Ambient Intelligence
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4 Ambient Intelligence: from Vision to Reality

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Abstract: According to the ISTAG vision statement, humans will, in an Ambient Intelligent (AmI) Environment, be surrounded by intelligent interfaces supported by computing and networking technology that is embedded in everyday objects such as furniture, clothes, vehicles, roads and smart materials - even particles of decorative substances like paint. AmI implies a seamless environment of computing, advanced networking technology and specific interfaces. This environment should be aware of the specific characteristics of human presence and personalities; adapt to the needs of users; be capable of responding intelligently to spoken or gestured indications of desire; and even result in systems that are capable of engaging in intelligent dialogue. Ambient Intelligence should also be unobtrusive - interaction should be relaxing and enjoyable for the citizen, and not involve a steep learning curve. Insofar as AmI is "a set of properties of an environment that we are in the process of creating", ISTAG does not think it necessary to more tightly define the term Ambient Intelligence. But it is important to appreciate that AmI remains an 'emerging property' and that future scenario building and iterations of the vision should treat AmI as an 'imagined concept' and not as a set of specified requirements.

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4.1 Introduction

During 2001 and 2002, ISTAG recognised that the EU strengths in ICT lie primarily in mobile and wireless systems, in consumer electronics, in sectors such as automotive or aerospace, that deploy embedded ICT extensively, and in application sectors such as banking and manufacturing, and software suppliers to these sectors.

ISTAG further recognised that promotion of the concept of Ambient Intelligence ('AmI') would build on these European strengths, facilitating the establishment of markets, thereby enabling more suppliers to grow and especially to gain critical mass for long-term viability.

This will strengthen the role of European industry in shaping the development of next-generation ICT.

In 2002, ISTAG published the report *"Strategic Orientations & Priorities for IST in FP6"* which derived, from the concept of Ambient Intelligence, the guiding principles for the Information Society aspects of Framework Programme 6.

During 2003, ISTAG has reconsidered the AmI vision, to check its validity and to determine what might be done to realise the vision, beyond the immediate activities in Calls 1 and 2 of the IST theme in FP6.

ISTAG believes that *it is necessary to take a holistic view of AmI, considering not just the technology, but the whole of the innovation supply-chain from science to end-user, and also the various features of the academic, industrial and administrative environment that facilitate or hinder realisation of the AmI vision.* There are several reasons for taking such a holistic view:

- The technical complexity of modern systems based on ICTs requires that all aspects of the innovation chain integrate their efforts
- The rapid co-evolution of the technology and the market
- The concentration and coherence required to achieve both significant technological development and significant market impact requires engagement of both academic and industrial researchers, which is conditioned by business strategy, which is in turn conditioned by investment strategy.

To inform their deliberations, ISTAG established a set of working groups spanning these issues, addressing:

- IST research content
- Human resources and infrastructures for research
- Exploitation of research results
- Funding mechanisms and partnership.

This report draws on the reports of those working groups and related discussion in ISTAG.

For the sake of presentation, the structure of this report is based on three perspectives – technology, business and resource on each of which there is a paragraph. These are preceded by an overview of the evolution of the AmI vision, and followed by a paragraph addressing specifically the requirement that, to realise the AmI vision will require not only a holistic concept of AmI, but a holistic approach to research, and to technology development and assessment.

The holistic nature of the problem is illustrated by the impossibility of 'pigeon-holing' some

of the topics. Open standards, for instance, have technical content but frequently they are essential to establish a business case for investment. Public procurement, to take another example, plays different roles according to each perspective - 'pulling' technology development, establishing a business market, and supplementing the resources applied. Topics such as these are presented where their main focus resides.

This report is neither comprehensive nor complete: its purpose is to draw attention to the key topics on which ISTAG believes the community should focus if the AmI vision is to be realised.

4.2 Evolution of the AmI vision: for participation – in society & business

According to the ISTAG vision statement, humans will, in an Ambient Intelligent Environment, be surrounded by intelligent interfaces supported by computing and networking technology that is embedded in everyday objects such as furniture, clothes, vehicles, roads and smart materials - even particles of decorative substances like paint. AmI implies a seamless environment of computing, advanced networking technology and specific interfaces. This environment should be aware of the specific characteristics of human presence and personalities; adapt to the needs of users; be capable of responding intelligently to spoken or gestured indications of desire; and even result in systems that are capable of engaging in intelligent dialogue. Ambient Intelligence should also be unobtrusive - interaction should be relaxing and enjoyable for the citizen, and not involve a steep learning curve.

Later reports have helped expand the AmI vision but have not significantly altered it.

The 2002 ISTAG Report *"Strategic Orientations & Priorities for IST in FP6"* added the notion of *'AmI Space' in which there will be seamless interoperation between different environments* – home, vehicle, public space, etc. There has also been the important recognition that, to be acceptable, *"AmI needs to be driven by humanistic concerns, not technologically determined ones"* and should be "controllable by ordinary people".

Insofar as AmI is *"a set of properties of an environment that we are in the process of creating"*, ISTAG does not think it necessary to more tightly define the term Ambient Intelligence. But *it is important to appreciate that AmI remains an 'emerging property' and that future scenario building and iterations of the vision should treat AmI as an 'imagined concept' and not as a set of specified requirements*.

While AmI should not be promoted as a universal panacea for social problems, it certainly represents a new paradigm for how people can work and live together and it provides radically new opportunities for both individual fulfillment and social discourse. *We should not underplay the radical social transformations that are likely to result from the implementation of the AmI vision.*

AmI enables and facilitates participation by the individual - in society, in multiplicity of social and business communities, and in the administration and management of all aspects of their lives, from entertainment to governance.

Participation in society

Further development of the AmI vision needs to progress towards a more holistic understanding of AmI and how it can be applied within a social context. In this iteration AmI is seen more as a feature of the dynamic process whereby people live in and navigate between

(both physically and virtually) different interconnected social settings (the home, workplace, school, hospital, social care facilities, cultural institutions etc.) Within each of these settings, the person will typically have different and even multiple roles and may have different needs that depend on both the physical context and the mood of the individual.

Participation in business

While the focus on AmI as a 'people first' vision should continue, ISTAG suggests that *the future development of the vision needs to combine the focus on the citizen and the individual person with more scenarios related to how the vision can be applied at the enterprise level* in both large companies and SMEs as well as in public sector and non-profit organisations.

Value-chain relationships will change significantly in the workplace under the impact of AmI and will affect every aspect of work processes. More effort is required in order to make employers, workers and trade organizations more aware of these potential changes, more able to respond to the new opportunities offered by AmI and more willing to experiment with the new forms of fluid business networks that permit independent organizations and multi- and interdisciplinary teams to easily come together in order to benefit from a business opportunity.

Section 4.2.1 which follows outlines some of the great potential that AmI offers for the individual, for society, for business, and for public administration. However, Section 4.2.2 concludes this paragraph by describing some of the challenges to realisation of thevision other than research and technology challenges: these must be addressed during the evolution of AmI.

4.2.1 Opportunities for AmI in Europe

The AmI vision starts with the recognition that, while the European Union is confronted with significant changes arising from globalisation and the challenges of a new knowledge-driven economy, information and communication technologies have the potential to enhance virtually every aspect of people's lives.

Significant *opportunities exist for AmI in relation to*:

- *Modernising the European social model* particularly in terms of: improving civi security; providing new leisure, learning and work opportunities within the networked home; facilitating community building and new social groupings; providing new forms of healthcare and social support; tackling environmental threats; supporting the democratic process and the delivery of public services.
- *Improving Europe's economy* in terms of: supporting new business processes increasing the opportunities for tele-working in the networked home; enhancing mobility and improving all forms of transport; supporting new approaches to sustainable development.

These are all supportive of the European Council's policy objective *"to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and social cohesion"*.

It is important to recognise that AmI not only has the potential to help address and solve socio-economic concerns over the longer term but that *AmI technologies and environments can already support efforts to implement existing policy strategies, objectives and targets*.

Community building and new social groupings: while numerous studies indicate that the

quality of social bonds is a powerful predictor of life satisfaction, people are increasingly living in a 'mosaic' society where they are disconnected from family, friends, neighbours and both local and national democratic structures. AmI can reinforce participation of the individual in social networks through building environments that facilitate the development of a collective, living or community memory.

Healthcare and social support: AmI provides many opportunities to support an aging population, as envisaged in the Commission's recent study *The future of health care and care for the elderly: guaranteeing accessibility, quality and financial viability.*

An AmI environment is a responsive and proactive environment that enables easy participation of the individual in their own healthcare management, including communication with professional carers, friends, family and the wider community. AmI enables remote monitoring of activity and physical well-being and *e-Inclusion* for people with physical disabilities. AmI can also support the care of other vulnerable groups in society, for example by monitoring the location and safety of children.

Home in a networked society: AmI has the potential to create a private domestic sanctuary - *"a place where one can lean back and be passive"*. But AmI can not only cocoon: it can also empower and enrich the individual within the home and provide additional and more flexible participation in work, learning, entertainment and family/social interactions. AmI can simultaneously help us to create a haven from the pace of modern life and provide the means whereby we can choose to 'reconnect' to society at times that better suit the needs and interests of the individual.

*Governance and public services***:** AmI offers many opportunities, enabling social support systems (including those related to child care, education and care of the elderly or infirm) to be delivered around the clock as befits a 24-hour economy and society. AmI also offers the possibility to deliver 'E-Public Service' and mobile and electronic 'me' government in a mass customised and location independent way so that E-Public Service can become truly citizen, customer and business friendly, anyplace and anywhere.

Civil security: AmI has the potential to make an important contribution in all phases of the risk management cycle including: risk assessment and hazard identification involving remote sensing and in-situ intelligent surveillance to inform both the individual and public services; immediate response to perceived threats requiring new decision-support systems capable of processing in near real time huge amounts of data; and damage assessment mechanisms requiring the integration of very high-resolution data with cadastral data and decision support.

Environment: the EU's Sixth Environment Action Programme *Environment 2010: Our future, Our Choice* points to major achievements in improving air and water quality but recognizes that we still face major problems. In this area AmI offers the potential to move from traditional monitoring tools to more ambitious end-to-end service delivery development involving advanced forms of decision-support and knowledge management for both pollution prevention and management of resources.

Mobility and transport: with AmI all 'actors' on the move, whether people or goods, can be location-aware and communicate with each other. Intelligent objects and networks for logistics can be integrated with intelligent mobile systems for people, creating Virtual Mobile Environments (VMEs). This will address both the physical fulfilment of e-commerce (through, for example, cargo-logistics) and the seamless services across networks and terminals for nomadic users, limiting the need to travel and optimising mobility.

The White Paper, *European Transport Policy for 2010: Time to Decide*, places users' needs at the heart of the European transport strategy and recognises that *"now is the time for less*

concrete and more intelligence in the transport system". On th roads, AmI will improve the safety of the vehicle, its occupants and other road users with on-board driver assistance systems and improvements in traffic management, including a reduction in congestion. In the air, advances in surveillance and communication in air traffic technologies enable more efficient and reliable air traffic control.

Sustainability: the European Union's strategy for sustainable development, *A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development*, recognises that, in the long term, economic growth, social cohesion and environmental protection must go hand in hand. AmI can be instrumental in the development of new technologies that use fewer natural resources, optimize energy efficiency, and help reduce pollution or risks to health and safety. AmI offers opportunities to reduce the impact of 'primary' effects of use of ICT by placing a greater emphasis on design for re-use and dismantling; moving away from dependence on batteries to energy on the fly; and by introducing clean manufacturing due to AmI production processes. AmI can enable beneficial 'secondary' effects by reducing and optimising physical mobility, by optimising energy usage, and by improving waste management. (The design of AmI must, however, take account of undesirable 'tertiary' effects – or undesirable consequences.)

Enterprise: AmI will support the Commission's *Enterprise policy in a knowledge-based economy (COM (2000) 256 final/2, May 2000)* and the multi-annual programme for enterprise and entrepreneurship (2001-2005). AmI can enable the formation of virtual enterprises, the fluid configuration of business processes, and the seamless inter-operation of underlying information systems. AmI will enable companies to participate in several networks simultaneously without the need to radically alter their company cultures and preferred methods of working.

4.2.2 Challenges in the evolution of AmI

It is important to recognise that, in many of the above areas where AmI has the potential to help solve socio-economic concerns, other factors may also need to be addressed at the same time that next generation ICTs are being offered as a response to demographic changes and the changing behaviours, attitudes and ambitions of Europe's citizens and businesses.

4.2.2.1 Confidence & Trust

The *development of the AmI space will require a heightened awareness of issues related to confidence and trust* in several of the above areas. With future domestic technologies like health at home or the growing online management of utilities and facilities (electricity, gas, water, etc.), the management of risks and of the security of this domestic infrastructure will increasingly become critical for the citizen. The anticipated benefits of Ambient Intelligence may be numerous but, given that AmI enabling technologies are also facilitating monitoring, surveillance, data searches and mining, AmI space deployment is likely to be of great concern to citizens, civil liberties groups, governments and industry.

Addressing the balance between privacy and security will be a core challenge for the future, related to the fundamental but complex interrelationship between what constitutes the private and the public space of the citizen.

Moreover, in the physical world, domicile and residence are carefully developed and recognised concepts in terms of privacy and security protection in its broadest sense - legal, social, economic and technological. In contrast with the real world, there are few social and

legal indicators of what constitutes a protected private space or an open public space in the virtual world. A comparable level of sophistication is needed in the future for people to feel at home within their smart homes, with their online activities, and facilitate the personalisation of their everyday environment in order to enhance their mobility.

4.2.2.2 Organisational Change

Organisational change is a key factor in determining whether investment in ICT leads to sustained productivity growth. *Anticipated productivity gains may simply no materialise if the technology is superimposed on old organisational infrastructures and business practices* that were not developed for trading in an electronic networked economy. Whether people respond positively to the opportunities presented by AmI in a variety of areas may depend heavily on the extent to which AmI complements rather than replaces existing methods of work and social discourse and the extent to which it requires fundamental changes to organisational structures.

Learning is also a key factor in ICT demand, and investment in learning can enable both public and private sector organisations to assimilate ICT more rapidly. A shortfall in the skills and competency base for applying AmI may well slow the diffusion process and reduce the economic impact of the investment. In short, *the opportunities highlighted for AmI may only be realised if the commitment to new technology deployments are matched by simultaneous investment in learning and organisational change strategies.*

4.2.2.3 Industrial support

At an even more fundamental level, the ability of AmI to help solve the above socio-economic concerns will only happen if Europe has industries committed to innovative research and development and entrepreneurial companies that are capable of delivering the AmI vision.

Regular monitoring of the potential of European industries to deliver the AmI vision will be necessary as new socio-economic challenges appear and existing priorities are reassessed.

4.2.2.4 Promotion of 'Ambient Intelligence'

The term Ambient Intelligence has a fairly recent provenance. In much of the general literature on technology futures AmI is not clearly distinguished from earlier concepts such as 'pervasive computing' or 'ubiquitous computing'.

More effort may be needed to explain the nature of the 'intelligence' being alluded to in the AmI vision - in particular where this 'intelligence' resides (in the environment network, device or content) and its relations to human cognition and older concepts of Artificial Intelligence.

In Europe we may generally be more skeptical towards the concept of intelligent technology, regarding it as inherently suspect and inferior to human and social intelligence.

The common perception is that "people communicate with people" rather than with an abstract 'intelligence'. There may possibly even be a reaction against the concept of AmI as something non-human that completely envelops and surrounds people even if it is unobtrusive or completely invisible. *It will be important to convey the intention that, in the ambient environment, intelligence is provided through interaction, or participation and can be appreciated more as something that is non-threatening, an assistive feature of the system or environment, which addresses the real needs and desires of the user.*

Apart from promotion to the public and to policy makers, the scientific community should be made aware of the many fundamental research challenges that realisation of the vision poses.

AmI depends on more than applied science and technology development. There are many fundamental research problems, such as the guaranteeing of emergent properties of integrated heterogeneous systems of systems – often of unknown provenance; next-generation open, 'conformable' trust and security techniques; and automatic, evolving, ontology generation. *The European Computer Science community has strengths in all the appropriate areas, but the AmI challenges must be recognised by the scientific community if the community is to be engaged in realisation of the vision*.

And Ami requires more than computer science. It can only be fully developed by a holistic approach, encompassing technical, economic and societal research. In return, *AmI offers scientists a rich field of research at the boundaries between disciplines*. Cognitive science is providing insights about how to present information to human beings so they can use it most effectively. From biology come important insights about the behaviour of complex dynamic systems. Although research aimed at improving and extending the knowledge in core scientific and technology domains remains a necessity, *it is at these interfaces between scientific domains that exciting things happen.*

In summary

The AmI vision should not be 'oversold' but neither ISTAG nor the IST research community should shrink from highlighting the exciting possibilities that will be offered to individuals who will live in the AmI space.

4.3 Making AmI happen: the technology perspective

There are a number of almost 'mandatory' research domains or components in which significant progress must be made in order to further develop and realise the AmI vision.

The analysis presented here attempts to move beyond that provided in the ISTAG paper on *Strategic orientations and priorities for IST in FP6*. In the model shown in Figure 4.1, the main structuring differentials between the domains are:

- A 'systems'/'environment'/'background' view (~'the ambient') versus a 'user'/'person'/'foreground' view (~ 'the intelligence')
- A 'components' view versus an 'integration' view.

Key research requirements for components related to 'ambience' and 'intelligence', are summarised in the table of the following sub-section, but ISTAG draws attention to the research requirements for integration in section 4.3.2. It is in this area of research to support integration that significant new avenues of research need to be opened.

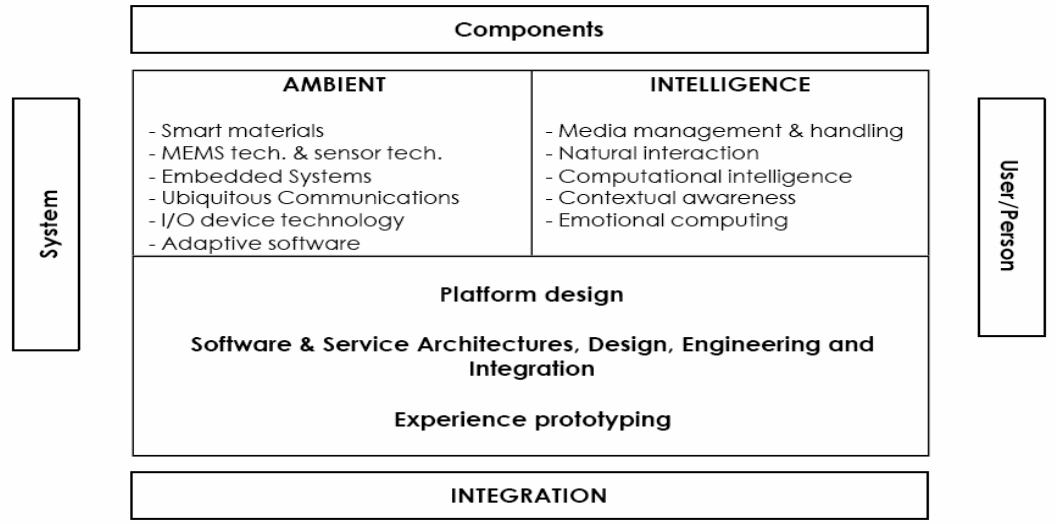

Figure 4.1 Technology research requirements for AmI

4.3.1 Research requirements for components of AmI

The table indicates just some of the technologies for Ambient Intelligence that require significant research.

Table 4.1 Research requirements for AmI

Components for Ambience	Components for Intelligence
Smart materials that can emit light efficiently; e.g. electronic wallpaper or large synthetic foils that can emit light, materials that can be used for touch and tactile movement, and synthetic materials that enable mass storage and processing of digital data, and that can be integrated into fabrics. ***MEMS and sensor technology***, including ultra low power (mechanical) effectuators, sensor devices bridging between the physical world and the cyber world, i.e., touch, vision, smell, and technology for the integration of smart materials, micro systems, and microelectronics into *systems*. ***Embedded Systems development technology*** for re-configurable real-time embedded computing platforms, for remote diagnostics and repair of embedded systems, and to build in security and trustworthiness to embedded systems. ***Ubiquitous communication*** including ubiquitous pico-radio networks for active and passive tagging, Internet accessibility for any physical object, and ubiquitous broadband access to content and data. ***I/O device technology*** that supports ubiquitous hands-free speech control, ubiquitous touch pads and whiteboards, and can turn any surface into a display. ***Adaptive software*** that is self-managing or has self-adjusting capabilities that can detect and adjust to the health or otherwise of its environment, re-allocating resources as required and automating much of the system configuration work that now has to be done manually.	***Media management and handling*** including presentation languages that support "produce once" and "present anywhere", methods and tools to analyse content and enrich it with metadata, and tools to exploit the Semantic Web. ***Natural interaction*** that combines speech, vision, gesture, and facial expression into a truly integrated multimodal interaction concept, that allows human beings to interact with virtual worlds through physical objects, and that enables people to navigate the seemingly infinite information they will be able to access. ***Computational intelligence*** including conversational search and dialogue systems, behavioural systems that can adapt to human behaviour, and computational methods to support complex search and planning tasks. ***Contextual awareness***, for instance systems that support navigation in public environments, e.g., in traffic, in airports and in hospitals, service discovery systems that enhance the shopping experience, and context aware control and surveillance systems. ***Emotional computing*** that models or embodies emotions in the computer, and systems that can respond to or recognise the moods of their users and systems that can express emotions.

4.3.2 Research to support integration

The development of the AmI space will depend not simply on finding solutions to the research challenges in each of the 'component' domains, but on the extent to which mechanisms can be found to ensure the successful, seamless, integration of components and their convergence into AmI systems. Architectures, methods and tools must be developed that are capable of combining technologies into AmI systems. New approaches will also need to be elaborated to integrate technologies across different usage environments.

ISTAG has identified three key 'layers':

- Platform Design
- Software and service architecture, design, engineering and integration
- Experience prototyping.

4.3.2.1 Platform Design

Each of the component technologies identified above and the associated AmI research challenges have strong internal coherence and build on certain basic facts and assumptions.

These differ from one component technology to the other.

The challenge of Platform Design is to provide the foundations, environment and tools for the mutual integration and cooperation of fundamental components based on a range of technologies without any common conceptual framework. Specific topics to be confronted in AmI platform design include:

- *Abstraction:* Future AmI platforms must cope with heterogeneity, intelligence and variability. There is a strong need to develop new concepts and extract suitably abstract models
- *Automatic Composition:* Interfaces, reusability and interconnectivity should be understood in the new context of intelligent and dynamic models of system configurations. Self -organization of the platform is a formidable challenge
- *Interaction Management:* The necessary interaction, inside the platform, of the ambient infrastructures and their intelligence, calls for a new look at issues related to co-ordination and orchestration. Intelligent collaboration of dynamic entities or conglomerates requires innovative interaction management techniques, based on the emerging field of 'algorithmics of interactions'
- *Computational Efficiency:* Platforms in AmI need to demonstrate high levels of performance related to complex intellectual tasks, perhaps surpassing the human level. This will require not only a new framework in knowledge engineering and elegant reasoning, but also a deeper understanding of the nature and limits of computations
- *Creativity:* The new platforms will be required to support actions beyond mere productivity. They should enable programmer-created design, and facilitate innovation and expression of personal style
- *Scalability and Evolution:* Platforms should facilitate the management of huge clusters of MEMS and architectures; migration of tasks and transparent load balancing is still a major challenge. The intelligence of the whole platform should allow for self-evolution of the whole system together with smart management of critical resources

- *Dependability:* Platforms should enable trouble-free systems to be used by millions o people worldwide. Consistency and trust are fundamental. In the 2002 Report *"Trust, Dependability, Security & Privacy for IST in FP6"*, ISTAG identified that security in AmI Space will require solutions very different from those of today's systems. This new paradigm will be characterised by 'conformable' security, in which the degree and nature of security associated with any particular type of action will change over time and with changing circumstances and with changing available information so as to suit the context.

4.3.2.2 Software and service architecture, design, engineering and integration

The realisation of *the AmI vision will require the development of extremely large, complex, heterogeneous, distributed systems*. These must be built on heterogeneous platforms capable of providing seamless networking so as to support the delivery of layers of value added services or functional services to the individual, to industry, and to administrations. The resulting systems, comprising a myriad interacting embedded software components, will need to be intelligent, self-configuring, self-healing, self-protective, and self-managed.

Today's software is often based on two main integration principles. Firstly, software is often partitioned into abstraction layers with fixed, simple interfaces between layers.

Secondly, systems are often vertically integrated with fixed, proprietary linkages between components. The AmI vision challenges both these principles. The need to anticipate user behaviour, to gather contextual information, to detect and adapt to all kinds of changes etc. entails a corresponding need for extensive cross-layer interactions that 'break open' the interfaces between layers. The need to augment all kinds of everyday things with computing, to harness sensory data, to disseminate information through a hyper-connected world entails a corresponding need for horizontal integration that goes far beyond the simple dynamic service discovery mechanisms that are the basis of new middleware paradigms such as Web Services.

AmI sets new challenges for the methodologies and technologies for service and application development. Service and software engineering processes will be required to facilitate user-oriented service creation. Service architectures, service components, and service platforms will, together with development tools, form an environment for the development of value added AmI services. This environment must provide interoperability between services and allow the building of new services by direct use of existing services, as well as available software and service components. New approaches to fundamental abstraction based on the characterisation of artefacts (e.g. agents), interactions, environments and organisations, might facilitate the definition of the necessary processes, methods and components. Existing paradigms for distributed processing concepts, such as architectural components, architectural frameworks, agents, and autonomic systems might be integrated to provide useful abstractions to engineer new categories of services.

Event architectures might provide the connective 'glue' between components, but research is required into the scalability of such architectures and the semantics o events. Tuple spaces may offer the required decoupling to enable flexible patterns of interaction between components. Component frameworks based on cybernetic control theory may serve as a foundation for integrating embedded systems into self-configuring, adaptive systems. New ways to conceptualise services are required so as to represent and reason about their functioning, while service discovery protocols appear to require standardization on service types, in which progress has so far been limited. New approaches to the conceptualisation of

user-interfaces, such as plasticity and generalization, may enable designers to abstract away from the idiosyncrasies of particular input and rendering devices.

4.3.2.3 Experience Prototyping & Simulation

The AmI vision anticipates that ICT will increasingly become part of the invisible background to peoples' activities and that social interaction and functionality will move to the foreground resulting in experiences that enhance peoples' lives. This not only requires insight into the design of sophisticated distributed systems; it also requires a deep understanding of how user needs can be translated into functional requirements.

Requirements engineering for Ambient Intelligent systems design can no longer be seen as a task that can be accomplished through the development of scenarios and the translation of use cases into system requirements.

System functionalities that generate true user experiences can only be determined in a reliable way from feasible prototypes providing proofs of concept. New approaches to prototyping are likely to be key to the successful development of AmI products and services.

Prototypes can motivate users to discuss new ideas about task requirements, concepts, dialogues, new interaction modes, navigation or presentation of the real world artifacts or phenomena. Prototypes can be used for classical user evaluation and they can be a useful way to measure the effectiveness and efficiency of users' tasks and the level of user satisfaction.

Prototypes can further be used to observe cognitive tasks, such as a user's attention, perception, projections for next steps and evaluations of the prototype's response.

Experience Prototyping is a form of prototyping that enables design team members, users and clients to gain first-hand appreciation of existing or future conditions through active engagement with prototypes. Prototypes allow developers to test new ideas either in a laboratory setting or in more realistic contexts in the field. Experience prototyping can be used to understand user experiences and their contexts, explore and evaluate new designs, and communicate ideas to designers and stakeholders.

Tools also now exist to allow researchers to model the physical world and to render and explore it using 3D visualization engines. The model can then be populated by users, devices, and all kinds of services and infrastructure. *It is easy to imagine that user trials could be conducted inside such VR simulation tools*. Such models could be distributed and literally serve as a virtual 'venue' or meeting ground for researchers and, in the process, facilitate experimentation and reuse of proposed solutions.

Insofar that experience prototyping places the emphasis on the quality of the users' interactions and experiences and less on the pure functionality and technology of the solution, it seems well suited to the AmI goal of addressing real user needs that reflect socio-economic problems. As AmI scenarios become more complex, it is also possible to see how further development of the experience prototyping approach could be an important means of making highly innovative, yet complex and abstract ideas physical and understandable. Nevertheless, a number of research challenges must also be addressed for experience prototyping to fulfill 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 metadata 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
- Find ways properly to evaluate the user experience offered by prototypes of AmI applications and environments.

In Paragraph 3.6 it is suggested that many of these challenges might be addressed by the formation of a network of Experience and Application Research Centres (EARCs).

4.4 Making AmI happen: the business perspective

There are various possible impacts of research activity. Advancing scientific and technology know-how is a valuable outcome provided that it has potential implications on society and economy. Scientific and technology breakthroughs often emerge as a result of intensive and sustained research effort exploring various avenues to address a specific problem. It is also clear that spin off results, not initially foreseen, are as important as (if not more than) those anticipated at the outset of a research action.

There is an extensive literature on technology transfer and exploitation of research results in Europe. They all converge on the capacity and the need in Europe to improve significantly research exploitation. The latest Communication of the Commission on how to reach the 3% of GDP for research includes a whole set of measures that can help improve the exploitation of research results in all fields. ISTAG has identified particular measures to improve the impact of ICT research in Europe in the context of the development of a European Research Area.

This includes the means to design and implement ICT research and innovation strategies across Europe that facilitate the transformation of research into value for the economy and society.

4.4.1 Open standards and interoperability

Consensus building and cooperation around common objectives (that are translated into open standards) are well-recognised assets of European ICT industry. The example of the GSM success illustrates this clearly. *Today, the situation in various ICT fields is nevertheless confusing with "no or many" open standards available. The danger is that proprietary systems become the only option for users and that market dominance by non-European companies in fields such as operating systems expands further to emerging fields. This would not only limit innovation: it would jeopardise the vary concept of 'seamlessness' in the AmI environment, and weaken the position of European industry*.

The means to help the emergence of consensus depend on each sector. There is no one method for standard developments and this should be addressed on a case-by-case basis. It is clear though is that it is facilitated by bringing the different actors together and helping the building of shared ambitions and goals across industry, academia and public authorities.

ISTAG therefore strongly supports the proactive establishment and support of forums to facilitate the early emergence of consensus.

Many existing forums in ICT exist today in a rather fragmented way. It is often the case that several standardisation bodies, research forums and regulatory or other policy related forums work at the same time on a particular topic in an uncoordinated way. More should be

done to bring these closer together on a systematic basis in the main ICT fields so that technology development is closely articulated with standardisation, regulatory measures and deployment policies. The different actors can then agree together on technology and implementation objectives and roadmaps to achieve them. Consensus at European level helps to enforce the European position and interests at the international level.

AmI-oriented projects in the Framework Programme – and, more generally in the ERA – should be required to describe the means whereby they will achieve the consensus necessary for acceptability in the market-place and interoperability of their results. It should be a condition of 'Experience and Application Research Centres' (see paragraph 6) that they commit to open standards and interoperability.

4.4.2 A 'system level' focus

Competition in innovative ICT is global and research is conducted worldwide and skills are starting to be available across the globe. ICT innovations today are stemming from the combined progress in different ICT fields and often from combining ICT with other disciplines. With Computing and Communication capabilities becoming ubiquitous and flexibility and programmability introduced at all levels, the borders between software and hardware development are blurred and technology layers are getting more and more encapsulated into increasingly complex systems. The increasing complexity affects not only the technical value chain but also the business and exploitation channels of ICT products and services.

More than ever, research needs to be embedded as early as possible in a full value chain development in order to enable the mastering of an increasingly complex chain of technologies and business channels. *The competitive edge is more in the capacity to master not only technology building blocks but also their integration into platforms or environments on which high value applications, products and services can be built*. This is, in general, a weakness in European research that translates into gaps between the building blocks and the applications. This gap needs to be filled with *focussed research to integrate the blocks as they become available*.

Mastering the technology chain is not sufficient. Innovation is not in the technology but in its use. For that, the alignment of business and technical expertise is vital. An early integration of business aspects (e.g. exploitation scenarios) needs to be done during the research phase, without limiting innovation and creativity. *The difference between ICT and most other research areas is that the technology adoption cycle can be very fast*. This adds new challenges to the mastering of the value chain from technology to exploitation, in business or society, and requires the systematic combination of expertise as well as iterative research-development-testing-validating processes.

The new instruments in FP6, in particular Integrated Projects, aim at addressing some of the above challenges. The presence of system-level research areas in the workprogramme and the calls is equally important.

4.4.3 Exchange and mix of people and skills across industries and academia

To maintain the pace of co-evolutionary development of the technologies and markets of AmI requires close coupling between research, development and exploitation. It is no longer adequate to consider technology transfer as a sequential process of knowledge generation in

academia followed by dissemination and subsequent exploitation. Elsewhere in this report ISTAG suggests some mechanisms for more coherent, co-ordinated working of all those involved in the chain from idea to innovation. In general, the greater efficacy and effectiveness of this intellectual supply chain requires greater intercourse between industry and academia, between large and small companies, and indeed between all those involved. The best channel for technology transfer is people – communicating and moving between working environments.

Intensive efforts have been deployed in the last 10 years to bring closer links in Europe between industrial and academic research in all technology fields. In this way a 2-way exchange of knowledge is achieved - academic results to industry and industrial requirements to academia. *Even more important for AmI is the building of shared research objectives and tacit agreement on compatible approaches*.

There are many best practices in the ICT field that can be shared between the member states and effort to achieve this should be sustained and reinforced. Success stories can be observed both in large EU countries with strong industrial bases as well as in smaller countries that have been able to draw industrial presence by the excellence of the research and the willingness to cooperate. ISTAG encourages even closer ties between industry and academia with, for example, on-campus industry-academia research labs.

SMEs are a vital source of innovation as they have the agility to react and adopt novel ideas as they emerge. Emerging mechanisms, such as clusters and networks, by which SMEs can be engaged more effectively in programmes, should be encouraged. *Equally important are the links between large and small companies that can benefit from each other*. Some large companies, for instance, ar increasingly establishing close ties with pools of SMEs around their core activities that they nurture and support. Some clusters and networks provide shared management and administrative facilities to ease inter-working with larger companies.

The interaction between large and small companies should be balanced to be effective and should be generating win-win situations by which SMEs gain access to large clients and markets.

The mix of industrial development poles (large companies and SMEs) with research and technology poles and higher education institutions has been extremely valuable in ICT and was instrumental for building European strengths. *The experiences in areas such as microelectronics and communication systems are highly successful and need to be repeated in a more systematic way in other ICT fields*.

Indeed *Framework Programme projects have been also instrumental to effective cooperation between industry (large and small) and academia across the Union*. There is a danger, though, that the new FP instruments will create ghettos for large companies (IPs), for academia (NoEs), and for SMEs (STREPs).

The ICT constituency can also make a better use of the Marie Curie fellowships of the Human Capital Programme to support the exchange of young researchers between industry and academia across the Union. The scheme can be very valuable and does not seem to be exploited sufficiently by the ICT industry, in particular by SMEs and public research labs. In order to support as well the exchange of people between academia and SMEs, Community projects should consider funding up to 100% researchers (Ph.D. students) hired by an SME for an EU project.

4.4.4 Encourage a culture for risk taking in ICT

If Europe is fully to exploit the potential of AmI for its industry and commerce, entrepreneurialism within Europe in the new and rapidly evolving markets must be encouraged.

There is concern that Europeans in general and researchers in ICT in particular have relatively little interest in entrepreneurship and risk-taking in comparison with their transatlantic colleagues. While entrepreneurship and risk taking could certainly be further promoted in Europe, *the big difference with the US has much to do with the financial and business environment and is not entirely due to the underlying behaviour of European researchers*.

It is essential to look at this particular aspect given the burst of the financial bubble.

Between 1995 and 2000, the US had exceptionally low interest rates (for a full employment period) and immense flows of financial capital poured into the technology field, in particular ICT, for its growth potential. This generated the financial bubble of dotcoms that eventually burst. *The unrealism of the 1995-2000 period and the burst of the bubble do not affect the fundamental potential of ICT: it is still a high growth field with many opportunities for European researchers and entrepreneurs*. To be able to seize the opportunities and transform technology progress into a sustained economic growth, *more needs to be done to introduce a solid business and entrepreneurship culture*.

ISTAG sees the need to *further develop initiatives such as networking, education and coaching that target potential ICT entrepreneurs* (e.g. common business-technical forums, 'coaching' networks). The aim is to foster experience sharing, innovators-investors interactions and mastery of combined business-marketing-technical skills. Many such *initiatives* exist already *such as the Investment Forums supported by the IST programme and by member states*. They *should be pursued and further strengthened both at national and community level*. There is also a stock of experience that member states and companies could share, through benchmarking and best practice dissemination, on spin-off creation in industry and academia.

In summary, the ambition is to change attitudes to risk-taking, give training in the skills required for entrepreneurs, and create the opportunities to exercise those skills.

4.4.5 New content value chains

The further development of digital technologies requires new content creation and delivery value chains. There is a 'chicken and egg' problem:

- Most services are dependent on availability of content but content providers are reluctant to make content available on line because there is no market, and if there were, their content cannot be protected
- The market cannot develop because there is no content, and the potential user has no confidence in the privacy or security of the systems.

Ways must be found to secure online services and also to protect content once it has been distributed within whatever devices the end users may have.

Meanwhile, the market value of the Content industry, especially the entertainment industry, is being harmed by downloading and copying. No law enforcement has been effective so far.

This problem will endanger all new creation and the further development of the technology.

Dialogue platforms bringing the different actors together at an international level are essential to be able to identify the underlying new values in the business chain and devise means to protect them appropriately and adequately.

4.5 Making AmI happen: the resource perspective

In the ICT sector, apart from microelectronics where public funding of ICT as a percentage of GDP is the same as in the US, public funding in the EU is 0.45% of GDP while in the US it is 1.15%. The overall support to ICT research in the EU would therefore need to be tripled in order to reach the US levels.

This would require a united effort involving both the public and private sectors. The means to increase the funding for research in general are highlighted in the Communication of the Commission *"Investing in research: an action plan for Europe"* The focus here is on ways to improve the efficacy of application of the available resources. Special attention is paid to the role of the public authorities in this process both as a key funding source and for creating the right framework for supporting research and innovation. There is also a strong requirement to revisit the coherence of the existing programmes and to enhance the leveraging effects of the various funding mechanisms.

In this context, ISTAG has considered the main challenges concerning the resources required to realise the AmI vision. *AmI cannot be achieved piecemeal: it requires coherent application of resources Europe-wide. AmI also offers an opportunity for co-ordinating resources* – which is generally accepted to be necessary t overcome the traditional fragmentation across the EU.

'Resources' are of several kinds:

- Individual and organisational competence (which it should be possible to apply effectively irrespective of geographical or administrative topology)
- Scientific knowledge
- Technological and organisational infrastructure
- Financial means and instruments.

In all these cases, the necessarily *limited resources available may be applied more effectively through greater coherence, co-ordination and concentration*. However, ISTAG has not attempted a review of all aspects of resource availability and application: this report does not attempt to be comprehensive. Instead, ISTAG has focused on certain specific measures pertinent to realisation of the AmI vision.

4.5.1 Finance: the role of public procurement

Overcoming the funding gap between the EU and US in ICT might seem impossible if only pure ICT research programmes and budgets are considered. In fact, most of the gap in public support to ICT research with the US and Japan is due to other funding mechanisms.

Funding of ICT research in the US is often done through the efficient use of public procurement of new ICT systems to upgrade and modernise services and infrastructures.

Public spending represents 15% of GDP in Europe and covers many fields where ICT can

bring significant improvements. Yet *in Europe, public administrations have seldom used their power to act as the big purchasers they are* or when they do, it i done only at national level *and does not represent a critical mass that can have a global impact*. This is a clear weakness that leads to missed opportunities for transforming ICT breakthroughs into business and societal successes. The weakness spreads across the economy. In particular, companies hesitate to develop new businesses using ICT for sectors strongly influenced by public financing or public sector activity. Companies directly or indirectly dealing with governments become increasingly conservative, which makes a significant portion of the economy an unfavourable area for new businesses growth.

Areas like eGovernment, eHealth, and eLearning are high on the political agenda. First steps towards the modernisation of public sectors have been achieved but the big challenges are still ahead. The role of ICT will become even more important with enlargement, demographic changes and with new security needs. In Paragraph 2 we saw the many ways in which AmI can improve such services. It can not only increase the efficiency and quality of services of governments and administrations but also provide new services and applications and improve the interactions between governments and citizens.

Europe's public sector therefore has the potential to develop a critical mass of first users in several ICT fields. This does not require additional public financing but redirecting of existing spending so as to increase efficiency and effectiveness.

Governments make ideal 'first buyers'. Such procurements should take into account previous experiences, successes and failures, so that errors of the past – like those in educational computers - are not repeated. One of the means to avoid such errors is to acquire or order novel ICT and applications through competition and 'technology neutral' approaches.

European-wide procurement initiatives have not just financial and technical implications: the AmI services must conform with national policies and regulations.

Taking schools as an example, in Europe innovators and companies have to deal with 25 different curricula and policies, that of course slows innovation. AmI for the European citizen requires interoperability across member states as well as across technological platforms, and AmI therefore offers member states a focus for aligning national policies – or at least enabling their interoperation. *Early involvement of policy makers in initiatives aligning R&D activities with deployment actions would be essential.*

ISTAG believes that *European governments should be at the forefront of ICT adoption* not only applying established technologies and solutions but *actively encouraging innovation and facilitating the establishment of new markets.*

This will need the establishment of mechanisms to expose policy-makers and implementers to the new possibilities, and to manage the associated first-buyer risks.

Open sources, open interfaces and open standards in public procurement

The development of a common open source base could be promoted through the procurement process. For example, some administrations in Europe have already taken the position that they will accept software only if it is provided with sufficiently detailed documentation to allow another contractor to make modifications or additions. More detailed discussion is required on mechanisms that can support the development of open standards but ISTAG suggests that public sector initiatives and projects have an important role to play here.

4.5.2 Strategic 'grand challenge' initiatives

Closely related to the more effective deployment of public investments, *ISTA suggests the identification of European-wide AmI initiatives that promote and advance European research and technology and capitalise on financial mechanisms such as public procurement*. Such initiatives need to be conducted at European level to ensure critical mass, risk sharing and cross-border implementations. They should be large scale and visionary, and harness the concentrated expertise, knowledge and capabilities of European personnel in the pursuit of identifiable objectives that will benefit European society and industry. A relatively small-scale initiative might be for every citizen to be able to have a heart check-up at any time, anywhere – in their car, up a mountain, …– .

Such initiatives should come in addition to, and in combination with a strong support to long and medium term (and/or high risk) research that is done within research programmes.

They would ensure a closer articulation between research and implementation actions and support the transfer of very advanced technology progress into applications.

Member States should sign up to such initiatives in order to bring all areas up to the same standard and ensure interoperability and coherence.

4.5.3 Co-ordination of RTD funding

Currently RTD funding is available from Member States and Regional Authorities, in addition to the funding available from the European Union, through a wide range of programmes.

Typically they address different aspects of the chain from idea, through invention, to innovation. Frequently there are gaps between programmes and inconsistencies in their implementation across the EU. The challenge is to co-ordinate the different research and funding mechanisms and programmes, addressing a range of short to long term aims, in order to provide a coherent and integrated portfolio of activities. In addition, efforts should be made as part of the establishment of the ERA to present the full panoply of EU and national mechanisms to the community in an easily accessible form.

ISTAG recommends that a clearer distribution of the roles is realised between the funding sources to ensure co-ordination between the EU and Member States' programmes, and that the rules governing public funding in Member states and at EU levels should be harmonised.

4.5.4 Achievement and assurance of excellence

It is by fostering, demonstrating and exploiting excellence that funding can be drawn to AmI research in Europe both from the public and the private sector. For that there is a need to concentrate European research efforts in order to give prominence to the high quality and internationally competitive research that is taking place in Europe. Experience has shown that in areas where such concentration of effort has been possible and such centres exist, Europe has been able to establish a clear industrial leadership world-wide. This is the case in particular in microelectronics and micro-systems.

The 'Networks of Excellence' introduced in the 6th Framework Programme are designed to reduce fragmentation and lead to permanent restructuring of the research base. ISTAG suggests that consideration be given to additional ways to concentrate resources in a way, which ensures the continued flexibility, responsiveness, and competitiveness of the RTD community.

Notwithstanding concerns that they are not sufficient, the resources deployed in RTD in Europe are still very considerable. In order to maximise the effective use of those resources, *ISTAG proposes that there should be a review of criteria and indicators for the assessment of the progress and contribution of projects and programmes* with view to quantitatively tracking the level of contribution and impact (scientific, industrial, market, social, and economic) of the work funded – i.e. going beyond monitoring of nominal deliverables.

Indicators should also be devised to illustrate the relative position of European AmI research compared to similar research projects in the US, Japan, Canada, Australia etc. and to enable a reliable assessment of those fields where Europe is taking a lead. *Regular benchmarking, using such indicators, would give greater visibility both within and outside the EU to the work of the ERA.*

4.5.5 New research directions and communities

New mechanisms and process may be needed to facilitate research that will remove stumbling blocks that are currently impeding realisation of the AmI vision.

It is important to recognise that, *while many of the component areas highlighted under 'technological perspectives' have a degree of maturity, others are less well developed and cannot easily build on established or structured research communities*. For example, it is essentially a case of pursuing *new directions* in such established fields as communication and network technologies, software technologies, interface and display technologies, embedded systems, microsystems and materials. Identifying priorities and roadmaps may be more difficult within what are still the emerging research domains of 'Emotional computing', 'Contextual awareness' and 'Computational intelligence' where research methodologies and communities are less well developed. *Communities in some of the newer research domains upon which AmI depends may require special forms of support to become established*.

There is also *a general need to stimulate the cross-fertilization of ideas and research between all disciplines*. As discussed in Paragraph 2, the overall premise is that exciting things happen at the interfaces - be it between neighbouring disciplines, activities, companies, regions or countries.

4.5.6 People

Europe should aim to become more attractive to ICT personnel and to become the place where successful ICT personnel want to work, engage in business, and attract inward investment.

The EU should introduce a number of prestige Fellowships with duration in the timescale of 3-5 years. The award of a Fellowship should correspond to the current scenario where a European researcher goes to the US for a few years to gain experience and then returns to his or her home institution.

Europe should strengthen its efforts to increase its in-take of non-European students and scientists in ICT, and also to enhance the mobility of young researchers. *An ambitious and attractive international ICT PhD programme would be an appropriate initiative*.

ISTAG recommends that *syllabus and education levels should be harmonised throughout Europe*. In particular, there should be an attempt to define the standard of the PhD across Europe.

4.6 Making AmI happen: a holistic approach

AmI will be realised through highly complex systems. *It will no longer be sufficient to perform specific research, embody the results of that research in particular technology developments and products, and then seek to commercialise those products. AmI will be realised through suites of interacting components in a multiplicity of open, interoperable architectures*. Even a 'single' class of services, such as eHealth using biosensors, will require the integration of a range of component technologies with demanding dependability and privacy requirements.

The economic viability of such services - for public service administrators as well as commercial companies - will depend on both technical viability and market viability as well as the added value for both the citizen and the administrations.

In preceding sections of this report we have seen that from the technological perspective the focus should be on the integration of technologies and the evaluation of that integration. From the business perspective we see the need to take a 'system-level view' in which research and technology development are embedded in a full value chain development. And from the perspective of resources, we see the need for large-scale, coordinated yet highly responsive research and development of technologies, applications and services. Furthermore, *to be effective, all of the research and business community must keep pace with the rapid co-evolution of the technology, the market, and social and administrative requirements*.

Figure 4.2 is a stylised representation of the holistic citizen-centred view adopted by ISTAG.

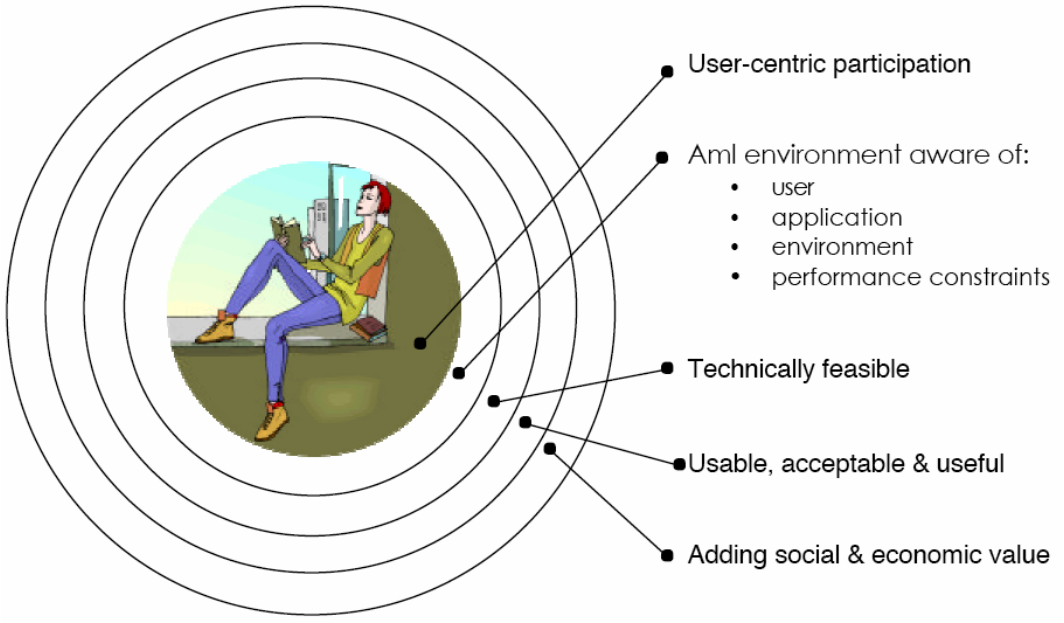

Figure 4.2 User-centred, participative, Ambient Intelligence

Figure 4.2 gives some indication of the range of different classes of issues that must be addressed, more or less concurrently, in order to realise the AmI vision.

The 'new instruments' go some way towards supporting the desired integration. *Integrated projects* encourage closer coupling between research, technology development and

development of applications and services. *Networks of excellence* support the closer co-operation of researchers from different but related disciplines.

However each project and each network, typically, tackles a limited range of the issues indicated in Figure 4.2 Notwithstanding attempts at 'concertation', each necessarily has its own set of objectives.

ISTAG now proposes the establishment of 'Experience and Application Research Centres'.

These should be designed to support performance of research in an integrated fashion and facilitate concurrent assessment of all the required properties of AmI as indicated in Figure 4.2.

'EARCS' are discussed below in Section 4.6.2.

4.6.1 AmI Research – a cultural approach

AmI research should enhance human capability by providing a suitable environment for the activities, which people perform within it. The environment is one in which local needs and remote needs - such as communication with colleagues -can be optimised. To arrive at a correct 'fit' for the design of the products, services and systems which people will use in different places and at different times, it will be necessary to consider how to optimise for particular activities whilst, at the same time, providing some enhancement of experience between and across activities. Thus the overall behaviour of the system over time – users and AmI together - needs to be considered. It will also be necessary to study the social behaviours, which can be enhanced through Ambient intelligence technologies so as to understand how users and technologies may cooperate synergistically to enhance human capability and quality of life.

A successful realisation of AmI, therefore, is likely to require new forms of experience design and prototyping involving social, cultural and psychological research an requiring that we pilot interactions, interfaces and conceptual maps across different cultures or cultural groups (see recommendation on Experience and Application Research Centres that follows).

This is needed in order to provide a systemic research base in order to understand the cultural factors that must be accounted for when designing for different ethnic groups, countries and regions. *We should not assume that one dominant cultural paradigm 'fits all'.*

4.6.2 Experience and Application Research Centres

In order to develop quality services and products for AmI it will be necessary to understand the complex set of technical, social and economic constraints under which they are built. For successful AmI development new ways must be found to help developers and stakeholders learn from experiences and exploit the result in knowledge in future development. ISTAG suggests that this will only happen if functional, technical, social, economic and cultural requirements of systems, gathered from users and stakeholders, are put in the centre of the development process and are revisited throughout design, implementation, checking, and testing. This approach is extremely challenging and extends well beyond the kind of requirements engineering for software design, which are in practical use today.

Facilities are needed to support fast prototyping of novel interaction concepts and resemble natural environments of use. These '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. In such a 'venue', integration technology can be

tested, researchers can reuse and improve upon earlier results, and comparisons can be conducted.

ISTAG suggests that *AmI research increasingly needs "to allow people to live in their own future"* in order to bring that research closer to the needs of citizens and business. ISTAG recommends that *a European network of Experience and Application Research Centres (EARCs)* should be established for this purpose. They 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 investigated with regard to their usability
- Validation and Demonstration centres: where promising prototypes are fully integrated into large scale real-life situations and validated through extensive user tests.

Within EARCs It will also be useful to think of 'open systems' in terms of a design approach that allows for adaptivity over time, taking into account peoples' preferences, individual routines and ways of doing things. Three levels of activities can be considered, all of which should be coherent and integrated from a user point-of-view:

- 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, activities and social groups.

EARCs would offer multi-dimensional strategies for involving users in the design process, recognising that acceptance of ICTs is not only shaped by their technological possibilities or by their functionality, but also by the micro-social context of the household and other social contexts.

4.7 Acknowledgments

This chapter is a reprint of the ISTAG Consolidated Draft Report prepared under the same name in September 2003 . We thank ISTAG for authorising us to include it in the book. The inclusion of this chapter *is not intended to reflect any endorsement* by ISTAG or by the European Commission of the views expressed in this book.

ISTAG (Information Society Technology Advisory Group - http://www.cordis.lu/ist/istag.htm) has been set up to advise the European Commission on the overall strategy for research and development activities of ICT at the European level, as well as on orientations for realising the European Research Area in the ICT field.

References

This chapter draws on a series of earlier ISTAG reports, including:

[1] ISTAG Working Group Report, September 2003, *IST Research Content*.
[2] ISTAG Working Group Report, September 2003, *Human resources, research infrastructures, funding mechanisms and partnership.*
[3] ISTAG Working Group Report, September 2003, *Research results exploitation*.
[4] IST Advisory Group Report, June 2002, *Strategic orientations and priorities for IST in FP6.*
[5] IST Advisory Group Report, June 2002, *Trust, dependability, security and privacy for IST in FP6.*
[6] IST Advisory Group Report, June 2002, *Software technologies, embedded systems and distributed system.*

All these reports contain additional specific references to sources.
The reports are available on the ISTAG pages of the CORDIS web site: http://www.cordis.lu/ist/istag-reports.htm