting SMEs;
- delivering improved education and training to the European workforce;
- contributing towards standardisation activities;
- assisting technology integration;
- involving citizens in R&D.

So, when evaluating the success of Experience and Application Research, projects could be asked to demonstrate what impact they have had. For example, the number of companies that have adopted new ways of working with users, or the innovations that have emerged as a result of the approach: innovations that would not have otherwise happened.

Finally, success and failure needs to be judged against some reference point. Any shortfall between achievement and the ideal could be based on criteria. But the measurement could also be based on the impact or contribution towards improved competitiveness or profitability. However, the shortfall could also be based on comparison with what is happening elsewhere, that is to say, Japan and the United States, for example, how sophisticated or advanced is Europe in relation to these other countries? Who has the lead?

It is suggested that the success of Experience and Application Research should eventually be assessed using the following criteria:

- financial sustainability of the proposed centres based on income received from Experience and Application Research services;
- shorter time-to-market for new products;
- improved selection of research portfolios and allocation of research funds;
- reduced risks arising from the elimination of poor ideas and those that lack market potential;
- increased European competitiveness in relation to other market regions;
- stimulation of creativity and innovation.

5.6 Methods and tools

There are a wide variety of methods and tools that can be used in Experience and Application Research that fit into the Experience and Application Research lifecycle shown in Figure 1. Appendix 3 provides some brief information about some relevant methods. Some of these are well established, other are just emerging. Methods and tools encompass those that can be used for working with users on software and system development, as well as those that are used for researching user-related issues.

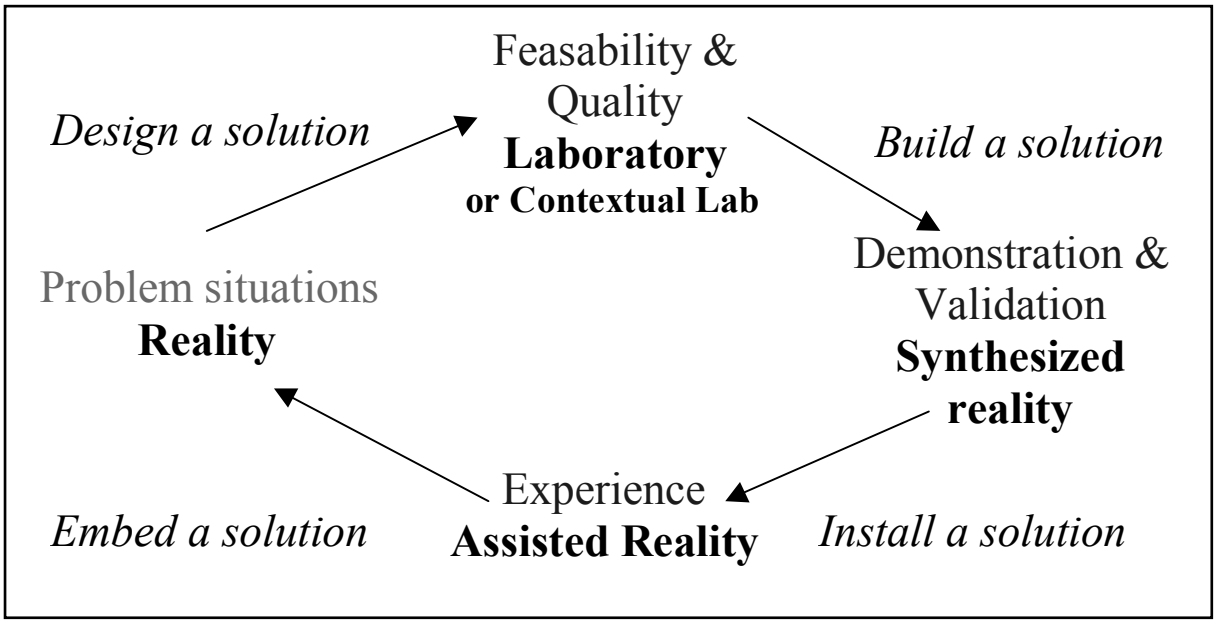

Figure 1: Experience and Application Research Lifecycle

Usability is a term that is often used. Typically there is an interest in assessing the usability of human-computer interfaces or pieces of software. Usability however, has traditionally focussed on an interpretation of quality based on effectiveness, efficiency and satisfaction. However, concepts such as empathy, trust, fun, aesthetics, etc. may be more appropriate measures of quality, especially for ambient intelligence. This is an area that requires further research.

Some methods and tools have not been widely used and it is not clear if they work properly. Methods and tools should be suitable for the emerging characteristics of ambient intelligence. Approaches that provide context are also important for ambient intelligence applications. A key point is that there is a need to research which methods and tools are appropriate for specific ambient intelligence applications, and possibly also to develop new methods.

For example, there are two distinctive types of ambient intelligence applications; one type involves employees and the other type, citizens. In a work environment there will be applications that are used by employees; these applications will support their work. But there may also, in the same environment, be applications to support citizens, who for example, may be customers or users of services offered by government. In the home the emphasis is more on citizens, but taking into account distance working, some aspects of the work environment may also apply in the home as well.

The point is that both experiences have distinctive characteristics. The work environment leads to consideration of work organisation, and business processes, co-operation, working methods, etc. These types of issues do not arise in the home (normally). Thus for working environment applications, methods and tools that address organisational change, organisational design, co-operative working, culture change, etc. are needed.

To investigate these types of issues a number of ambient intelligence applications should be investigated and research work undertaken to determine and test the most appropriate methods and tools. This will also help to identify which methods and tools are missing.

There is no need to be prescriptive about which methods and tools should be used, so long as they address all the issues and involve users in appropriate ways for the application or for the research being addressed. Sharing of methods and tools is also important, along with ensuring access by a wider community.

5.7 Software and interface requirements

The proposed types of Experience and Application Research Centres need to take into consideration a number of software related issues to fulfil the criteria of compatibility and portability, and to enable synergies to be achieved across the Experience and Application Research Centres.

There are six issues that must be addressed:

- avoid supporting developments based on proprietary environments;
- ensure compatibility among the centres;
- adopt portability requirements oriented to open-systems;
- take into account existing and emerging interface and data format standards;

- make use of, or apply, existing software platforms and developments;
- develop and identify the behaviour models of the user community.

Further details of the proposals with respect to this are given in Appendix 4.

6 Conclusions and Recommendations

ICT are entering a new era: that of ambient intelligence. This is a vision that places human beings at the centre of future development of the knowledge-based society and ICT. Computing devices will be embedded in everyday objects and these technologies will be almost invisible to those who use them, and interfaces will be easy and natural to use.

Experience and Application Research can be seen as a means of furthering the development of and for realising the vision of ambient intelligence. The research can develop the multidisciplinary skills and approaches that will be needed to realise ambient intelligence technologies, systems and products. Most importantly, the research can provide a platform for significant user involvement in the development of ambient intelligence, across all stages of the R&D process.

Since multidisciplinary approaches and the involvement of users are both key requirements for the successful development and deployment of ambient intelligence systems, Experience and Application Research can be seen as strategically important for Europe. The research can also offer European industry and Europe's citizens a number of significant benefits. These include:

- reducing the barriers to the development and take-up of ambient intelligence;
- improving industrial competitiveness;
- supporting emerging industrial practices;
- developing new ways of undertaking research;
- supporting SMEs;
- delivering improved education and training to the European workforce;
- contributing towards standardisation activities;
- assisting technology integration;
- involving citizens in R&D.

Experience and Application Research has the potential to considerably develop the activities of the IST programme in a number of ways. It will enhance the systems approach, reinforcing consideration of an aspect of information and communications systems, namely users, which is often not given sufficient attention. Furthermore, Experience and Application Research, being based on the involvement of users, will help to improve research focus, because poor ideas and those that have limited market value will be more quickly identified and eliminated. Finally, Experience and Application Research will help SMEs, by providing opportunities for small firms to integrate their products with others, within an existing infrastructure. Centres of excellence in Experience and Application Research could also form hubs around which larger firms may build networks of innovative smaller companies.

Experience and Application Research is a bridge between the world of researchers, developers and designers on the one side, and the world of users on the other. The proposed work is founded on the understanding that users vary, both across Europe, and across the globe. Furthermore, Experience and Application Research provides the means of developing closer relationships with customers, and applying emerging industrial practices such as customisation and co-creation with customers. Location is therefore critical to success. To understand European users and to create closer links with European customers, Experience and Application Research needs to be undertaken in Europe.

Experience and Application Research should be undertaken with support from the IST Programme. There are 11 specific recommendations about Experience and Application Research.

Recommendation 1: Support Experience and Application Research through centres and field trials

Experience and Application Research should be undertaken within the context of centres and field trials. Field trials can be either small or large-scale. There should be two types of centre: Feasibility and Usability Centres, and Demonstration and Evaluation Centres. The focus of Feasibility and Usability Centres should be on advanced concepts, technologies and prototypes that are typically five or more years away from the market, and these centres should undertake studies with small numbers of people using one-to-one data collection, directed at identifying patterns, relationships, etc. The focus of Demonstration and Evaluation Centres should be on technologies and prototypes that are close to market, and these centres should address many people in less depth using mass data collection techniques to identify trends.

Recommendation 2: Create synergies

It is fundamentally important that the centres and field trials work together to create synergies. These can be achieved through common use of standards for integration, sharing methods and tools, exchanging best practices, sharing data, working together to create common platforms, exchanging people, having common working groups, sharing tasks, and undertaking cross-border studies, etc.

Recommendation 3: Ensure the wide community has access to results

To ensure wider take-up of the results of Experience and Application Research, access by a wider community, to results, methods and tools, background data, etc., must be an obligation on projects. A database containing methods and tools, background data, and other results, should be created, with open access guaranteed.

Recommendation 4: Support mobility of researchers

Europe has an established tradition of working with users, especially in the Scandinavian countries, although the skills and knowledge base is fragmented and under-used. Experience and Application Research will enable this existing expertise to be developed and disseminated more widely. To facilitate this, opportunities for transferring expertise through mobility of researchers should be provided.

Recommendation 5: Use additional criteria for proposal evaluations

The success of Experience and Application Research depends upon a number of features. These are related to user involvement, interdisciplinary approaches, use of appropriate methods and tools, adopting a new approach to research, wider impact, availability of infrastructure, and coherence with other aspects of the research. Thus, there is a need to apply additional criteria beyond the standard ones used for proposal evaluation.

Recommendation 6: Provide funding within the context of work-programme 2005-06

In the short-term, Experience and Application Research should be addressed within a few selected Strategic Objectives in the context of work-programme 2005-06, and if the work is successful, Experience and Application Research should be extended to a broader range of research in Framework Programme Seven. In the short-term, the Strategic Objectives *Applications and Services for the Mobile User and Worker*, and *eInclusion*, provide the best platform for developing Experience and Application Research within the IST Programme.

Recommendation 7: Build on existing centres and expertise

Most existing centres and skills are based on the home or office of the future. Projects should tap into this existing infrastructure and expertise and build on it, but in the context of work-programme 2005-06 there should also be an effort to expand beyond home and office applications, for example, into areas such as consumer electronic systems for cars and for the home.

Recommendation 8: Use funded projects to build a bridge to Framework Programme Seven

Funded Experience and Application Research projects in Framework Programme Six should undertake feasibility studies and road mapping exercises to establish what should be addressed in Framework Programme Seven.

Recommendation 9: Address interdisciplinary issues

Experience and Application Research is a long-term activity which is focused on interdisciplinary work. Given the importance of the interdisciplinary aspects of Experience and Application Research, there is a need to consider Experience and Application Research from this perspective and how this can be developed in Framework Programme Seven.

Recommendation 10: Research user-related methods and tools for ambient intelligence

Ambient intelligence provides a new set of circumstances for the use of user-related methods and tools. Research into user-related methods and tools for ambient intelligence therefore needs to be undertaken. A number of ambient intelligence applications should be investigated and research work undertaken to determine and test the most appropriate methods and tools. This will also help to identify which methods and tools are missing.

Recommendation 11: Develop centres of excellence

Centres of excellence in Experience and Application Research should be developed. These will help to maintain and to improve the attractiveness of Europe as a place to undertake ICT-related research.

7 Appendix One – Relevant Recommendations from the ISTAG Research Content Report

The Working Group report on IST Research Content, published in September 2003, produced seven recommendations:

- Recommendation 1: Put holistic and dynamic user requirements at the centre of the development process and create a multidisciplinary European network of Experience and Application Research Centres;
- Recommendation 2: Support open standards in ambient intelligence projects and encourage their development via public sector initiatives and projects;
- Recommendation 3: Support distributed software development including the certification of components;
- Recommendation 4: Encourage research that supports the *graceful degradation* of software in complex ambient intelligence systems;
- Recommendation 5: Place sufficient emphasis on work at the boundaries between research disciplines;
- Recommendation 6: Increase awareness of the ambient intelligence vision among computer scientists and researchers in other disciplines;
- Recommendation 7: Improve the ability to track participation in and the impact of ambient intelligence research.

The present report is primarily concerned with the first recommendation. Details of this particular recommendation are therefore given below.

Recommendation 1: Put holistic and dynamic user requirements at the centre of the development process and create a multidisciplinary European network of Experience and Application Research Centres.

To develop high quality services and products for ambient intelligence it will be necessary to understand the complex set of technical, social and economic constraints under which they are built. Research is required to elicit the problem domain and the boundaries of the system to its environment, including people, natural systems, physical systems, and other ambient intelligence components. In ambient intelligence, these boundaries become more critical since there is a need to take into account an all-encompassing view of extremely complex systems, and decisions have to be taken about the requirements of systems over extended periods of time. Research is required to understand how software designs are constrained by requirements related to quality and resource usage, and also how design choices are made and validated. Design decisions are crucial in ambient intelligence since they will include a wider variety of components and devices.

For successful ambient intelligence development, new ways must be found to help developers and stakeholders learn from experiences and exploit the resulting knowledge in future development. ISTAG suggests that this will only happen if functional, technical, social and economic requirements of systems, gathered from users and stakeholders, are put at the centre of the development process and are revisited throughout design, implementation, checking, and testing. This approach, however, is extremely challenging and extends well beyond the requirements for software design that are in practical use today. Thus, it is essential that research be conducted on mechanisms that can capture the new meaning, semantics and

performance goals. Such an effort will benefit substantially from the design of innovative extensions to precise formal and mathematical ways of stating new, stronger, and more diverse requirements, and the development of techniques, methodologies, and automated tools for checking such requirements. Innovative extensions of the interface of the new requirements with the design process are also needed.

Important steps towards increased user-centred design have already been taken, such as the ISO 13407 *Human-centred Design for Interactive Systems* and the *Design for All* standards for accessibility of information technology products. However, more needs to be done in this area. For example, requirements engineering for ambient intelligent systems design can no longer be seen as a task that can be accomplished primarily through the development of scenarios and the translation of use-cases into system requirements. System functionality that generates true user experiences can only be determined in a reliable way from feasible prototypes providing proof of concept. These are called *experience prototypes* and, to support their effective and efficient development, prototyping environments are needed that facilitate both feasibility and usability studies. More specifically this means that laboratories are required which contain infrastructures that support fast prototyping of novel interaction concepts and that resembles natural environments of use. Experience prototyping centres should also be equipped with an observation infrastructure that can capture and analyse the behaviour of people that interact with the experience prototypes.

A number of centres in both Europe and the United States are already showing the benefits of the experience prototyping approach. The Philips' *HomeLab*, for example, is a combined feasibility and usability laboratory that investigates, through extensive empirical research, which embedded interaction technologies are perceived by people as life enhancing experiences. *HomeLab* engineers build prototypes of embedded distributed systems that implement novel interaction concepts developed by industrial designers; cognitive psychologists subsequently evaluate these prototypes through extensive user tests. This advanced research centre consists of a feasibility nucleus surrounded by a usability shell. The feasibility nucleus is identical to an ordinary house with a hall, a living area, and a kitchen on the ground floor, and parents' bedroom, children's bedroom, a den, and a bathroom on the first floor. The usability shell consists of a sophisticated observation system with cameras, microphones, display monitors, and a storage system that can be used to record observed behaviour that can be analyses to validate certain working hypothesis supporting the use of novel interaction paradigms. For Philips the *HomeLab* has become an important instrument in the development of insight into user needs and their translation to functional requirements for distributed embedded systems. In Norway, Telenor has had similar success with its home of the future project and has gained important feedback from users, not just on technical usability, but also on the commercial viability of broadband services via a large-scale VDSL trial involving 750 households in Stavanger.

Building on these and similar approaches to experience prototyping, ISTAG suggests that ambient intelligence research increasingly needs *to allow people to live in their own future* to bring research closer to the needs of citizens and business. ISTAG recommends that instruments should be developed to create a European network of Experience and Application Research Centres for this purpose which could operate on a number of layers:

- science and technology centres: where basic research is conducted on component technologies for ambient intelligence;

- feasibility and usability centres: where components are integrated into real user environments on a small scale and usability is investigated;
- validation and demonstration centres: where promising prototypes are fully integrated into large scale real-life circumstances and validated through extensive user tests.

Within Experience and Application Research Centres it will also be useful to think of open systems in terms of a design approach that allows for adaptation over time, taking into account peoples' preferences, individual routines and ways of doing things. With these elements in mind, it is possible to consider three levels of activities:

- micro: this level addresses the individual's interaction with a product, service, environment or system – this is the traditional domain of user interface design or human-computer interaction;
- meso: this is the level of the group, or community which involves a multi-user locale with links to a distributed network. Examples are: the home, the school, the business, the hospital;
- macro: this is the level of the individual's movement across places and through time. In this scenario the focus is on time rather than place, and design needs to reflect the individual or group's experience across locales and activities. This is therefore a more holistic design approach that addresses societal interactions.

In any aspect of design the optimum outcome is that all three levels are coherent and integrated from a user perspective. For example, it is not desirable to design an interface at the micro level without taking into account the meso level of the context of the activity. Thought of in this way, the role of the Experience and Application Research Centres is to study the three levels of experience, based on insights from psychology and sociology to propose relevant, culturally appropriate and context and location specific ambient intelligence systems.

In conclusion, Experience and Application Research Centres are required that provide multi-dimensional strategies to involve users in the design process. These should be a response to the growing recognition that acceptance of ICT is not only shaped by their technological possibilities or by their functionality, but also by the micro-social context of the household or of other social settings. As the recent European Media, Technology and Everyday Life research study observed, some technology designers have questioned whether in-depth studies of users in *living labs* or real life settings are too costly or time consuming. ISTAG recognises that the cost implications of establishing a European network of Experience and Application Research Centres are significant, but also suggests that the successful realisation of the ambient intelligence vision requires a new approach to user-centred design, prototyping and validation. The European Media, Technology and Everyday Life study concluded that, "the real challenge may lie in involving users in a sociological sense, that is to say, by taking into account the micro-context of their everyday lives." ISTAG recommends that Experience and Application Research Centres can be an important instrument in helping to address this challenge.

8 Appendix Two – Examples of Experience and Application Research

8.1 Brazilian Sao Paulo e-Government Facility

The Electronic Government Innovation and Access (eGOIA) project [11,12,13,14] is a European Union funded activity within the @LIS program. The intent is to further develop and integrate some European research activities and results with the Latin American e-Government developments and goals for extended use. The project involves partners from Germany, United Kingdom, and Portugal in Europe and partners from Brazil and Peru.

In the context of the Experience and Application Research, the relevance of this project is its focus on user perspectives in a field trial providing an online e-Government-support system, for the inhabitants of the city of Sao Paulo in Brazil. In the long-term this system should support 18 million people. To handle this huge number each day with all the citizens' services the city has to offer, the Sao Paulo field trial has taken a first step. All the services such as passport, drivers licence, job offers, credits, etc., are offered in eight offices spread across the city. These centres allow the customer to access, at one point, all the services.

In the next step they have started to provide these services online and it is planned to offer them via the internet. As this system has to serve 18 million people with many levels of education and experience, user adaptation has become a significant focus for usability and acceptance.

A first set of services is online for test purposes. Customer services are available that support the users as needed. The service team, to get appropriate feedback from the user to the developer, documents the user experiences. In addition to these fully functional pilot installations, one installation is set up to analyse the direct behaviour of test persons willing to participate in such tests. Cameras watch the users, and their actions are documented. In this way the ergonomic use and human factors can be analysed, based on these user experiments and experiences.

In the context of Experience and Application Research this example shows use and test, directly in the users' environment. Of course this forces the researchers to take all necessary steps to confer with users and to create a functioning system.

8.2 German strategic research projects

The German government has funded a number of strategic projects of similar size to an Integrated Project. The typical number of participating partners from research and industry is between 20 and 50 partners. The intention is a further use of the results as products and platforms for future development, which is similar to the goal of Experience and Application Research. The global idea of Experience and Application Research however goes much further beyond the perspective of the German projects. However, these projects may offer some helpful experiences and insights. The projects of relevance are:

- iViP – Integrated Virtual Product Development and Demonstration Centre for Virtual Product and Production Development;
- Arvika;
- Embassi;

- MAP – Multimedia Work place of the future;
- Office of the Future – Office Plus;
- Office Innovation Centre.

The German Government funded the iViP (*Integrated Virtual Product Development and Demonstration Centre for Virtual Product and Production Development*) project [15]. It was a very large project, with about 50 partners from R&D as well as industry, and software developers, suppliers and producers. Within the project a platform was defined and developed as the basis for the integration of the different services needed to fulfil the requirements addressed. The idea was to develop an environment to be used by a variety of companies and allowing an easy integration of new services offered in the information technology support in the production process.

The perspective of the project was to make results available as a development platform, commercial products, and applicable user solutions. This has been reached partly already throughout the project. To further support the developments and trends, the iViP consortium joined the ProSTEP Association, which is involved in promoting STEP (Standard for Exchanging Product Model Data). The new ProSTEP-iViP Association with more than 200 member companies is marketing these ideas.

Independent of this, some of the results are available on the market from some members of the consortium. In parallel the Fraunhofer Society has set up the *Demonstration Centre for Virtual Product and Production Development* (DZ ViPro) [16]. This distributed centre is based on two main locations and four remote locations and different institutes each with its focus in this context. The target is the integration of processes, methods and tools in development and production in realistic application scenarios. The goal is to provide the defined platform and services for future developments, demonstration of prototypes and the use of the systems. The intent is to especially support SMEs that lack their own research capacities, through consulting, seminars, workshops, etc. The Demo-Centre offers the opportunity in parallel to the current operation to run the applications smoothly and to implement innovative concepts.

This idea was well received by customers, but this is still a laboratory environment, lacking real working conditions.

The co-ordinating project Arvika [17] aims to research and to realise Augmented Reality technologies which will support development, production and servicing in relation to complex technical products in a user-oriented and application driven manner. Through the visual superimposition of real objects on computer generated virtual objects, Augmented Reality technology makes it possible to act appropriately, in the sense of this extended reality, in real working environments.

This consortium involves the automotive industry, and their suppliers, as users, together with R&D groups as well as technology development companies. Different products were developed and are being, or will be, commercialised by the technology partners and a spin-off company set-up by the R&D partners is being established.

The goal of the Embassi project is to develop an integrated assistant concept, which optimally supports users in their day-to-day use of technology applications. Embassi follows an approach of a dynamic networked system, enabling users to access and to interact in a natural

way with systems. This user-centred approach does not focus on the functional opportunities, but on the requirements and goals of the user of the technology. With multimodal methods, like speech and gesture recognition, users can express their needs to the system. These expressions are interpreted by the system and fulfilled as appropriate for the user.

Goal-oriented interaction is another step to support the user intentions in relation to the given target. To reach this goal, the rules and functions are provided and the sequence of actions leading to the goal. All the integrated devices, with their functionality, provide the system-oriented view, which offers the user the perspective of integrated devices of one system as interacting components leading to the goal.

To demonstrate and test the usability and feasibility of the results, technologies from the private sector were selected. Different generic, but re-usable, concepts and prototypes were developed to support users in handling the systems.

The project *Multimedia-Arbeitsplatz der Zukunft* (MAP) or *Multimedia Workplace of the Future* [18] aims at relieving users from time consuming routine tasks by applying innovative agent and assistance concepts. Using mobile computers, permanent and ubiquitous, circumstance-driven assistance with tasks involving high mobility will be provided. One project (*Mobile Basis and Assistance*) is developing a personal task management assistant. This assistant will be able to actively support the user in tracing and managing diverse activities and contexts. Using sensor-based cognition, it independently identifies activities and contexts relevant in the actual situation. Thus it is able to provide the right information in the right circumstances. Moreover, it can suggest the execution of tasks to reach a predefined goal efficiently.

The Office Plus project at Fraunhofer-IGD developed a system, which takes into account the new concept of the workplace office with two main purposes. One hand a new desk is being developed, considering the requirements of dynamically changing office environment; on the other hand a system is being developed, offering users the support needed, delegating the actions to the system, like an assistant or like a tool for a worker. In this case the users handle the system to solve their problems.

The decision support and its handling require special knowledge, to use the tools adequately and to be goal-oriented. The target of this project is to develop symmetry between users and the system. Users can delegate tasks to the assistants, which can then use special independent software-agents to solve task. The agent-based software platform is developed as a modular system. This can be adapted to special expectations by adding or integrating additional components.

At the Fraunhofer Office Innovation Centre, the future of work is being researched, lived and demonstrated. Experts from five Fraunhofer institutes work out prototypical solutions for the office world of tomorrow. The Federal Government, the regional Government of Baden-Württemberg, and numerous enterprises support this project, which is unique in Germany. The concept of this demonstration centre offers various possibilities to manufacturers and users alike to engage themselves actively in this joint project. The Office Innovation Centre offers the following services to enterprises:

- consultations on modern and innovative solutions for the realisation of economic and creative office concepts;

- testing of partners products and assessment of their future potential;
- use the Office Innovation Centre for R&D as well as for marketing;
- collaboration with the Office Innovation Centre and other enterprises;
- use of the Office Innovation Centre's virtual platform as a marketplace for products and a basis to open up new markets;
- synergy with other contributors and sector-wide co-operation.

8.3 The Intelligent House Duisburg Innovation Center – inHaus

The inHaus project [19] offers a networked living environment following an integral concept of product-oriented innovations and networked life. The facility offers areas of home, workshop, car and garden.

The common goal is co-operative support of innovation, R&D, acceptance, and marketing for the *intelligent home*, through networking with partners about ideas, technologies, products, and activities. With a long-term contract, the project offers a:

- a living laboratory for testing, including the social and market research;
- comprehensive centre for integration, research, testing, development.

In addition there is also a demonstration of intelligent living, which was set up with the goal of marketing smart-living products and services.

The benefits of the project are results from market and technology acceptance research with respect to novel smart-living products, functions, and services. These results can then be developed in laboratories, and then later tested in the inHaus facility. A close feedback practice between the partners and activities provides the basis for an accurate and thoroughly analysed evaluation of results. A point of concern is that there are a few properly working applications with proven useful effects.

8.4 Living Tomorrow

Living Tomorrow [20] is a new-technology demonstration centre in Brussels which was first established in 1995. The original facility was replaced in 2000 by a new one, which cost €14 million, and this will also be replaced in 2005 by another updated centre. There is also a sister demonstration centre in Amsterdam, which cost €20 million. Similar facilities are also planned elsewhere in the world.

Funding for Living Tomorrow comes from companies that participate in projects. The benefits to the participating companies are support for their development activities, collaboration with other partners, demonstration of products and prototypes to a wide audience, image building, and publicity. Projects are organised so that no competitors participate in a particular project, although competitors may participate in other projects. The company that owns and operates Living Tomorrow is a not-for-profit organisation and does not own any intellectual property arising from any of the projects that it runs.

A wide range of companies is involved as partners in projects. They include enterprises that supply building components, electrical equipment suppliers, heating and energy systems companies, ICT vendors, and manufacturers of household appliances. Other companies fall

within the categories of: interior design materials; public relations; furniture manufacture; environmental systems; food products; security; and garden furniture and construction materials.

The Living Tomorrow facility in Brussels consists of a house of the future with home office, and an office of the future. About 80% of the technologies on show are close to market. The other 20% are more advanced concepts several years away from market introduction.

Living Tomorrow provides a vision of how people may live and work in the future. This is based on tangible demonstrations of technologies and systems, integrated into quasi-realistic home and office environments. The technologies demonstrated are not just limited to ICT, but also include architecture; building materials, components and systems; heating and ventilation systems; furniture; etc.

The target groups are mainly professionals and students. About 80% of visitors to the Brussels facility fall into these two categories. The remaining 20% are the general public. Visitors are given a guided tour. The primary activity is demonstration. There is a small amount of evaluation based on optional questionnaires.

The house of the future demonstration consists of a bathroom, kitchen, dining area, bedroom, home office, etc. In the home there are: facilities for on-line shopping; facilities for remote control of home devices, heating, lighting etc.; information systems; digital television; and home entertainment. For the home office there are facilities such as internet, personal computers, and videoconferencing.

The office of the future demonstration consists of a number of technologies and systems. There is a demonstration of telephone calls using the internet protocol. Also on show are demonstrations of e-banking, e-commerce, e-security, e-collaboration, and e-publishing. Some of the technologies used include speech recognition, a web-enabled call centre, wireless application protocol, track and trace technologies, web services, biometric recognition, broadband communications, and active collaborative filtering.

8.5 Philips HomeLab

Philips has set up a special observation home, called HomeLab [2], in which multidisciplinary teams of researchers can try out technologies in realistic settings and observe people using ambient intelligence in normal home surroundings. HomeLab is part of a research effort addressing the practical implementation of ambient intelligence in ordinary homes. The aim is to identify the technical problems that have to be overcome, and what user objections need to be resolved.

The Home is a two-story house with a living room, a kitchen, two bedrooms, a bathroom and a study. It looks like a normal family home; only the location of the home and the small black domes in the ceilings concealing cameras and microphones indicate that it is something different.

The Lab, next door, has two observation rooms from which researchers can watch what is going on in the Home via two-way mirrors and video cameras. The main observation room looks on to the living room, while the other observation room, located upstairs, looks on to the

bathroom, so that researchers can watch people shaving, drying their hair or cleaning their teeth. The two-way mirrors here can be turned into *smart mirrors*, which enable people to check the news, traffic position or even their weight.

HomeLab has been used to investigate a number of problems:

- locating people;
- interaction with speech-based systems;
- gesture recognition;
- interference between wireless systems;
- practicalities of hiding systems;
- quality of user experiences.

Locating people is a problem because radio and ultrasound waves can locate people under ideal conditions, but in the home, furniture and people move around which complicates normal reflections and transmissions. With speech recognition systems, echoes and background noise can prevent the system from hearing clearly. And video recognition of gestures is possible in good lighting conditions, but opening or closing a door, or someone walking around, or reflections from shiny surfaces and changing light conditions, can cause problems.

Interference between wireless systems is also a potential problem area. People will want their information or entertainment wherever they are in the home. Portable devices that can be used anywhere in the house require *ad hoc* wireless networks. Quite likely, several systems on the same frequency band will be used. The question then arises how to solve problems of mutual interference or the influence of walls and ceilings.

Ambient intelligence technologies will be largely hidden, but in practice many issues emerge when trying to hide everything away. The Home has all the potentially problematic elements found in a real house, for example, walls that block the infrared beam of a remote control. With the adjacent location of the Lab it is possible to simulate ambient intelligence applications in the Home next door, ahead of the time when sufficient miniaturisation will have been achieved.

Finally, there is the question of how people will use ambient intelligence. How will they use the interfaces? Which ones will they prefer? Will they want certain aspects of their ambient intelligence to be visible? The only way to answer these and the many more questions that will arise as ambient intelligence evolves is through iterative processes of testing, observation and refinement.

HomeLab provides a unique environment that allows Philips' developers not only to examine individual issues, but also to investigate peoples' experience of ambient intelligence; ultimately it is the quality of this experience that will be the touchstone of success

8.6 Telenor's House of the Future

Telenor's *House of the Future* [21] was built as a *laboratory for living* in the sense that the research included user experiences of living with technology in everyday life in the future. The activities undertaken were split between basic research and laboratory work, and more outward looking work and profiling. The house has also been used for customer seminars and piloting products from Telenor's business units. The technical activities have spanned different areas and concentrated on technical infrastructure, home automation and home networks, user behaviour and user interfaces.

Researchers from different disciplines collaborated through a series of workshops with the architects in designing the house and laboratory. It is estimated that the costs for this preparatory work were about €57,500, not counting Telenor's labour costs.

The house was built on Telenor property, so the costs of site were not included in the budgets. However, the lack of control over the property resulted in the research being prematurely terminated, owing to development plans for the area.

The actual building costs amounted to about €517,000. The Norwegian State Housing Bank provided a grant of 33% for the building costs. This is more than an average house of similar size (150 square metres), but the laboratory had special qualities such as the possibility of creating flexibility, for instance, flexibility of cabling and flexibility of creating a variety of space plan solutions. Basic technological infrastructure costs were €172,000, with the annual need of about €57,500 for technological renewal in relation to basic research.

Costs of operation and maintenance were equivalent to one person working full-time, amounting to about €115,000 annually. However, the largest investments were made through the research itself. The level of activity in Telenor's house has been equivalent to seven to eight researchers employed each year, adding up to a cost of about €1,150,000 annually.

Thus the cost of setting up this facility shows that relatively similar facilities may be established for about €750,000, with this covering the costs of preparatory work, building costs and infrastructure.

The building represents a focal point and a physical manifestation of a willingness to invest in an area of user research. Telenor experienced the house to be of great value for external co-operation and collaboration. It has received a lot of media exposure, which created interest and attention and brought the research into the public sphere. However, internal collaboration has been a challenge. Bringing research from concepts and product ideas to commercial products needs close integration and collaboration between researchers and product developers in the business units.

Telenor's experience was that the house contributed to research in the following ways:

- focus and frames: the house was an arena with set frames that directed and focused the research;
- collaboration: it is simpler to agree and collaborate on the level of uses of technology in an actual physical context;

- interdisciplinary: solving problems together in a full-scale laboratory makes it easier to cross the barriers of disciplines;
- communication: the context that the house provided and the facilitators helped in communication of complex solutions such as new technologies, or future uses of technology. It was also an opportunity to apply unconventional methods in communication, such as demonstrators, videos and installations;
- a homepage on the internet also provided communication possibilities: this feature can contribute to research by providing news from projects, results, and help researchers make contact with one another, and give users experiences, for instance a walk-through of the house with demonstrations.

Studies have identified *distributed families* as a new user group. These have specific needs for communication and personalisation of services and physical surroundings. These findings were the basis for co-operation with IKEA and the Norwegian State Housing Bank, looking more closely at the relationship between technology and the use of space. The results were refined and developed into a flexible room in the *House of the Future*. Telenor R&D demonstrated various technologies and possibilities for personalisation through a surrounding interface. For example, a smells interface has been developed, as has a video mosaic (dynamic wallpaper) and different forms of projections on to walls and other objects. Together with earlier demonstrations in the house, these interfaces provide opportunities to adapt surroundings to the particular person at any given time.

8.7 Telenor's field trials

Telenor has executed a number of small and medium scale field trials of new technologies throughout the years. Their experience is that such studies are very useful, they provide data for high quality research, and may bridge the gap between technological development and market implementation.

A field trial can be based on existing infrastructure on site, for example in a home, hospital or nursing home. In some cases pilot tests are performed in conjunction with already planned rollouts of new networks and services. Tests of mobile services may be especially inexpensive and easy to set up, the only requirement for adding new users may be to provide them with mobile telephones with software.

The following studies are presented as examples, with resource estimates and lessons learned.

VDSL pilot in Stavanger

The purpose of the very high speed digital subscriber loop (VDSL) and Triple Play pilot project in Stavanger was to prepare for the launch of television and video via digital subscriber loop (DSL) technology, to reduce the risks connected with marketing, development and investment. Technical solutions and products have been verified through piloting with 720 users in Stavanger.

The tests were based on an existing infrastructure, or the continuing development of new infrastructure in the area, in this case, a VDSL network. Equipment to perform the tests mainly included set-top boxes with installation.

The costs for the pilot consisted of a technical part and the user evaluations. The technical part includes equipment (€234,000), installation (€162,500) and technical maintenance (€199,000) adding up to approximately €585,000. The costs for the user evaluations were approximately €140,000. The costs for each user for the pilot were €1000.

The main lessons learnt are:

- longitudinal field research (3 years) captures changes in patterns of usage;
- that discrepancies arose between attitude to usage expressed in interviews and surveys, and data from computer logs of actual use;
- patterns of usage changed as the pilot services went from being free to being subject to a charge.

The Youngster Project

The Youngster project, supported by the IST programme, developed technologies to create a new open active mobile multimedia environment that is accessible from anywhere by a wide range of devices and networks and supports context-aware features, including location-awareness, allowing seamless and highly adaptive delivery of services. A mobile service platform was developed and a demonstration of the new services was performed through a field trial with a dedicated user group of 64 teenagers. The Youngster project followed a user-driven approach, which was implemented from the outset of the project. Starting with pre-trial information about the social networks, estimates for use, demographics and comparative analysis, user requirements were collected, starting from the beginning of the project. During the trial all user data was logged (Youngster service and telecom traffic data) and qualitative interviews were performed to get direct feedback. This approach was used to incorporate user feedback into feature enhancement and new youngster services [22].

The total costs for realising the pilot were €406,000. Other costs related to end user support; the refund of end user general packet radio service (GPRS) traffic and subscription costs of the order of €8,200. Cost related to hardware and software was negligible since existing hardware and open-source software were used. The human resources costs related to the pilot were broken down into the following categories: Integration of Services with the MSP (€113,474); Planning of the User Trials (€46,650); Execution of the User Trials (€94,561); Analysis of the User Trial Results (€75,650); Other (€65,489).

The main lessons learnt are:

- field research provided contradictory results to those previously obtained from focus group research, and provided more valid results about the attractiveness of new applications;
- the field trial provided insight into user creativity in the use of technology (making the technology their own);
- the field trial created an opportunity to test stability of technological solutions.

Home-School communication

Telenor has developed a web-based application for home-school collaboration, which was tested in a pilot study [23]. The application is designed to reduce the barriers, for teachers and parents, to use digital information through new communication channels. The application can

send email and text messages, and provides streaming of multimedia data, about school activities, to the parents at home or in their offices. The application was tested in the field involving eight school classes in a suburban primary school in Oslo. The trial was based on interviews with teachers and parents about their practices and needs for communication towards one another. The cost of the field research is estimated for the school year 2003/04 to be about €188,000, including operation, licences and user evaluation (questioners and interviews). The cost for development of the application was about €9,700.

Work on this project was still continuing at the time of publication of this report. The main lessons learnt up to this point are:

- users want to be actively involved in field trials, and contribute to adjustments in applications;
- users provide useful feedback for product development.

The Memo Project

A field trial with multimedia message service (MMS) use in three different groups of users was launched in June 2003, giving 28 employees in different mobile teams access to MMS for a period of six months. The groups were all relatively small but highly integrated with a dense internal network of communication. The three groups included: a team of mobile sales people for a soft drinks company; a group of real estate sales people; and a team of carpenters. During the field trials, group interviews were held as well as collection of data from formal individual interviews and observations of use. In addition, MMS messages were collected to provide insight into actual types of use. Actual cost for the complete study during one year was €185,152.

The main lessons learnt are:

- the usage of a mobile multimedia messaging system (MMS) depends on the development of genres of use if it is to be recognised as a useful tool by professionals;
- based on field trial, several general genres of use were identified.

Mobile Public Key Infrastructure projects

Telenor Mobile has performed a number of mobile Public Key Infrastructure (PKI) pilot tests in the Oslo area. These were small-scale field tests of services based on authentication and digital signature on documents like applications for kindergarten and building licences. The number of users in each pilot was typically 15-30.

The costs for these field trials were made up of a number of person-hours for integration of the PKI infrastructure with the county council ICT systems, training of the users and preparations for the tests, in addition to a mobile telephone, with software, for each user. The typical number of person-hours for a field test was 60-70.

The main lessons learnt is that field tests, with users in their own environment (at work, at school or at home) are important in:

- getting relevant feedback for the final design of services;
- preparing the market for new services.

9 Appendix Three – Methods and Tools for Experience and Applications Research

9.1 Introduction

This appendix provides a short overview of the methods that can be applied in Experience and Application Research, along with the subject of further research into methods for R&D activities carried out in Experience and Application Research. This short overview is not exhaustive, but serves as a starting point for discussions. The methods that are suitable for different types of Experience and Application Research activities are not prescribed.

9.2 Methods involving the user

This section lists methods that have been designed specifically to involve the user in the development of software, specifically requirement analysis that involves systems with a user interface. Each method is briefly described.

User-centred design [24]. Not only are users involved, but also in their own context. Emphasis is on iterative short cycles and prototypes. User-centred design is multidisciplinary.

Participatory design [25]. The goal is to work directly with users in designing computer systems that are a part of human work. Participatory design is rooted in Scandinavian countries with strong labour unions and democracy in the workplace. It has then moved on to other parts of the world. Muller, Wildman and White [26] give an overview of participatory design practices and thereby answer questions such as: Who participates with whom and in what? Where do they participate in the development lifecycle? What are the appropriate sizes of groups? The users participate in the design and are not merely a subject of research.

Co-creation. Designers and users are partners in design, and users participate actively in the design, not only as evaluators, but also as designers. End-user programming, where users write their own programmes may be classified under this method.

Contextual design [27] has different parts: contextual inquiry; work modelling; consolidation of work models through affinity diagrams; work redesign; user environment design; mock-up and test with customers; and putting the new design into practice.

Activity theory [28]: What sets activity theory apart is that it takes into considerations the capabilities of the individual groups instead of addressing the generic user. It concerns itself also with collaboration of humans instead of focusing only on one user's work. There is also strong focus on artefacts and their role in work activities.

Scenario based development of human-computer interaction [29]. Scenarios are used throughout the software development, first in requirements analysis and then through design, documentation and evaluation. Scenarios describe a sequence of interactions between a user and a computer, its contexts, and users' mental activities such as goals, plans and reactions. Trade-offs are a fundamental aspect, as well as prototypes.

9.3 Research Methods

The methods listed in this section are more general research methods than those listed in the previous section and much broader than those used for the development of software. The first two are research methods categories.

Qualitative research [30]. This is gaining more popularity, perhaps because of the need to do contextual work. Grounded theory is an attempt to make analysis from qualitative data more formal. Qualitative research still lacks connection to *formal* work products needed by engineers.

Quantitative research. This is suitable when there is a need to measure something quantitatively with numbers, in an objective manner.

Action research. This is iterative, and humans are not seen as subjects, but are actively involved.

Soft systems methodology [31]. This method is applied to what Checkland describes as human-activity systems where desirable ends cannot be taken as given.

9.4 Quality of human-computer interaction

Usability is traditionally defined as effectiveness, efficiency, and satisfaction, but this understanding may be changing to aim for empathy, fun, motivation, trust and aesthetics, and competitiveness.

When evaluating a design, other measures than usability may be interesting, such as usefulness and intention to use. Davis [32,33] has proposed a Technology Application Model that subjectively measures these aspects with a set of questions.

There is a need to specify the quality of use or quality of human-computer interaction, that is to say, measures against which ambient intelligence can be evaluated. The evaluation can be seen as formative, that is to say, giving further input into the development, or summative, that is to say, verifying that targeted qualities have been reached. Quality models for human-computer interaction should not be viewed in isolation, but along with other quality attributes such as security, reliability, portability and maintainability. These quality attributes no doubt affect ease of use.

Several evaluations methods are in use, such as heuristics evaluation and user testing (think-aloud protocol), but without assurance that they work for different application areas and complexity. Evaluation methods can be divided into predictive, user-based and model-based techniques. They can be either manual or automatic and be tailored for different types of platforms or domains. Practitioners will demand that human-computer interaction research be founded with empirical studies of these and other methods.

9.5 Models

A model is a description of a system and its interaction with other systems. Initially the model describes what problem systems should solve, and then it can be gradually refined to describe how the system solves the problem. Finally when operational, the system can be viewed as a model of some domain behaviour and characteristics.

Models can be informal or formal (or semi-formal) the first one often suitable to show users, but the latter more appropriate for engineers. Examples of informal models are prototypes of various kinds, text scenarios, storyboards, sketches, props, etc. Formal models can be divided into several categories depending on what they describe, that is to say, cognitive processes, software systems, or interactions between these. Other categories may be useful to describe other systems in ambient intelligence, for example, biological, natural, or physical systems. Examples of cognitive models are concurrent task trees [34], cognitive work analysis [35] PUMA, GOMS, SOAR and ACT-R (see for example, the overview by Dix [36]). Examples of software system models include state models, ontology, activity and collaboration models, and use case models. Interactions are modelled with dialogue and communication models. Different languages are used to describe those models, for example, diagrammatic semi-formal like Universal Modelling Language [37] or formal ones Z, VDM, B, ASM and Petri-nets to name a few.

9.6 Development lifecycles

A development lifecycle organises different fundamental software development processes into phases and prescribes in what order they are carried out. In addition, a lifecycle may describe to what extent the software development processes are relevant and how they are implemented.

The current trend in software development lifecycle is in-line with Experience and Application Research. The waterfall model, where there is a strict sequence of phases, is being replaced with more iterative and incremental lifecycles. The spiral model is risk driven as is the Unified Software Development Processes, which is additionally architectural and user-centric. Recently a class of lifecycle methods, such as DSDM, Extreme Programming (XP), Feature-based Development and a range of others have been termed as Agile Development [38].

9.7 Emerging approaches

There are other emerging approaches that are of interest. The methods investigated or applied in Experience and Application Research also need to be suitable for the characteristics of ambient intelligence. It is suggested that the methods take ambient intelligence into account and consider the following:

- *Community-centred:* Focuses on human-human interaction mediated by technology includes, for example, distributed cognition that emphasises the interaction between humans as well as with other phenomena in the environment;
- *Problem oriented:* Finding solutions to problems instead of being purely technology driven. A balanced view is aimed for between problem and technology that iterates between the two poles;

- *Context-dependent*: Carried out in context for systems sensitive to context;
- *Mobile and transparent***:** Entities are able to move between communities and cultures and changing roles;
- *Inclusive*: Tailored towards individuals, taking into account learning, growth and the changes of individuals;
- *Intelligent;*
- *Targeted for competitiveness or public service;*
- *Quality as focus;*

10 Appendix Four – Software and Interface Requirements

European projects must, in general, avoid supporting developments based on proprietary environments. The requirement is to make results accessible and usable for other participants and users. This is especially relevant to Experience and Application Research, since the proposed plan calls for a number of centres and activities. These need to be linked in two ways:

- technological developments must be able to fit in different application, or cultural environments, to address the different types of users;
- technology will be developed from the feasibility level through to the demonstration and experience level, and will be moved from one environment to another in successive stages of its development.

The main issue is to ensure compatibility among the technologies for easy integration in the centres. This applies not only for the set up of demonstrators, but also to allow compatibility among the centres. This is not only important for the applications, but also for the tools to be developed for the analysis and the evaluation of the scenarios and user behaviour and experiences. This will be the basic condition to re-use the results, methods and tools across Experience and Application Research Centres.

Ambient intelligence is still developing and it is not possible to predict the standard platform for ambient intelligent systems in two years' time, and the main recommendation is to require that consortia applying for funding to set up and run centres, adopt portability requirements oriented to open-systems. This does not only apply to the preference for open-source solutions, instead of proprietary ones as platforms, but also to *open up* the results with respect to interfaces and algorithms as needed, to allow the integration of modules and the exchange of data.

Interface and data formats standards, such as the universal mobile telecommunications standard (UMTS) for mobility must be taken into consideration as they become available, and also during their development. The development and setting of standards is an important issue for the European Commission, and therefore these matters have to be included in the experiences, application testing and evaluation process.

To make best use of software technology, developers must, as far as possible, make use of, or apply, existing platforms and developments for agent technologies, plug-and-play technologies, and the semantic web.

The intention is for Experience and Application Research Centres to set-up new technologies in real life environments. It is therefore important to develop and identify the behaviour models of the user community. The mutual effects of the different technologies recommended for, and used in the new environment, have to be taken into consideration. They cannot be seen only as stand alone technologies, but must be addressed as part of the new infrastructure.

To give the proposers and developers some guidance in the context of the system environment, a reference model should be defined, showing the conditions for the integration of modules and tools and for the participation in one or more Experience and Application Research Centre. This could define an open ambient intelligence platform or infrastructure. This reference model would have to be followed by the consortia setting up Experience and Application Research Centres, as well as by the technology development partners.

11 Appendix Five - References

[1] ISTAG in FP6, Working Group 1 Report, *IST Research Content*, http://www.cordis.lu/ist/istag-reports.htm, September 2003

[2] Emile Aarts and Stefano Marzano (eds.)*: The New Everyday, Views on Ambient Intelligence*, 010 Publishers, Rotterdam, The Netherlands (ISBN 90-6450-502-0), 2003

[3] Andries van Dam: User Interfaces: Disappearing, Dissolving, and Evolving, *Communications of the ACM*, March 2001

[4] Hartmut Raffler: The Market Potential for Human-Computer Interaction Technologies. Statustagung zur Mensch-Technik-Interaktion in der Wissensgesellschaft, DLR im Auftrag vom Bmb+f., October 2001

[5] Floyd C. and Keil R., Adapting Software Development for Systems Design with Users. In *Systems Design For, With, and By the Users* (In Briefs U., Ciborra C. and Schneider L. eds.), Amsterdam: North-Holland, 1983

[6] Gane C. and Sarson T., *Structured Systems Analysis: Tools and Techniques*. Woking: McDonnel Douglas Corporation, 1977

[7] Boehm B.W, A Spiral Model of Software Development and Enhancement. *IEEE Computer Society Magazine*, May, 1988, pp61-72

[8] Seaman, Mendonca, Basili, Kim, User Interface evaluation and Empirically-Based evolution of a prototype Experience Management Tool

[9] Wenger, Etienne, Communities of Practice and Social Learning Systems, *Organisation Articles*. 2000, Vol 7 (2): 225-246.

[10] Williams, F. Rice R. E. and Rogers, E. M., *Research Methods and the New Media,* The Free Press, New York, 1988

[11] eGOIA project: http://www.egoia.info

[12] The green book of the Brazilian Information Society Program can be seen visiting the web site: http://www.socinfo.org.br/livro_verde/ingles/index.htm

[13] Hoepner, Petra, 2003. Electronic Government Innovation and Access - The Basics of eGOIA. IFIP I3E Conference, Guarujá, Brazil, Workshop “e-Government: Best practice solutions and standardization activities”.

[14] Jarbas Lopes Cardoso Junior1, Manuel de Jesus Mendes1, Romildo Monte1, Petra Hopner2, Implementing Electronic Government: The eGOIA Project

[15] iViP project: http://www.iViP.de

[16] Demo Center ViPro: http://www.DZVIPRO.de

[17] ARVIKA project: http://www.arvika.de/

[18] MAP project: http://www.map21.de/

[19] inHaus project: http://www.inhaus-duisburg.de/en/

[20] Living Tomorrow: http://www.livtom.be

[21] Telenor’s House of the future: http://www.fremtidshuset.com

[22] the Youngster project web site: www.ist-youngster.org

[23] home-school communication web site: http://www.boler.gs.oslo.no/

[24] Gulliksen, J., Göransson, B., Lif, M, A user-centred Approach to Object-oriented user Interface Design, in *Object Modelling and User Interface Design*, Mark Van Harmelen Editor, Addison-Wesley 2001

[25] Kuhn, Sara and Muller, Michael, Guest Editors of Special Issue on Participatory Design (1993) Participatory Design, *Communication of the ACM*, Vol. 36, No. 4

[26] Michael J. Muller, Daniel M. Wildman, Ellen A. White, Taxonomy Of PD Practices: A Brief Practitioner's Guide, June 1993, *Communications of the ACM*, Volume 36 Issue 6

[27] Beyer, Hugh and Holtzblatt, Karen, (1998) *Contextual Design,* Morgan Kaufman

[28] Bertelsen, Olav W. and Bødker, Susanne, (2003) Activity theory, in *HCI Models, Theories and Frameworks,* John M. Carroll, editor, Elsevier Science.

[29] Rosson, M.B. and Carroll, J. (2002), *Usability Engineering, Scenario-based Development of Human-computer Interaction,* Morgan Kaufmann

[30] Taylor, Steven J. and Bogdan, Roberg, (1998) *Introduction to Qualitative Research Methods,* third edition, Wiley

[31] Checkland, Peter and Scholes, Jim (1999), *Soft Systems Methodology in Action*, Wiley

[32] Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 319-340.

[33] Venkatesh, V., Davis, F. 2000, A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies, *Management Science* © 2000 INFORMS Vol. 46, No. 2, February 2000 pp. 186–204

[34] Paterno, Fabio, 2003 ConcurTaskTrees: An Engineered Notation for Task Models
F.Paternò, Chapter 24, in Diaper, D., Stanton, N. (Eds.), The Handbook of Task Analysis for Human-Computer Interaction, pp.483-503, Lawrence Erlbaum Associates, Mahwah
[35] Vicente, Kim J. (1999) *Cognitive Work Analysis,* Lawrence Erlbaum associates
[36] Dix, Finlay, Abowd, Beale, 2004, *Human-Computer Interaction*, 4th edition, Prentice Hall
[37] Larman, Craig, (2002) *Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and the Unified Process* (Second Edition), Prentice-Hall
[38] Cohen D., Lindvall M., and Costa P., "Agile Software Development", Tech Report Number: DACS-SOAR-11 , DACS State-of-the-Art-Report. The Data & Analysis Center for Software (DACS) is a Department of Defense (DoD) Information Analysis Center (IAC). 2003. Available at: http://www.thedacs.com/techs/agile/

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