ISTAG Report on

Strategic Orientations for Information and Communication Technologies Research in Europe

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Strategic Orientations for Information and Communication Technologies Research in Europe

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1 Executive Summary

Information and communication technologies (ICTs) already enable people, organisations and society to live or operate in an improved way. Future ICTs promise a wide range of social benefits that cannot yet be imagined and importantly, innovation in this field will continue to be a driver for economic growth. There is also no question that future ICTs will remain a key enabling technology for the sciences and research activities. Sustaining this innovation is crucial for the continuing development of the European Union economies.

New opportunities linked to the increasing pervasiveness of these technologies and the way they are developed need to be seized now. This is key to maintaining Europe's existing leads in the ICT sector but also in other vertical sectors such as, for instance, in car or aircraft manufacturing. More importantly, new leading positions will be made possible by future ICTs and related services.

The ISTAG has previously developed a vision of ambient intelligence for future ICTs and their uses. It provides a distinctive European perspective on how computing and networking technologies are increasingly becoming pervasive and how this trend can be shaped to Europe's advantage. The challenge now for Europe is to master, help shape and progress this new wave of technology, taking advantage of European strengths.

ICTs and the related research are facing changing circumstances such as globalisation and growing complexity. The challenges are not just technical. Matters such as trust and confidence and interoperability need to be addressed. Competition affects more and more research activities. It is necessary to cope with the emergence of new competitors such as India and China, and potentially, with the declining attractiveness of Europe as a place to undertake research.

If the maximum amount of innovation is to happen in Europe, enabling it to be a place of first choice for ICT research investments, it will be necessary to reinforce research capacities and also to develop new means of investing in research.

This notably implies strengthening excellence, supporting collaborative research permitting risk sharing and achieving critical mass, and developing advanced infrastructures. This requires more harmonisation of research priorities and funding rules across Europe. Attention should be paid to research, bringing technology development and use closer together. The involvement of users in every stage of the process, rather than just classical end stage user testing, must be explored. The full cycle of innovation through short, medium, and long-term activities must be stimulated and importantly, these three types of research should be interwoven.

Europe must be at the forefront in pushing the limits of ICTs and their use. Mechanisms need to be developed to ensure the successful and seamless integration of components and their convergence into new types of systems and environments. In addition, ICT research frontiers are blurring with other disciplines such as cognitive sciences, bio and nanotechnologies. New avenues for research and a wide range of innovations will result from this expanding ICT field.

The ISTAG welcomes the ambition of the Commission in proposing to increase drastically the budget for research at European Union level. The ISTAG also believes that now is the time to reinforce European Union efforts in ICTs and related research and that it should be one of the priorities that must strongly benefit from an increase in research funding within the Seventh Framework Programme.

2 Introduction

Major transitions are taking place in information and communication technologies (ICTs) and the scope of the changes goes beyond the obvious. Significant opportunities lie ahead, but there are also some major challenges that need to be addressed.

Over the past two years, the ISTAG has concentrated mainly on highlighting the changing circumstances affecting research and development in ICTs and identifying new opportunities. And it has reflected upon on how Europe should address these matters. Nine reports detailing these reflections have been produced by the ISTAG[1]. This document presents those key conclusions from these reports that address policy and decision making for future ICT research, and in particular the next Community Framework Programme.

Continuing efforts are needed to develop new technologies and to apply these; but this alone is not enough. The policy decisions that will be made in the next few years relating to ICTs will shape, for better or worse, Europe's socio-economic and political position. This observation is not just relevant to the self-evident information and communication technology markets, but also applies more broadly to areas such as social wellbeing, and the global competitiveness of the whole of European industry and of Europe's research and innovation capacities. Why is this so?

ICTs are in the process of becoming a taken-for-granted part of everyday life. Herein, lies a danger. As has been the case over the last 50 years with every major breakthrough in ICT, it is tempting to think that the limits have been reached. Today, as was the case in previous years, this is obviously not the case. As computing and networking begin to move out of boxes and become integrated into the everyday environment, a world of opportunities lies ahead.

3 ICT and related research, an engine for innovation, a source of societal and economical benefit and an enabler to all science fields

Historically, it has been virtually impossible to predict what will be the greatest payoffs from investment in technological development. New technologies not only enable existing tasks and activities to be done before more quickly and efficiently, but also enable completely new kinds of things; for this reason, technology creates entirely new industries and new areas of science. Firms such as Nokia, SAP and Vodafone, major drivers of the European economy today, emerged directly from the information revolution of the 1990s. Further advances in ICT will fuel the continuing development of these and other ICT intensive industries that are already central to the health of the European economy. The next generation of ICT will provide the infrastructure to integrate European businesses into a more efficient and competitive economic web. More importantly, it will also lead to entirely new flourishing and leading enterprises by providing products and services that do not exist today.

Innovation in the ICT field is a driver for economic growth, job creation and improvements in productivity: failure to ensure that this innovation is sustained will be very damaging for the European Union economies.

Digital technologies have steadily been incorporated into the fabric of society: banking, retailing, manufacturing, transport, entertainment, education, and many other activities have become highly dependent on those technologies. Other critical and strategic fields have also become dependent; notably defence, civil security, healthcare, environment, eGovernment

[1] See ISTAG reports : http://www.cordis.lu/ist/istag.htm

and social cohesion in general. Future ICT can do a lot also for the integration of Europe's many and diverse cultures and languages, without destroying them.

As examples: the issues associated with healthcare represent a looming threat for Europe in view of projected demographic changes. Within a few decades, nearly half the European population will be at retirement age or beyond, placing a great burden on the European economy. Exploration has only just begun of the potential for ICTs to augment the abilities of elderly people to care for themselves, and also to help in the care of the ill and the disabled.

With the world facing global warming and potential environmental disasters, ICT is required to monitor and model the environment in order to provide accurate predictions of local changes and to inform local decision-making. Increasing oil costs will result in progressively increasing transport and energy costs. Therefore, ICT can help to reduce transport costs by increasing remote working and by improving the efficiency and safety of transport systems.

There is also no question that ICTs have become and will remain a key enabling technology for the sciences and research activities. This is the case whether it be in the design and manufacture of advanced materials, in tackling the vast complexity presented by the human genome, and, more generally, in gaining insight into complex, multi-component systems ranging from global climate to marine ecosystems, not to mention human society itself. This century's science will depend on ICT just as the last century's depended on mathematics.

4 Technology alone is not enough

Individual technologies alone are not the answer however. There is a number of key issues that need to be addressed if the full potential of ICTs is to be realised.

Confidence and trust must be developed. Businesses and citizens will not fully accept or use these technologies if they fear them, or if they suspect that important democratic freedoms such as privacy are being destroyed, or if they lead to further criminal activities, or if the risks of use are perceived to be too high. Thus the matter of public, industrial and government support must be addressed; it is important that circumstances are not allowed to develop where opinion is against further developments in the information society. Social, ethical, trust, privacy, security and legal issues will become increasingly important, and public, industrial and government support is more likely if proper consideration is given to these matters at an early stage and as part of technology development.

Systems, software, and communication networks must be capable of inter-operating, otherwise they will remain as isolated elements, or not be fully integrated, thus diminishing the potential benefits. This is not purely a technical matter. The deployment of future seamless services will also imply the interoperability between different domains, using, for instance, different nomenclatures and ontologies. This level of interoperability must also be addressed and concerns about security and privacy must be taken into account. Lack of secure and trusted interoperability will also mean that seamless services, for example in healthcare, cannot be provided across national boundaries; this will have a negative impact on the mobility of European citizens.

Organisational change must also be addressed; new technologies should not be installed into outdated organisational structures that are incompatible with the new technologies. Process change is also needed to create efficient and effective processes that are customer focussed.

Research in ICT must therefore be seen as an integral part of a wider policy of technological development and its best use.

5 The importance of a European strategic vision on future ICTand its use

ICTs are becoming pervasive: they are part of products, services and our surroundings, and are adding intelligence to living and working environments.

There has been a diffusion of ICTs into everyday objects and these developments highlight the strategic importance of the vision of ambient intelligence developed by the ISTAG. The view of computers as boxes on desks or in computer rooms is misleading. Computers can be found just about everywhere, but their presence is not noticed, because the technologies are often embedded within items. Moreover, the ICT part of many products, for example cars, is continuing to increase.

The challenge for Europe is now to master, help shape and progress this new "wave of technology" so that, taking advantage of European strengths, it will benefit citizens and businesses through its development and exploitation.

The ISTAG has provided a European perspective on how the trend towards pervasive computing can be shaped to Europe's advantage, and to the benefit of its businesses and citizens. Ambient intelligence places users at the centre of the development of ICTs, and this will lead in itself to innovations. This is a generic vision and not a prescriptive one; it is recognised that specific industries or application domains will have their own visions overlapping with the ambient intelligence vision. What is important is that the ambient intelligence vision provides the long-term perspective to guide and inspire further innovation for the benefit of all.

6 Changing circumstances: global competition and complexity

Global competition is increasing – not only for production and marketing but also for research and development. While outsourcing continues of such activities as software programming to firms in countries like India, a new phenomenon, known as "off shoring of research" has developed. There is increasing emphasis in the emerging economies, such as India, China and others, on research and development, and these countries are now competing with Europe for the allocation of research funds by European companies.

Costs, local aspects such as market considerations and the possibility to develop new products or services around the clock with research teams working in different continents, are part of the reasons why European ICT firms are investing in off shore research, but they are other significant factors. Very important are the flexibility of legal operating frameworks and the workforce, high quality human resources in the form of well trained and outstanding scientists and technologists, and unique knowledge found in particular locations.

Complexity is a multifaceted issue. It is partly related to technologies and systems, partly to users and their needs, and partly to the innovation process and distributed value chains. ICT systems are becoming more complicated, by virtue of the technologies, functionality, the number and variety of component parts, interactions between components, and emergent properties, as well as variety in application contexts and among different users.

The innovation process itself is also more complicated than previously. No longer is there a simple chain linking innovation with adoption. Innovation processes are much more cyclical with more interactions between stages. Time-to-market is still decreasing and the pace of innovation is increasing. Value chains are also subject to innovations and are constantly being changed. This leads to increased uncertainties about how new technologies will be used to deliver value, which thus requires more flexibility in developing them.

Mastering complexity is therefore a major challenge that needs to be addressed. Europe has demonstrated that dealing with complexity is one of its strengths, along with the handling of quality. The enlarged European Union provides additional competencies – such as strengths in mathematics – that are key assets for coping with this complexity.

More must be done to build on Europe's strengths. Important in this respect are capabilities to apply complex systems in applications that will deliver high value, and to embed technologies in process chains. Research programmes also need to be more flexible; to respond more quickly to changes occurring in technologies, applications and value chains.

Addressing the above requires more ambitious and different ways of doing of research in an expanding ICT field.

7 Making Europe a first choice for research investments in information and communication technology

The European Union must not be seen as a second choice for research investments in ICTs. The competitiveness of European research is at stake, and improving the attractiveness of the European Union for research and development investments is a key issue. Steps must also be taken to encourage researchers to stay in Europe; to attract back those that have already left to pursue careers elsewhere; to attract top class foreign researchers.

Important in this respect are several elements. Excellence must be reinforced with concern to create critical mass for a better visibility of the research teams and exploitation of the results achieved. The European Union must have good well-focused research programmes that will encourage researchers to work and companies to invest in Europe. Relations and partnerships must be developed inside, but also outside Europe. Finally, the best research infrastructures must be provided and activities creating uniqueness in Europe must be supported.

One way to create this uniqueness in Europe is through research that is location dependent, for example, research that involves users in the development of ambient intelligence, helping enterprises to understand better local European users and their needs, and how these vary across the European Union countries. The production of high quality and high value services, enabled by an open standard software infrastructure, which will require providers to develop close relationships with their customers, is another example. Importantly, both these examples provide opportunities to develop a distinctive European approach.

It is by bringing closer together technology development and its use that Europe can make a difference and new innovations can be triggered. Europe should therefore be experimenting more with the use of advanced technology in real settings to make sure that technology progress corresponds to the needs of its citizens and businesses.

8 New means and ways of investing in research

The ISTAG insists that there are some key objectives that Europe has to achieve in the coming years, and that new means must be investigated for supporting research in ICT and improving its impact. Support and activities should be organised in a way that stimulates the full cycle of innovation – from basic research through to exploitation. This implies an ability to address different timelines and motivations and to organise the necessary interactions between them.

Collaboration at the European level has shown to be effective and to be a major factor underpinning European successes in the ICT sector. This is crucial for achieving critical mass, for permitting risk sharing, for developing excellence and complementing expertise toward common objectives.

- ***Reinforce European excellence***

It is mainly by fostering, demonstrating and exploiting excellence that funding and investment can be drawn to ICT research in Europe. One way to achieve excellence is to concentrate efforts and 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 centres of excellence exist, as in microelectronics and micro-systems, Europe has been able to establish industrial leadership worldwide.

The Networks of Excellence introduced in the Sixth Framework Programme are intended to reduce fragmentation and lead to permanent restructuring of the research base. Consideration must be given to additional ways to concentrate effort in a way that will ensure continuing flexibility, responsiveness, and competitiveness of the research and technology development community. The development of centres of excellence and knowledge networks between them, within the European Union and involving industry and academia, is one way of achieving this. This will also help to maintain the attractiveness of Europe as a place to undertake research.

Another area that will help improve the attractiveness of Europe as a place to pursue a research career, is that of European level competitions for the purpose of technology evaluation. These types of competitions are undertaken mostly in the United States at the moment, and in some cases the best European research teams are attracted to these competitions. Such competitions should become part of the European research scene.

- ***More harmonisation of research priorities and funding across Europe is required***

Whatever the increase of the budget for the next Framework Programme will be, most of the funding will still come from the Member States and Regional Authorities and more resources at the European Union level should not mean less at these levels.

Considering the wide range of European (for example, Framework Programmes and Eureka), National and Regional Programmes, there is a need for a clearer distribution of the roles of the various funding sources and to continue the effort towards the identification of common priorities and the achievement of the European Research Area. The rules governing public funding at Member State and at European Union levels should be harmonised, to ensure compatibility and co-ordination among programmes and to achieve an integrated portfolio of activities. In general, the limited resources available may be applied more effectively through greater coherence, co-ordination and concentration. All parts of the innovation supply chain from ideas to markets should be engaged, requiring effective ways of inter-working between industry and academia, and between small and medium size enterprises and larger organisations.

Continuation of the effort towards the achievement of the European Research Area is necessary. In addition, the concept of European Technology Platforms, with the commitment of the stakeholders, should facilitate the setting of priorities and the pooling of public and private resources.

- ***Reinforce research and knowledge infrastructures***

Development of the research and knowledge infrastructure is important to help ensure the excellence of European research and to attract top class researchers. This is true for pursuing the technology race for ever smaller-size, for creating, experimenting with, integrating and validating new technologies and systems at the relevant scale, and for facilitating collaboration in research with the access to highly specialised laboratories, databases, libraries and facilities.

However, the escalating investment costs for such facilities push them beyond the level of individual Member States or market players, providing a clear imperative for action at European level. As the same time, it is vital to underline that the regional dimension of science and technology is becoming increasingly important. European support for infrastructures should be coupled with incentives for strong local infrastructures and networks of leading industries and research institutes that will help strengthen regional capabilities and establish highly innovative regions.

In particular, to compete and collaborate successfully at global level, the European research community must continue to have access to world-class high-speed research networks and computing and semantic enabled knowledge infrastructures. In the Sixth Framework Programme one important goal is to create, on top of the pan-European network for research GÉANT, a pan-European infrastructure that is based on GRID architectures. A major priority is to build a pan-European GRID-empowered e-infrastructure of production quality that will serve the concrete and actual needs of all researchers. This will create the conditions to undertake research and development in Europe in a qualitatively different way and will support the implementation of the European Research Area. Significantly, the new e-infrastructure will also be crucial for implementing future research orientations for ICTs.

- ***Develop experience and application research***

Successful research and development for addressing challenges such as those raised by the vision of ambient intelligence needs a new approach based on the involvement of those that will be affected by the presence of such systems. 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 research and development, 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[2] has been proposed as a means of addressing the challenge of creating a human-centred approach to research and development 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 research and development 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: research on design processes for ambient intelligence, development of methods for usability testing;

[2] See http://www.cordis.lu/ist/istag.htm : ISTAG report on Experience and Application Research

- *development of prototypes*, 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 components in quasi-realistic environments;
- *feasibility tests and validation* of solutions in field environments.

The research can be undertaken in centres, physical or virtual, via co-operative networks, or through field trials. There are three possible types of centres. The first are Science and Technology Centres, where basic research is conducted on component technologies. The second are Feasibility and Usability Centres, where basic research is conducted with users on component technologies and systems and where components are integrated into real user environments on a small scale and usability is investigated. The third type of centre are 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.

- ***Stimulate the full cycle of innovation : support the deployment of new technologies and new services (short-term activities, 3 to 5 years)***

The ISTAG suggests the identification of large scale and visionary European-wide initiatives[3] that promote and advance European research and technology and capitalise on financial mechanisms such as public procurement. Such initiatives should be implemented in addition to, and in combination with research programmes. The initiatives would ensure a closer articulation between research and implementation actions and support the transfer of advanced technology into applications. Member States should sign up to these initiatives to bring all areas up to the same standard and to ensure interoperability and coherence.

When considering application domains, such as health, road transport, eGovernment, the main difficulty is not developing new ICT related systems, but ensuring that these are deployed at a National or Regional level across Member States. Without commitment from stakeholders, past experience has shown that research and technology development projects often do not realise their full potential. This calls for European-wide initiatives involving all organisations in the innovation cycle – from research through to exploitation, and in particular, involving end user requirements and experiences.

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. The initiatives should leverage new funding mechanisms since the cycle is more than "strategic research and technology development" (for example, within the IST programme) and "development" (for example, within Eureka etc.). They should use procurement as a powerful mechanism.

Public procurement provides opportunities that should be investigated. Public spending represents 15% of Gross Domestic Product in Europe in many fields where ICTs can bring significant improvements. Yet public administrations seldom use their power as significant purchasers to achieve a global impact: there have been missed opportunities for transforming ICT breakthroughs into business and societal successes.

[3] See http://www.cordis.lu/ist/istag.htm : ISTAG report on European-wide Initiatives

The above will not require additional public financing, but the redirection of existing spending to increase efficiency and effectiveness. European Governments should be at the forefront of the adoption of ICTs, not only applying established technologies and solutions, but also actively encouraging innovation and facilitating the establishment of new markets.

Even if the concept of European-wide initiatives goes beyond pure research and development activities with some focus on shorter term deployment, the concept of Technology Platforms introduces interesting synergies to be exploited particularly regarding the commitment of stakeholders towards common ambitions. In addition, the will expressed by the Commission in the preparation of the future budget (financial perspectives) to dedicate more money to programmes supporting deployment of ICT at the European Union level offers interesting opportunities to stimulate further the innovation cycle.

- ***Stimulate the full cycle of innovation: address the medium-term (5 to 10 years) through more integrated approaches***

Significant technological progress and innovations can arise from projects having clear and specific goals, the achievement of which can be easily recognised. Previous concrete projects, such as putting a man on the moon or sequencing the human genome, had natural milestones and provided strong incentives for technological advancement. Based on this principle, "grand challenge" projects are needed in ICTs to stimulate research and development and innovation in key areas and to help the European Union to achieve its social and economic goals[4].

The ISTAG's view is that the Internet and today's global networks of mobile communication technologies presage an era in which IST will be dominated by complex, integrated information technology systems. Europe's strength is the design, engineering and deployment of large-scale integrated information technology solutions. The major challenge for research and development will lie in further learning how to design and manage complex, networked systems comprising thousands of heterogeneous components, while ensuring that these systems bring benefits to European society.

At the same time, the boundaries of ICT research are now rapidly expanding and prospects for further growth are also increasingly relying upon cross-fertilisation of ICTs with many other scientific disciplines, in particular material, biological and the life sciences. The grand challenges aim to achieve these goals by furthering the seamless integration of diverse ICTs with upcoming advances in other relevant disciplines.

The ISTAG has sought to identify visionary projects leading to "concrete pictures of the future", focusing 5 to 10 years ahead, that will demand interdisciplinary research and engineering in many key areas and that exemplify application domains of particular promise for growth in Europe. They must promise direct payoffs in the form of specific and highly practical technical capabilities, as well as new businesses and even industries. The ISTAG has also sought grand challenges in specific technological areas in which Europe has a real chance to exploit its existing expertise.

Illustrative examples are:

- *The 100% Safe Car*: Road accidents entail enormous human suffering and burden European society with tremendous financial and human costs. Hence, projects are envisioned with ICT systems leading to the realisation of the 100% safe automobile to almost eliminate traffic fatalities;

[4] See http://www.cordis.lu/ist/istag.htm : ISTAG report on Grand Challenges

- *The Service Robot Companion*: As the European population ages, spiralling health-related costs will place an immense burden on European economies. The development of flexible home-care service robots is envisioned, which will help people to care for themselves, improve their comfort of living and entertain them;
- *The Disease and Treatment Simulator*: The vision is the development of a computational platform for simulating the function of diseases. This simulator will enable medicines to be tested without putting people at risk, and will accelerate research into damaging ailments such as heart disease and cancer;
- *The Intelligent Retail Store:* Intelligent retail stores are envisioned in which emerging ICTs are integrated to bring more information and efficiency to both retailers and their customers.

- ***Stimulate the full cycle of innovation: support basic research***

Basic research at European level should be aimed at encouraging and promoting competition among research teams. It should strengthen Europe's performance and nurture and stimulate creativity and excellence. It should also contribute towards creating a more attractive environment for research in Europe. European level basic research must complement existing national schemes, for example by addressing issues that require a European wide approach. Funding at the European level must be additional to, and not diminish the amount of funding available at Member State level, while ensuring some co-ordination with National schemes.

The allocation of funds to grants within a given field or major area should be based fundamentally on the research excellence of the individual proposals through a bottom-up process. However, a higher-level authority should decide the allocation of funds to major areas (such as, for example, ICT). The funding devoted to basic research in information and communication sciences and in their combination with other relevant disciplines should be considerable to achieve the significant progress needed in many ICT areas, including, computer science, communications, and nanoelectronics.

- ***Interwoven innovation activities***

Traditionally, short, medium and long-term research have been seen as independent activities. However, in modern innovation cycles these three types of research are interwoven. Therefore there is a need to bring together short, medium and long-term research, as well as research and non-research activities. New ways of structuring all these activities need to be investigated. The proposed approaches would benefit from being "integrated" with European Technology Platforms, which can run in parallel to the innovation cycle.

9 New technology challenges and an expanding ICT field

Many technology challenges and opportunities lie ahead.

Pushing the limits of ICT and its use

As a new generation of mobile systems is steadily rolling out, the promise of a completely wireless computing and communication world is getting closer. However the achievement of this requires that hurdles such as power consumption, spectrum management, reconfigurability of devices and systems, interoperability, security, and management and control of ad-hoc connections be addressed.

Progress in technologies (for example, broadband, coding and compression), the continuously expanding trend for mobility, the increasing deployment of broadband accesses, and new features of terminals, are bringing a new form of "convergence". This will be facilitated by the ability to provide content on a wide variety of terminals and consumer devices over all possible delivery platforms.

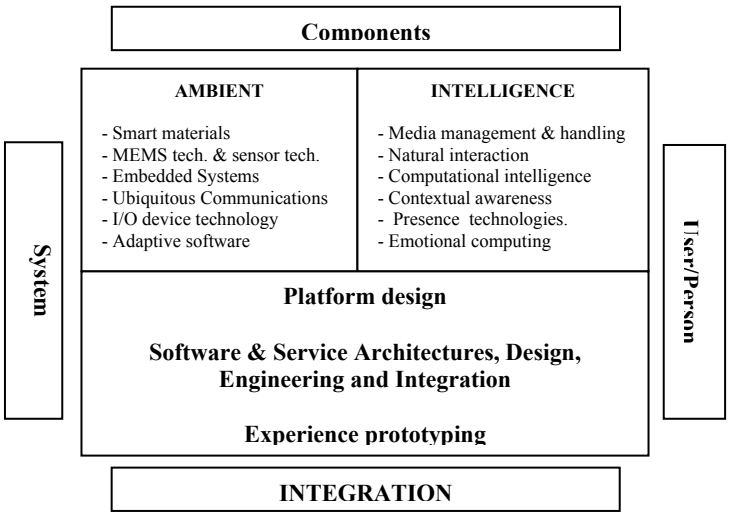
Progress in miniaturisation is pushing technology to the ultimately small, helping integrate on single chips an immense number of functions at affordable costs. It is also increasingly possible to integrate heterogeneous elements from electronics to mechanical or organic systems that will help incorporate not only intelligence but also sensing and action in all types of artefacts.

The scientific foundations of computing are starting to be understood, engineering techniques to produce reliable, large-scale software systems are emerging, and knowledge and computing GRIDS and support to virtual organisations are at the beginnings of becoming routine parts of many activities.

At the heart of future ICTs will be presence and awareness technologies that will enable the context of information and users' behaviours to be defined. These latter technologies should enable ICT devices and artefacts to learn and adapt from sophisticated perception systems mimicking humans and natural behaviours.

Learning from natural cognition will bring radical transformations to ICT-based products and services in all types of applications from knowledge handling to new computing paradigms and artificial systems, for example, in medicine and manufacturing.

Integration is key



Most importantly, the ISTAG draws attention to significant new avenues of research that need to be opened for integration, in which mechanisms need to be found to ensure the successful, seamless integration of components and their convergence into new type of systems and environments[5].

Architectures, methods and tools must be developed that are capable of combining technologies into these systems. New approaches will also need to be elaborated to integrate technologies across different usage environments.

Stimulating and exploiting progress in ICT requires mostly the capacity to build systems of various sizes of increasing complexity, and bringing together developments in multiple disciplines. This should be done whilst keeping track of usability and the utility of the technology and bringing closer together technology progress and its use.

[5] See http://www.cordis.lu/ist/istag.htm : ISTAG Research Content report

The case of software and middleware infrastructure

A critical element in an increasingly interconnected world will be the software that will implement most functionality and will also ensure the secure and reliable integration and interoperability of mobile, fixed, personal and corporate heterogeneous resources and applications. This will require advanced technology for the development of highly functional and high-quality software, and a truly semantically enabled middleware infrastructure for its interoperability[6]. Open standards and open-source software are also crucial. Important for European industry is availability of secure, robust, common and open infrastructure standards, including amongst others, GRID and web services middleware. The emergence of open-source software and the transformation of the middleware infrastructure into a commodity are also leading to a level playing field, and there is an important window of opportunity in GRID and web services middleware that European Union companies can exploit.

Blurring frontiers between ICT and other disciplines

The ISTAG also foresees major breakthroughs emerging from the blurring of frontiers between ICT and other fields such as biotechnologies, materials science at the nano scale, the chemistry of the infinitely small, and cognitive sciences. Interdisciplinary research is developing at the interface between the organic and the non-organic, the so-called *wet frontier*, and in the context of ambient intelligence, between the (intelligent) environment and information and communication systems.

Over the next decade, ICTs will be moving closer to biology and life sciences whilst ICT artefacts will increasingly involve and exploit the properties of living material including cognition, perception and action. Not only will other disciplines such as biotechnology, material science and cognition be brought into ICT, as in the design and manufacturing of novel sensors or in new computing processes, but ICT will also flow back into scientific disciplines, acting as an enabler for new discoveries.

The cross over will be most clear in medicine, but also in realistic efforts to develop implementations of "human augmentation" – the ICT-based enhancement of human characteristics. These two trends will, of course, amplify one another.

[6] See http://www.cordis.lu/ist/istag.htm : ISTAG report on GRID, Distributed Systems and Software Architectures

10 Conclusion

Given the increasing pervasiveness of ICTs and the significant progress that has been achieved in research so far, it is possible to foresee in the years to come, a myriad of novelties and new types of services and applications for the citizen in everyday life and for creating and improving businesses. This will have a strong impact on European growth, productivity and employment.

The most significant benefits will be achieved in Europe if there is a readiness to seize the opportunities that lie ahead.

Europe is in a relatively good position in some key ICT domains (for example, microelectronics, mobile and fixed communication, consumer electronics). It has however some weaknesses, with almost no computer and generic software industry. The evolution of ICTs and their increasing pervasiveness offer opportunities to catch up and develop new leaderships (such as the creation of a level playing field for software and middleware infrastructure).

Europe can build on its strengths in the above fields but also in areas such as embedded systems, and on its scientific know-how in mathematics, physics and in biology. It has also to build on its well recognised capacity to transform complex technologies and systems into reliable and high value products, services and infrastructures in all sectors and for all the citizen and businesses.

In the context of increasing global competition in research and development, these are essential assets. To be able to exploit them, Europe must be more proactive in researching and developing ICTs, in reinforcing the related scientific and industrial research capacities, and in creating the conditions that will attract investors and researchers.

The Framework Programme plays a unique, direct and also catalytic role in stimulating and structuring research in Europe. It offers increased visibility and helps to create the critical mass necessary to address a range of research challenges. In addition, the exemplary dimension of the Framework Programme towards national or regional activities should not be underestimated.

The Commission is proposing[7] six main objectives for supporting research at the European Union level. As underlined in this document, all of them are important for the development of future ICTs. However, the optimal European support will depend on the way these objectives are combined taking into account the specificity of each sector or research thematic priority. Collaboration at the European level has been shown to be effective and to be a major factor underpinning European successes in the ICT sector. Collaboration European research is crucial for achieving critical mass, for permitting risk sharing, for developing excellence and complementing expertise toward common objectives.

The ISTAG welcomes the ambition of the Commission in proposing drastically to increase the budget for research at the European Union level and **insists that the ICT sector and related research be one of the priorities that must strongly benefit from such an increase**. This increase should not be symbolic or isolated, and **has to be followed by national or regional efforts** with respect to maintaining momentum on the achievement of the European Research Area in the ICT field.

[7] Commission Communication: Science and technology, the key to Europe's future – Guidelines for future European Union policy to support research

European Commission

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