Building the
European Robotics Platform
EUROP

The High Level View

May 2005

Contents

Executive Summary

Robotics is a technology at the cusp. Long accepted by industry to improve factory quality, performance and efficiency, robotics has for at least three decades been a key technology in engineering industries (automotive, electronics, etc.) for increasing industrial productivity and for competitive manufacturing. After decades of hype and disappointment, robots are at last moving out of the shop-floor to find their way into a range of new markets that promise to dramatically expand the robotics market and bring social and economic benefits to a greater range of peoples' lives.

In industrial robotics, where Europe has one of the leading positions worldwide in both the production and usage of manufacturing based systems, advances in robotics technologies are allowing them to be applied in new, manpower-intensive areas such as food production, aircraft assembly and recycling of goods. As technology further develops, we will soon see the teaming of workers with robots so that the resulting networked systems become more capable and agile. Robots will thus become workers' assistants and collaborators in all areas of production, providing more flexible approaches to manufacturing and assembly and bringing to these industries the benefits of increased productivity and quality, enhanced health and safety.

The same technologies needed to drive forward industrial robots are also forming the basis of the emerging service robot market. Novel robot machines are thus increasingly finding their way into our homes, in hospitals and in other public spaces, in the form of self-navigating vacuum cleaners, lawn mowers, window washers, toys, or surgical robots. Robots will soon be capable of performing more challenging tasks though, in professional markets, in the home or at leisure. They will be operating in field areas like forestry, agriculture, cleaning, mining, freight transport, demolition, etc. New robot systems will also enable a greater proportion of the population to live independently in their homes (by providing personal assistance to the elderly and the infirm) and add further convenience to our daily life by helping us carrying out everyday chores. The robot service market, while small, is currently growing exponentially. It will become a major influence on most areas of people's lives and a very large worldwide supply network will develop in the provision of robotic products and support services.
At the same time, the recent dramatic events are pushing many countries to develop new effective solutions to increase civil protection and security, fight against terrorism and crime and monitor illegal immigration. As the quickly growing use in the defence field has demonstrated, the use of robots in civil security applications can be catalytic for protecting human lives. Examples of emerging robotics applications include: border, costal and sea patrol, surveillance of critical infrastructure, environmental monitoring & surveillance, fire and bomb fighting, search & rescue missions.

Robotics is also becoming a mandatory technology in many space applications, either because it is the only available solution, e.g., searching for life elsewhere during long space missions, or for protecting human lives in space assembly & repair operations.

The worldwide market for both industrial and service robots is forecast by UNECE and IFR to be in excess of $66Bn by 2025. Expectations for a huge market growth in civil security applications also exist, although no precise figures are available today. Such prospects still very much depend though on our capacity to drastically improve the autonomy and performance of robots and their interaction capabilities with people and other robots.

In order to make progress in these, all our major competitors, particularly Japan, Korea and the USA, are funding multi-million research initiatives aimed at securing their country's position as major suppliers in the newly emerging robotic markets.

That the application markets discussed will emerge is certain, what is uncertain is whether Europe will be amongst the leaders in developing, producing and using these technologies, products and services. The imperative for being among the leaders is clear. The benefits that future robotics industries will bring are essential in meeting the Lisbon objectives of increased competitiveness and increased social inclusion. Without a leading supply chain capability, European companies and citizens will be disadvantaged from not being able to access leading edge systems. With regard to production there is a clear economic argument for maintaining and developing further the European capability in robotics.
In fact, only Europe, among the existing major manufacturers and users of robot systems, is lacking such an initiative. While there are many research funding opportunities, these are fragmented over

individual Member States and European institutions (ESA, the EU Framework Programmes, EUREKA, etc).

To help overcome the present fragmentation of efforts and other obstacles, boost Europe's innovation capacity and achieve European world leadership in this sector, the Robotics Action Group (a grouping of top executives from leading robotic industrial and research organisations) strongly endorses the need for a European Technology Platform in Robotics – EUROP.

The vision for this European Technology Platform can be summarised as follows:

> *A consolidated European R&D strategy in robotics is a requisite for preparing a new generation of robots that would closely collaborate with workers and move out of the factory to conquer a new wave of novel service, security and space application markets.*
>
> *As industrial, service and security/space robotics increasingly share the same research challenges and agendas, such initiative would aim to maintain Europe's leadership in industrial robotics and expand it into the burgeoning service and security markets. It would also aim to ensure increased public and personal security levels as well as new levels of quality of life by providing technologies required to enable society to address challenges in terms of ageing and well-being.*

The vision is that of empowering European citizens and the basis of this empowerment is robots that work with people rather than away from people; and, robots that interact with people and with each other and which evolve, learn and adapt their behaviour to the requirements of the task they are given and the environment they are in. Moreover, the growing spread of ubiquitous computing and communication environments, will lead to robot technologies being embedded into ubiquitous ICT networks to become the agents of physical action. Robots as units capable of moving around, sensing, understanding and acting will become part of these networks for delivering, individually or collectively as a group, novel capabilities, applications and services.

The ambition of the platform is to unite all the main industrial and academic robotics stakeholders and public authorities around this common vision, where research goals and priorities of industrial relevance, timeframes and action plans on a number of strategically important issues can be agreed and relevant actions implemented. This is an ambitious mission, which, if successful, will see Europe maintaining its leading position in robotics and develop new companies and supply networks to meet the new technology needs while also supporting the Lisbon objectives of enabling greater European industrial competitiveness and greater social inclusion.

On one hand, an improved co-ordination between European civil RTD efforts and, on the other hand, the cross-fertilisation of such efforts with similar defence-related RTD can pave the way for an accelerated development of generic underpinning robotic technologies and integrated robotic systems that would be beneficial both for civil and military applications

1 Introduction

Robotics has become a synonym for competitive manufacturing and for novel, fascinating machines, which are about to be used in all areas of modern life. Furthermore robotics is seen as a key technology which enables the creation of new, valuable products or which adds performance and functionality to future machines.

By robotics we understand machines, technologies and components that aim at the development, installation and operation of:

- **Industrial robot systems** to achieve high-quality and cost-effective flexible manufacturing and logistics in all major industrial branches thus strengthening the economic base of Europe.
- **Service robots** to be found outside manufacturing in all domains of our life thus creating new product opportunities for highly receptive markets: in professional services, in health and rehabilitation, in domestic and leisure environments and in hazardous environments.
- **Space and Security robots** concerned with the use of robots in land, sea, subsea, air, space and crisis or security management missions.

These are the **three application domains** addressed by the EUROP platform.

The major challenge is to develop robotic **systems with more elaborated behaviours**, embedding typical robot technologies (sensors, actuators, controls, and man-machine-interfaces) in a wide spectrum of future products (ranging from vehicles and medical devices, through intelligent consumer products and home automation devices, to space rovers). Such robots will have greater perception capabilities to reason about their environment, goals and actions. Exploiting networking capabilities, they will be more interactive, co-operative and collaborative with people, other robots and information systems. They will also be able to evolve, using learning abilities, as well as to adapt more easily to the environment and to goal contingencies. Using these capabilities, future robot systems will enable new kinds of industrial automation, provide a wide range of innovative services as well as performing future security and space missions.

Robotics affects a broad sector of economic activities, and research and development in this field will strongly contribute to the creation of new opportunities towards European employment and growth. These opportunities are even more pronounced when facing socio-economic factors such as the aging of our society, increasing European competitiveness or the need to develop a knowledge-based society as formulated in the Lisbon strategy[1] and reinforced by the follow-up review[2]. Robotics is able to address sustainable perspectives for all of these factors.

Europe is still in the fortunate situation that an innovation-driven and export-oriented robot industry has established itself during the last 25 years. Furthermore, first product opportunities regarding service robots have been taken up mostly by start-ups. Currently it is estimated that some 250 universities and research institutes offer education and research in robotics thus creating an unparalleled basis in qualification and knowledge. Robotic networks such as EURON[3] and professional organizations such as EUnited Robotics[4] significantly contribute to improve the coordination of European research and innovation-related activities.

There is a wide consensus within robotics research and industry on future challenges regarding robotics research and on economic opportunities which is reflected by a solid statistical framework, White Papers and roadmaps. However, international efforts towards large robotics R&D initiatives, building new robotics industries and preparing markets for robotic products are underway outside of Europe, particularly within Korea, Japan, and the US. These initiatives address similar opportunities

[1] Lisbon European Council: Presidency Conclusions (24/03/2000 – No. 100/1/00)
[2] Facing the Challenge. The Lisbon strategy for growth and employment. Report from the High Level Group chaired by Wim Kok, Nov. 2004.
[3] http://www.euron.org
[4] http://www.eu-nited-robotics.net

and socio-economic challenges, reinforcing the need for the formulation and implementation of a European initiative in this strategically important area.

The first meeting of a high-level group of robotics research and industries took place at the presentation at the UN/ECE in October 2004, followed by an intense workshop of the Robotics Action Group to develop a vision and a strategy towards a Robotics platform for Europe. This was followed by expanded group meetings in Brussels and Barcelona to establish the agenda for a European Technology Platform in Robotics. This report is the result of their deliberations.

2 Motivations and Vision[5]

For decades researchers have been striving to develop machines that can perceive, reason and autonomously carry out tasks in their environment. Robotics has already revolutionized automotive and electronic industries, and is now at a decision point where its scope is dramatically expanding throughout the development of new markets in the 21st century. This will impact everyday customer's products up to large scale systems geographically distributed. Their development will transform every day 's life as well as industry processes in an order of magnitude similar to internet technologies at the end of the 20th c. Evident challenges in security and space exploration will also pave the way for future generations. These markets are driven by social aspirations and economic benefits impacting a wide range of people's lives, at the core of our European society. The **three application domains** are representative of the robotic perspectives in terms of societal changes and vision.

2.1 Societal Challenges

The Lisbon strategy, committed to establish the EC as the most dynamic and competitive knowledge-based economy in the world, was critically assessed and reinforced by the Kok Commission. This Commission identified major societal challenges: the greying Europe, the EC enlargement, economic growth, productivity and employment. In addition, the ability to take appropriate precautions against security threats has become a major topic of concern for the European citizen.

The greying Europe

Over the next two decades the industrialized world is going to experience a significant growth in the number of people above 65 so that the dependency ratio is going to grow from about 22% to more than 45% in almost all EU countries. Contrary to this trend, the employment rate is declining even for physically demanding jobs. This is going to challenge the present economy in terms of economic efficiency and at the same time leisure will be even more valued. This will call for added efficiency in the industry and the introduction of aids in our daily lives to provide a maximum of free time to pursue "quality activities", i.e. spending time with the loved ones and relaxing.

Growth, productivity and employment

The European growth gap to the US and Asia has widened, which can be attributed to a lower investment per employee and to a slow-down of the technical progress in the mid-1990s. Increasingly newly created jobs tend to be low-wage jobs, which is in contrast to the required investments in R&D, training and education. Also it is often cited that Europe's industrial structure is based on more low- and medium-tech industries than its direct competitors. Europe needs to be identifying and developing new knowledge-based industries that will be competitive in their own right and which support manufacturing industry in driving up productivity.

EC enlargement

Current and future enlargement of the EC will, besides an increase in population, add significant, and mostly low-cost, manufacturing capacity. The transformation process from a low-cost to a knowledge and skill-driven manufacturing is critical as it implies significant investments in manufacturing equipment, new processes, high-added value products and trained personal.

New security threats

Geo-strategic and geopolitical changes of the previous century have generated new threats that are complex, versatile and difficult to identify and characterise. Addressing these changes will require a flexible response capability with the ability to react quickly to a wide range of novel threats and alerts. Moreover, evident progresses can be achieved in crisis management (such as floods, earthquake, forest fire), where search and rescue missions can benefit from advanced robots. Also, monitoring illegal and clandestine activities, border surveillance and everyday security concerns can benefit from robot systems.

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[5] The numbers provided in this section are primary taken from the UNECE statistical report "World Robotics 2004"

2.2 A Vision for the Future

Many examples of the key contribution robotics can make are to be found in the three application domains: automating production of complex equipments, providing in-home assistance to the infirm and elderly, expanding the range and choice of education and leisure facilities of European citizens, developing efficient surveillance of threatened infrastructures (airports, train stations, …).

Robotics is in essence the science of the Artificial by contrast to the science of Nature. In the same way as mobile phones and laptops have changed our daily lives, robots are poised to become, sooner or later, a part of everyday life, as our appliances, servants and assistants, as our helpers and elder-care companions, assisting surgeons in medical operations, intervening in hazardous or life-critical environments for search and rescue operations, cleaning and repairing pipes or searching for life elsewhere.

The vision for robotics is therefore that of empowering European citizens. Empowering workers to be more productive and increasing their skill level. Empowering the infirm and the elderly to lead independent lives, without burdening relatives or the state. Empowering individuals by giving them more time and choice in their education and entertainment activities. Empowering officials to monitor, survey and act in remote, complex and often hostile / hazardous environments. Empowering everyone by increasing the security of society.

The basis of this empowerment is the provision of robots that work with people rather than away from people; robots that interact with people and with each other and which adapt their behaviour to the requirements of the task they are given and the environment they are in. The robot systems of the next decade will be human assistants, helping people do what they want to do in a natural and intuitive manner. These assistants will include:

- Robot co-workers in the workplace that serve the worker and can be integrated as an agent in symbiotic manufacturing systems. These robot assistants will be at the core of human-centred automation and will allow automation to spread to the majority of manufacturing industry (increasing the 15% currently exploited). This in turn will contribute to less unemployment as more competitive segments of the industry and associated manufacturing capacity will remain in Europe.

- Robot companions in the home that provide assistance by carrying out everyday tasks such as fetch-and-carry jobs, mobility aid and multi-media services.

- Robot assistants to service professionals that work with the professional to enable him or her perform a task quicker, safer, with higher quality and more economically. These robot assistants will be in all spheres of the service industries, from surgery to physiotherapy, from construction to demolition, from subsea inspection and repair to space exploration, and from surveillance of the environment and of critical infrastructure to crisis, crime and illegal immigration monitoring.

- Robot servants and playmates that carry out domestic chores or are truly interactive toys.

Still the vision where people and robots interact and work symbiotically together is still some way off. Today’s robots are far from being able to understand and reason about their environments, their goals and their own capabilities, to learn both from experience and from what they have been taught.

The evolution of information society is characterised by ubiquitous computing and communications, and by the development of services that are location-aware and context-aware. One facet is the development of artefacts with embedded computing and communication and of ad hoc networks of sensors forming what has been termed “ambient intelligence”. With the growing emergence of ubiquitous computing and communications, robots will be able to call upon an unlimited knowledge base and coordinate their activities with other devices and systems. Further, the growing spread of ubiquitous computing will lead to robot technologies being embedded into networks to become the agents of physical action, resulting in the active home, office and public environment. In this context, robots as units capable of moving around, sensing, actuating, decision making and acting will become part of these networks of artefacts for delivering, individually or collectively as a group, novel capabilities, applications and services.

A key component of this vision is that it will be European industries and research that will be at the heart of providing the technology, the systems and the standards for these next generation robotic technologies and European industry will extend its current leading position in industrial robotics to be the leading export-oriented producer of industrial, service and security robots. This industry will encompass a supply chain from SME customisation or component manufacture to large scale system builders.

Such a vision of a thriving knowledge based industry will only result from proactive joint effort. The vision of future European Robotics and the action that will bring it about can be summarised as:

> *"A consolidated European R&D strategy in robotics is a requisite for preparing a new generation of robots that would closely collaborate with workers and move out of the factory to conquer a new wave of novel service, security and space application markets.*
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> *As industrial, service and security/space robotics increasingly share the same research challenges and agendas, such initiative would aim to maintain Europe's leadership in industrial robotics and expand it into the burgeoning service and security markets. It would also aim to ensure increased public and personal security levels as well as new levels of quality of life by providing technologies required to enable society to address challenges in terms of ageing and well-being."*

Robotics represents impressive feats of engineering. By developing robotic systems, companies can both demonstrate technological prowess and benefit from ancillary breakthroughs that emerge along the way. Robotics is highly interdisciplinary and there is a unique opportunity with a platform initiative to integrate both across the involved disciplines and across the involved application domains a strong industrial basis that will ensure sustainable growth and maintain manufacturing jobs within the European Community. Only through an investment in robotics it is possible to ensure that industry can remain competitive for manufacturing while at the same time providing the basis for the new industrial domain of service and security robotics.

3 The industrial perspective

As well as bringing significant benefit to European citizens, robotic products and technologies will be a source of economic prosperity for those companies involved in the supply chain. To maintain first mover advantage in terms of increasing the productivity of European manufacturing industry and providing systems which meet the needs of European citizens, it is vital that a strong robotic supply industry is maintained in Europe and that it grows and adapts to the needs of the new markets arising from the new technologies. This section examines the current and emerging markets for robotics that will be common technology platforms, subsystems and components.

3.1 Present Market Status

3.1.1 Industrial Robots

Robotics has, for at least three decades now, been widely used in engineering industries[6], which account for some 70% of all industrial applications. Typical industrial use involves the car industry and manufacturing of electronic goods. In the car manufacturing, the introduction of robots has in particular enabled a more homogenous quality of products and at the same time contributed to a dramatic cutting of costs. The industrial robotics market has experienced a steady growth over the last decade and today about 30.000 new units are installed each year in Europe, within an annual world market of around 80,000 new units. The estimated number of robots in use in Europe is at present about 250.000. In the period 2004-2007 the annual average growth rate in terms of unit shipments is expected to be at about 6-8% with the overall market sales volume remaining roughly the same. New application areas of robots aim at the food industry, where a higher degree of hygiene and increased productivity can be achieved by minimising human handling of the raw food items, as well as in the recycling industry of various consumer goods.

Large enterprises in high-volume markets have remained competitive, thus maintaining qualified jobs by increasing their productivity through, among other things, incrementally adopting robotics. While robotics has become a synonym for competitive manufacturing, so far robots have been mainly used in the automotive and electronics industries which, including their supply chains, account for more than 60% of annual total robot sales. Therefore robot technology has been mainly driven by the needs of these high volume market industries.

It is recognized that future manufacturing scenarios throughout all industrial branches will have to combine highest productivity and flexibility with minimal manufacturing equipment life-cycle-cost. This paradigm is particularly valid for today's small and medium sized productions as these are particularly prone to relocation due to high labour costs. The response of the 2000 Lisbon Summit to these globalisation challenges was to concentrate on high added-valued products, skilled work forces and superior manufacturing technology. This holds particularly for the situation in the New Member States where a sustainable alternative to typical low-wage manufacturing has to be offered.

Current robot automation technologies have been specifically developed for capital-intensive large-volume manufacturing, resulting in relatively costly and complex systems, which often cannot be used in small and medium sized manufacturing. Thus, future robot systems will not be a simple extrapolation of today's technology but rather follow new design principles required by a wide range of possible applications (application pull). Novel technologies, particularly from the IT world and mass markets will have an increasing impact on the design, performance and cost of industrial robot automation (technology push). From the current trends it is evident that the operation of robots will increasingly depend on information generated by sensors, worker instructions or CAD product data. Thus it can be expected that manufacturing competence will be further concentrated on robot systems as a key component in the digital factory of the future.

[6] Engineering industries consist of the branches: metal products, machinery, electronic, electrical and optical equipment, and transport equipment.

Europe has achieved a leading position in manufacturing and use of robotics equipment, estimated at about €3.1B annually in robots directly which corresponds to some 33% of global sales. When taking into account sales of robot components, system integration and other services, total annual revenues add up to some €13B. In terms of economic indicators such as export share, research and development budgets, growth rates, and employment, the robotic industries stand out as a role model for successful European industries.

Robots are special in that they both enable flexible knowledge-based production and are a complex knowledge-based product by themselves. The relatively few European robot companies and component manufacturers have a pivotal role in this supply chain.

Robotics has been a major topic in funded research and development both on a national and EC level. The Integrated Project SMErobot (FP6-NMP) represents a major initiative in robotics technology and applications. This project, which involves all the major European robot suppliers, is aimed at creating a radically new type of robot system – a whole family of SME-suitable robots – that is to become a commodity within SME manufacturing.

However competitive international efforts are well established. The Japanese Robot Association (JARA) has launched robotics initiatives worth €300m Korean research and industry is in the progress of a 10-years strategic robotics research programme worth €1B. Both programmes are embedded into large national roadmaps towards gaining competitive edges in a critical key technology for future manufacturing across all industries.

3.1.2 Service Robots

Meanwhile a new breed of robots has emerged, to be used outside the manufacturing field: Service robots. By end of the year 2003 some 21.000 service robots were used in professional applications world wide, in addition to more than 1,3 million service robots for personal and private use (lawnmowers, autonomous vacuum cleaners, robot toys, etc) with strong future forecasts (6.7 billion turnover expected form 2004 to 2007). Over the last 5 years there has been an exponential growth in service robotics for private use in homes. Since the introduction of the autonomous vacuum cleaner in 2000 the market has grown to more than 600.000 units shipped per year. At the same time the market has also seen other significant products, such as autonomous lawn mowers. The market is at present experiencing an exponential growth with an increase of more than 400% per year. Some 220 companies (about 70% of these are young start-ups) develop and distribute service robots thus forming a new breed of innovative driven, high added value industry.

When the current product lines were introduced, Europe was also the leader in this domain. However, today the leadership in service robotics is in most cases in USA or Asia. One needs here to recognize some important changes. In the white goods industry the lifetime of products has typically been 5-15 years. The lifetime of newer types of service robots is on the order of 1-3 years, at best. The differences in business style between old and new types of products are thus very significant. Service robots will be found in all domains of our future life. They represent not only a hope for a most convenient world but also a massive new market for high technology industry. This new sector offers significant business opportunities for European industry.

If we divide the service robotics in three market segments (professional applications, domestic use and entertainment) we can describe very different situations. In the professional market, diffusion is gradually happening and Europe has a number of dominant suppliers in this domain. However non-European companies are rapidly entering the market. Through setup of joint technology platform, it will be possible for Europe to maintain its leadership in a domain that is expected to have an economic value of at least €2B over the next 4 years.

In the domestic sector, the market is going to expand very rapidly, as has already been seen in USA and Korea. Traditionally Europe has very strong brand names in high-end white goods and domestic services through such companies as Bosch, Dyson, Electrolux, Husqvarna, Kärcher, Miele, Philips and Siemens but at present the market leaders are American and Korean. These countries outside of the EU have been faster to adapt their business models to be in line with the new market dynamics (iRobot, Aquaproduct, LG, Samsung). It is here crucial for Europe to build strategic alliances between the traditional companies and the technology providers to ensure a market leadership.

The entertainment sector is without doubt the most interesting economy. That is probably why Japanese industry was involved very early in this domain. More than 200.000 units have been sold of AIBO, the world famous Sony's dog robot. Other major Japanese companies, such as NEC, Sanyo, have developed a high quality offer in this domain. These international companies have dominated the mass-market part of the segment and there is a rather limited history of an entertainment industry in Europe.

3.1.3 Security and Space Robots

Robotics has also the near-term potential to become a major technology in a host of civil security applications. Today however, apart from some very specific niches (e.g., fire and bomb fighting, chemical spraying and dusting in large agricultural areas, etc), the civil security robotics market is very small compared to the military one, where defence systems are increasingly integrating robotics in the design of present and future combat systems (like networked drones and other air and ground unmanned platforms, but also exoskeletons for empowering soldiers, etc.). With the massive investment of DARPA and the strong ties between Industrials and Research Labs, the US are constructing a significant industrial capability, driven by the demand in the defence segment. Meanwhile, the demand for civil security solutions is slowly starting to build and a few early adopters already use them. The expectations for future market growth in the next 10-20 years are high (in the order of a multibillion Euros).

Robots for security applications are mainly driven by the need to address the new worldwide threat of terrorism . They can either be fully controlled by humans, semi-autonomously controlled, or completely autonomous and they need to operate in hostile, tedious, or hard-to-access environments that are usually partially or completely unknown, very complex or poorly structured. They can be in the form of unmanned ground, aerial or underwater vehicles (UGVs, UAVs and UUVs, respectively). High dependability properties are essential in the preparation and execution phases of a mission in security applications. Furthermore usability, versatility and flexibility are required to adapt the robot to its mission and the context of operations. Complex mission challenges for security applications will increasingly require the deployment and co-operation of many robotic systems that are inter-operable, inter-communicate, and closely collaborate and interact.

Currently, the market for robot systems in civil and commercial security applications is small when compared to the military market. The latter represents the largest procurement opportunities today but involves expensive and lengthy development processes. According to a 2004 study from the United Nations Economic Commission for Europe (UNECE), so far about 1000 UGV and UAV units have been put into use worldwide. These are mainly units for defence, rescue and security applications. The sales forecast for the period 2004-2007 is for ~2,700 units (US $360M).

In the next 10-15 years, the expectations for market growth of civil and commercial security applications are very high and are driven by the increasing need for homeland security and the monitoring of illegal immigration. In Europe, significant civil markets for Unmanned Ground, Aerial and Underwater Vehicles are still to emerge, with only limited niche applications being currently available.

Experience in the USA, Japan and other non-European nations shows that civil applications will emerge in application areas such as surveillance, border watch, agriculture (spraying and dusting), off-shore production and pipeline inspection.

The market for robotics in military applications is established and growing thanks to initiatives such as the US Department of Defence (DoD) vision of having 15% of its ground transport under autonomous control by 2015. In particular, the global market for military UAVs is growing very fast and the demand varies from manned aircraft size to small micro-vehicles. The US DoD published a roadmap in 2002 for the development of UAVs that included a R&D and procurement budget of US$15 B over seven years. The European aggregated military UAV budget is expected to reach € 5.5 B between 2004 and 2012.

As for robotic applications in space, these fall into two categories: planetary exploration and assembly/repair in space. Rough terrain robotic vehicles and manipulators for orbital assembly, inspection and maintenance are the current objectives of ongoing projects financed by both the US and EU government organizations. The European Space Agency (ESA) has been so far the most important source of funding for European research and development into space robotics.

The application of robotics in space is unique in that it forces the robot to survive and function without direct human assistance and acts as a platform for the projection of human capabilities to remote and hostile environments. Robotics is one of the key technologies for space exploration and for addressing one of the most exciting scientific endeavours of the 21st century: the search for life elsewhere.

Today, the International Space Station is a large and very complex space structure that necessitates the regular operation of two astronauts for configuring external equipment, connecting services and carrying out maintenance operations. The recent emergence of highly dexterous space robots could help relieving the cosmonauts of many routine inspection and maintenance chores and assisting them in more complex operating tasks.

In the past five years, the incidence of on-orbit failures has reached epidemic proportions. Space-based robotic manipulators provide the basis for on-orbit servicing of satellites, through the replacement of equipment modules.

ESA's and NASA's visions for space exploration now include teams that combine the information-gathering and problem-solving skills of astronauts with the survivability and physical capabilities of robots. The NASA vision has been upgraded based on the recent success of the Spirit and Opportunity vehicles that operated on Mars for more than 6 to 9 months. The next mission is expected to include fully autonomous deployment and recovery of a vehicle for return of specimens from Mars to Earth by 2009.

3.2 Business cases and economic perspective

3.2.1 Industrial Robots

Industrial robotics will increasingly gain importance as a central cornerstone in future manufacturing scenarios. Hence, competitive manufacturing of the future will depend on the progress of robotics and the availability of robotic products and related services.

First, by having robot assistants serving the workers at the manual workplace, this will allow delegation to the robot to carry out the repetitive and strenuous parts of a task that a worker currently must undertake. This should go some way safeguarding workers from accidents and other relevant health care problems, thus alleviating the concerns of rising health care costs, particularly for small manufacturers.

Second, with regard to the industrial robot sector, we expect significant socio-economic impact in four stakeholder categories: end-user industries, existing robot automation manufacturers and system integrators, new start-ups in robotics and product related service-industries.

The objective regarding **end-user industries** is to maintain competitiveness and create high-quality jobs. Manufacturing is facing a potential deficit of highly qualified employees with specific educational backgrounds and skills, especially those specific skills needed to produce high added-value manufactured goods. New robotic technologies will both increase the

New designs and technologies will allow accelerated expansion of new branches of robot automation such as food, logistics, recycling etc.

The European food and drink industry, which buys and adds value to around 70% of all EU agricultural produce is the largest manufacturing sector in the EU. Its production volume in 2001 was € 620B, which amounted to 13% of total manufacturing and 13% of employment in manufacturing.

The European logistics market (warehousing, transport, etc.) is valued at €710 B (including €320B, which are outsourced), equal to 8% of Europe's GDP, employing over 5 million people and generates a turnover of € 1.8 B[7]).

Regarding existing **robot manufacturers and system integrators,** robots will remain a growth market for the foreseeable future, as manufacturing will depend on further productivity gains both in the automotive and particularly in the non-automotive industries. The creation of novel products, solutions and services in non-automotive sectors is vital for robot manufacturers and system integrators, since it will permit them to stop relying upon robotic technologies that are tailored only to automotive applications. Technological advances may open up important benefits and options for both robot manufacturers and system integrators:

- Increasing productivity in labour-intensive industries through a scalable robot automation approach, thus providing competitive solutions for new manufacturing paradigms, new products and innovative business models.
- Penetration in flexible small scale manufacturing and in crafts, especially by introducing new assistive robots.
- Some new and very specific robotic products, especially cooperative robots or solutions which address the needs of specific applications or manufacturing requirements, may be outside the product portfolios of existing robot manufacturers. These new technologies will be provided by innovative spin-offs.
- Life-cycle-oriented approaches in the planning, implementation and operation of robot systems offer chances for new services and businesses in a growing market.

3.2.2 Service Robots

In the service robot sector the main stakeholders to derive socio-economic benefit are the robot system builders, the end-user industries and the end-user consumers. With regard to the system builders and their supply chain, the potential of the service market is even greater than the industrial robot sector. There is a clear case for Europe establishing a significant share of this high-value industry.

For the service robot end-user industries the benefits gained are those that previously could only be obtained within the manufacturing industries, i.e. increased quality and repeatability, increased productivity, in-built traceability and improved health and safety conditions for employees.

Although there are many intangible and social benefits to end-user consumers, the overwhelming business case is associated with the avoided welfare and support costs arising from enabling infirm and older people to lead independent lives. With the ageing population profile and with health care costs rising faster than inflation, the cost of institutionalised support will become a significant drain of a nation’s economy if current trends are maintained. Robot companions which can perform basic everyday tasks and which can monitor the well being of the people could extend the time a person could live in its own home by a considerable factor and substantially reduce the support costs. Three main business segments can be analysed:

- Professional service robots, ranging from transportation (smart cab) to medical applications (prosthetic, medical intervention) and including smart attendant, hostesses, etc
- Domestic robots, such as home appliances, advanced cleaning robots, sports trainer, smart caddies (supermarkets, airports). The sport trainers are an interesting business case as they can be designed either for amateurs to target mass media sports (trainers or smart partners in tennis, football, rugby, etc) or customised for high-level competition (stability in canoeing, arm-leg co-ordination in fencing, etc).
- Education and entertainment robots, which could be used in schools or home. In education, emulating physical feedback is a promising way to develop robotic markets. A classical example is the force feedback to simulate medical intervention. Again, education robots can assist high-level student training (flight or vehicle simulation, medical simulations,) or interact

[7] "Global Logistics," Philippe-Pierre Dornier and Michel Fender

with children to improve their learning skills in playing. Other classes of robot toys can be imagined (fighters, smart figurines, etc)

This simplified presentation hides a very heterogeneous set of applications and a complex market. Some of them will undoubtedly generate massive revenues in the future, but will be also very competitive and highly versatile. The key problem is to really understand the market agenda and the role of key-technologies in order to anticipate growth in this area.

3.2.3 Security and Space Robots

In the medium term, the main civil security robot application driver will be Domestic (homeland) Security for addressing the threat of terrorism, which has now come to the forefront of the EU agenda.

The main use of security ground robots is currently for Explosive Ordnance Disposal (EOD), demining, and exploration, as part of military missions. The primary driver for deployment of ground based security robots in civilian applications is to avoid bringing harm or risk to the people involved. The applications involve:

- EOD intervention for police and security forces
- Inspection of suspicious transport vehicles or dangerous objects
- Fire fighting
- Mapping of structures after a terrorist incident
- Search for people in inaccessible places

Security enforcement, particularly on large borders but also on more limited areas, will rely more and more on automated systems in the coming years. In a first place, civil security missions will likely be similar to military ones, focusing around Intelligence Surveillance Reconnaissance (ISR) tasks. These include:

- Surveillance of critical infrastructure like telecommunication and power lines, water, gas and oil pipelines, etc. but also,
- Extended border and coastal patrol boosted by the shift of EU borders to the East and the need to monitor illegal immigration fluxes.

In the longer term, other major application drivers will also include:

- ***Maritime Surveillance:*** maritime traffic control and monitoring of ship movements, supervising (illegal) fishery, search and rescue operations, etc.
- ***Crime monitoring:*** crowd, car & boat surveillance and chase operations, etc.
- ***Environmental monitoring:*** fire detection and fire fighting, aerial photography, oil spill discovery and monitoring disaster assessment, search and rescue, etc.
- ***Surveillance of hazardous materials:*** for tracking and escorting highly sensitive individual shipments to their destination.
- ***Commercial applications:*** Flying robotic platforms for communication applications serving as broadcasting platforms or as cellular relays, monitoring of power lines, crop chemical spraying and dusting as well as monitoring operations for the agriculture, etc.

For space applications, robots will be our agents of planetary surface and deep space exploration, handling the repetitive and time-consuming tasks of data collection and data reduction. Teams of robots will survey vast regions, and will classify geological features and formations and search for evidence of life.

Robots will be humankind’s agents and partners in space, constructing and servicing orbital and surface facilities with millions of components. They will operate on distant planets, using high level directives, responding to and interacting with humans.

4 Challenges Ahead

Europe faces the challenge to stay at the forefront of robotics development, production and use. A sustainable competitiveness of its industrial robot industries and its expansion into the burgeoning service and security markets calls for a coordinated action involving all stakeholder groups, in particular from the side of technology, systems and market developers.

4.1 Technological Challenges

Functionalities and performance data of robots depend on a vast spectrum of technologies. The convergence of technologies and components throughout the robotics domains regarding manufacturing, service, and security and space applications is obvious. This means that most of the listed technological challenges are shared among the robot sectors regarding manufacturing, services, security and space. Examples stressing the scope and generality of the technological challenges are given in the following:

- **Manipulation and grasping**. A flexible arm with a payload/weight ratio of 1:1 or better (compared to a ratio of 1:10 today) would be required to enable safe operation in the service sector to assist people with clearing of a table, or assisting a person to get up from a sofa. Similarly these light-weight low-inertia arms would open up important options in human-worker cooperation in the industrial sector to account for increased flexibility and productivity.

- **Autonomy and dependability**. Autonomous behaviour for robots acting in everyday environments and coping with a wide set of tasks in all operational modes constitutes a fundamental requirement for unmanned machines such as spacecraft, space probes, aerial and ground vehicles. In this area, mixed initiative planning and scheduling is regarded a key-element in robot navigation and operation. These systems should detect unforeseen situation and recover into a controlled state.

- **Intuitive human-robot-interaction**. The transfer of information and instructions of tasks, skills, objects or environments between human and robot should be as intuitive and efficient as the communication between two persons. To enable citizens to use robots for tasks that are more complicated than vacuum cleaning, it is essential that the robots are equipped with user-friendly interfaces that require minimal training and that render the robots socially acceptable. Intuitive and efficient instruction schemes are also critical for cooperating industrial robots

- **Sensing and control.** For everyday situations there is a need to acquire a sufficient understanding of the environment, to be aware of situations, to detect objects and people and to monitor processes with a minimum of instruction. These requirements call for more advanced sensory feedback and use of such information for control. Rich sensory feedback could also be applied in the industry to adjust to changing manufacturing conditions, and to account for variability and tolerances in the workpieces.

- **Intelligent, distributed environments.** Both in manufacturing, public or home environments robots will be embedded into networks and complementary IT services. At the same time homes are increasingly equipped with “intelligent” utilities. In a domotics context this requirement is an extension to the current concept of ambient intelligent in the sense that the environment will be physically interacting with persons, objects and infrastructure. Also in manufacturing robots will be part of a network which coherently reaches from internet based e-commerce and procurement platforms over manufacturing execution systems (MES) to the manufacturing process in real time. Thus robotics becomes a cornerstone of the “customer controlled manufacturing” paradigm.

- **Mechatronic design and miniaturization.** Mechatronic design principles stress encapsulated functional modules, their miniaturization and integration within standard hardware and software architectures. Besides opening up new options in cost and functionality of components, particularly sensors, new types of robots on a mini or micro-scale miniaturization evolve in the area of distributed intelligence such as micro aerial robots or micro-vehicles for exploration.

In order to meet these and future challenges of future robotic systems design and application depends on implementing a coherent agenda addressing research and technical development regarding ***basic technologies, components, miniaturization and system engineering techniques***. The multi-disciplinary nature of robotics requires that developments are multidisciplinary in terms of mechanical, control, electronic, electrical, computer, software and systems engineering as well as human factors and ergonomics design, artificial intelligence and materials engineering. Furthermore general algorithms, methods, engineering practices and standardization efforts have to be stressed which affect all three application domains in robotics RTD and application.

4.1.1 Components

Key to establishing a pan-application robot producer base in Europe is the concept of common low-cost components and modules that can readily be incorporated into standard architectures. This "economy of scale" effect supports specific low volume system designs at attractive life-cycle costs.

Actuators. One of the most fundamental components in any robotics system is the highly integrated actuation subsystem consisting of the mechanical structure, motors, gears and controls. There is a need for intrinsically safe robot arms, fully back-drivable high-torque motor systems and grippers that accommodate variable object or work-piece geometries.

Sensors: In order to work cooperatively with humans, the next generation of robots must be able to sense environmental conditions, situations, human presence, objects and tasks. To enable this a new generation of low cost sensors is required particularly 3D sensors, tactile sensors and force/torque sensors. A general trend is that all types of sensors will offer better resolution and that efforts are made to reduce weight and power consumption.

Processing and communications. Due to modern processing power and communication capabilities, the design space of embedded processing systems is now wide open. For instance, it is now possible to design redundant distributed control within a single robot, while satisfying real-time and robot safety constraints. Also, it is now possible to embed processing intensive algorithms such as data fusion, planning and scheduling, diagnostic to achieve sophisticated behaviours. The increase capabilities in term of processing and communications will allow engineers to distribute sensing, control and other cognitive functions in the robot more easily. It will be also easier to interface robots with external network-centric systems.

Man-machine-Interfaces. Future robot will have to infer the intention of the operator, assess the action context and the environment (possibly in the dialogue with the operator) and convert those into purposeful actions. Communication between humans and service robot has to be intuitive and multimodal. Simultaneous use of several information channels such as language, gestures, graphics, haptics have to be merged into meaningful and correct inputs. New input devices include sensors for gesture recognition, haptic and tactile devices have to be developed.

4.1.2 R&D for breakthrough in behavioural requirements

Common to nearly all future robotic applications are the requirements of the robot operating in unstructured environments, making real-time planning decisions, dealing with a wide range of objects and interacting with people and other robots. This neccesitates major breakthroughs in the following areas:

Cognitive skills (perception, decision making and collective behaviours). For operation in poorly structured environments, there is a need to endow the systems with higher cognitive functions that allows recognition of context, reasoning about actions and a higher degree of error diagnostics and failure recovery. Such flexibility can only be achieved through use of advanced artificial intelligence techniques and cognitive skills, which is a major departure for the present approach to system design and requires elements of perception (multiple sensor fusion and detailed environment representation), decision making (including task and route planning), machine learning and other intelligent systems (including knowldge-based inference and self awareness capabilities).

Collective behaviours: Involve co-operative and collaborative actions, sharing of goals and resources. Arising in network centric systems, collective behaviours will emerge due to progress in communication technologies. Systems of systems and systems of robots are generalising these concepts. Again, strongly related to decision making, this collaboration and cooperation (between robots and humans) involve strong coordination, synchronisation problems. Mastering collective behaviour in security operations is a critical problem.

Rich Sensory-motor Skills. Today most robots operate with a minimum of sensory feedback or highly task specific sensory feedback. In new application domains there is a need for a significant change in system design to rely on less accurate (and much cheaper) mechanical structures that are complemented with a rich set of sensory feedback to provide a performance that is beyond that of present technology. This means, by using lower quality mechanical structures with sensory feedback and adaptive control it is still possible to generate a new generation of robots systems with a higher performance. Such an approach does, however, require adoption of new control methods and significantly more flexible sensory systems.

Real time control and physical actuation, this also includes different forms of control beyond traditional open / closed loop control paradigms. Example are distributed control for complex robots with redundant / multiple degrees of freedom, Model-Predictive Control to tackle hard constraints etc.

4.1.3 Human Factors

A system's acceptance is the result the combinations of apparent user benefit, pleasant appearance, safety and ease of use. Ergonomics in robotics is concerned with all geometric dimensions, kinematic and kinetic properties of the robot. Robot ergonomics comprise a physical interaction (social distances, interaction forces and energies) and an informational interaction (design, evaluation and implementation of interactive computing systems for human use). While most robots are package nicely for good looks, major challenges remain critical:

- To allow service robots to be used by citizens with no or minimum training the new generation of robots must be equipped with more intuitive and flexible user interfaces. At the same time it must be recognized that robotic systems require design of user interfaces that are radically different than those used in most IT systems, as the system directly changes the physical environment and poses new problems in terms of skill modelling and task adaptation. The success of a new generation of robots will to a large extent depend on the quality of its user-interface.
- Cognitive skills are highly relevant to effectively and safely use robot systems and thus increase user acceptance. Bio-inspired robotics, even though limited by complexity, may contribute methods in a physical sense such as snake-like arms, artificial skins, bio-kinematic locomotion, multi-fingered hand to endorse human acceptance. Appearance and interaction future robot systems may include expressive motions, mimics, emotions, affective computing etc.

4.1.4 Robotic Systems Engineering

The new generations of robots will be significantly more complex than present day systems and there will be a higher demand for integration of different systems into complete production / ambient environment systems. This will call for methods to design, model and deploy highly complex systems, which call for new methods in systems engineering. Here it is important that standards are established that will enable a much higher degree of flexibility in the design of complete and versatile systems. For the development of large scale robotics systems there is a strong need for systems engineering. In this domain the leadership is divided between the US and Europe. In the US, the systems engineering efforts are almost exclusively driven by the Department of Defence. At the same time Europe has a strong record on systems engineering through major companies. For large-scale industrial use of robotics such system engineering competence is crucial as it facilitates integration of discrete robot units with complete production lines, and the systems engineering companies have significant knowledge on human-machine interaction that is a significant value for design of new systems.

The design of software methods for deployment of new generation of systems is of major importance both in terms of basic software engineering methodologies, programming/specification methods, and embedded control systems. The design of such systems will also be driven forward by independent efforts and it is essential to form strategic alliances with such efforts to enable early transfer of results.

- System engineering issues span a range of high level design topics from addressing specific aspects such as energy, traction and propulsion systems and communication systems; to design methods and tools for modular autonomous platforms and underlying standardisation issues; to specific system integration issues and to the development of network-centric systems.

Dependability issues constitute an important design parameter for robots involving in everyday environments and is a concept which not only involves robot safety but also its operating robustness, particularly the system's availability, security, reliability, and maintainability in every day's operating scenarios. Design for dependability will be one of the most pronounced R&D challenges in service robot systems which will affect any aspect of service robot R&D from architectures to key component functionality and design.

4.1.5 Miniaturised Robotics

A range of new, very small and highly distributed micro and nano-robots needs to be developed for a variety of application areas. Relevant R&D issues include:

- New actuation, sensing, control and perception mechanisms.
- New forms of bio-inspired climbing, walking or flying locomotion.
- Energy related aspects.
- Programmable micro-/nano- assembly & manipulation.
- Programming, coordination, interaction and control of (a large number of) miniature robots with micro/nano/bio-components.

4.1.6 Energy autonomy

In almost all new applications the energy problem has to be addressed. In particular for the service applications there is a need to consider the integration of new types of fuel cells to enable long-term operation. In addition it is also important to consider overall product design as the holistic design of a product often can result in the adoption of new strategies that allow for a significant reduction in energy requirements. At the same time it must be recognized that the fuel cell problem will not be solved by R&D in robotics, but it will be important to have a close interaction with other fields in which such research is performed.

4.2 Non-technology challenges

4.2.1 Education and Skills

Europe today has a highly educated skill base. For keeping a significant production base of mass-manufacturing in Europe, high productivity gains through a higher degree of automation need to be achieved, as the a significant portion of the final product price is labour costs. Such labour is less expensive elsewhere, particularly in Asia. However, as we experience a higher degree of single product customization and shorter product life cycles there will be a break-even point beyond which Europe will remain competitive. Such products will typically be knowledge "intensive" and the added automation will be a major factor to maintain an economic edge. At the same time, it has been acknowledged that several service applications have to be adapted to differences in culture and some of the services to be offered cannot be moved out of the region. Given the present age structure of Europe it can be expected that the region will be an early adopter of such technology, which will naturally result in primary development close to the market.

Robotics skills are often taught in a sectorial fashion, i.e. with a focus in mechanical-, electrical-, computer-, or systems engineering. To address the general problems of robotics, there is a need for a more holistic approach to the problem. It is important to not only have skills in one of the areas of robotics, but across all and for this one needs to have a solid interdisciplinary background. At the same time, related areas such as design are also required. Additional knowledge in specific applications will also play an important role. For example, in applications such as cleaning, chemistry provides key-knowledge for the process, and in other domains similar considerations come into play. It is thus essential to breed a new generation of engineers and systems designers that have a sufficient broad perspective to undertake the development of the system platform and its integration into applications. The scope of the education must however not be at the expense of depth, as the problems to be addressed are fundamental and difficult. Consequently team-work will be a requirement for the integration of systems.

An important aspect of robotics for attracting students is also that it is “fun”. Today many countries are experiencing a decline in admission to engineering educations, due to lack of interest in purely technical educations. There is often an increased interest in topics such as design and holistic topics such as product development. Here robotics can play a crucial role. By definition robotics must consider the full scope from basic mechanical design to control and intelligence so as to provide an acceptable solution. The combination of systems engineering and “fun” can be utilized as a catalyst to demonstrate how robotics is a confluence of many different disciplines. In education it can be used to generate interest and at the same time provide a basis for education of a new generation of engineers. It is here important to recognize that research ought to be a component at all levels of education to ensure European leadership across many different sectors.

4.2.2 Structural Challenges

The changes in demographics that have been widely reported (see for example table EU-15 of the Kok report) will have a deep impact on most aspects of European industry. There is first and foremost a need to change industry to ensure an economic growth that is at least 100% over the next 10-15 years to maintain the present economic structure. In addition the increased number of elderly people will imply a much higher demand for services. Robotics will be an important enabler to achieve the increased industrial efficiency and at the same time the new branch of service robotics will be crucial for the elderly and for an increased “quality of life” for everyone.

It must also be recognized that the introduction of robotics into new domains poses a major challenge. The successful application of robotics in e.g., the car industry has required a long-term strategic alliance between the car manufacturers and the robotics industry. To enter into new markets and build new product lines, there is a need for integration across traditional industrial boundaries. Here the role of systems integrators will play a very important role.

At the same time it remains to be seen if the service robotics sectors will become a natural extension of the present white-goods industry or if the result will be an entirely new industrial sector. It also remains to be seen if the civil security robotics industry will emerge from the evolution into civil applications of many large companies that are today purely defence-oriented or again or if the result will be an entirely new industrial sector. Either ways, the economic growth could be very significant.

The establishment of a service and security robot industry in particular faces a number of specific structural challenges including:

- The requirement for new business models. These business models must address both the growing pervasiveness of technology in all product and service markets as well as the short but financially significant product life cycles.
- Support infrastructure for service and security robots. Unlike traditional robotics, emerging applications will demand little skill or training of the user and require very different customer support mechanisms.
- Integration across traditional commercial barriers. Many of the new application domains will be in areas in which there is little interest from the domain experts in ownership of some of the core technologies. For such new application domains, the domain experts might have the sales and support structures in place, but there is a need to acquire key competencies from

technology experts. Such marriages across technological and business areas have so far been relatively rare; however entry into new markets might dictate such changes.

– The need to develop robotic solutions in emerging market segments. Robotics has so far primarily been applied in high-tech, high volume markets, but the new and emerging areas might be in market segments that traditionally have been dominated by use of technology with a limited complexity. In these new markets it can be expected that there will be new roles for SME's and for integration of a variety of components, which potentially could generate an entirely new industrial sector.
– Acceptance of service and security robots in society. For technologies such as robotics, there exist some technology related ethical issues that must be considered. The media heavily bias the public view of robotics and that view is predominantly negative. There is thus a significant need to communicate to the public the real value of robotics. At the same time there is a general view that "robotics is replacing the workforce to reduce cost". Yet, in most cases the labour cost issues is secondary or non-existing. In addition robots take away dangerous and dull jobs and thereby they protect human lives or remove tasks that may cause sickness if performed by humans. Only through a concerted effort can this general view by public be changed.

5 Conclusions and the way ahead

The formation of a joint robotics platform is expected to provide a number of core technologies that can be used in many application domains. European leadership in robotics technology, manufacture and application can only be assured through use of a common platform for the R&D efforts. No activities are known in the USA that could lead to the setup of a comparable platform. In Japan the emphasis has been on robots that have a structure that is similar to humans – so called “Humanoids”. The Japanese Humanoid Programme was sponsored at a level of 30 M€/year. It is, however, judged that this platform is too complicated to control and the benefits compared to traditional wheeled robots are rather limited. In Korea a national programme has been launched (100 M€/yr in 10 years) to gain leadership in both industrial and service robotics. The programme is generously sponsored and it could lead to a significant reliance on Korean technology for service and industrial applications as major companies such as Samsung, LGe, and KIA are backing this effort. However, Europe has a strong base in small and medium size enterprises that provide a rich mechanism for faster adoption of technology. Such start-up companies might provide the nucleus for an entirely new business sector in terms of original applications and as component providers for larger companies. It is here important to recognize that similar entrepreneurial activities only are present in the US, where there is a lack of related public efforts to define a commercial platform, and Korea is not a likely contender for set-up of a diverse range of new start-up companies. However for Europe to succeed there is a need to have incentives in place to assist new start-up companies in picking up and using R&D results.

Suggested actions and next steps

So far, more than 30 companies, including both high-tech SMEs and large companies covering a wide spectrum of robotic robots and applications, have endorsed the initiative for a European Technology Platform in Robotics. Annex I provides the list of participating entities. Moreover, a governance structure for the initiative and the terms of reference of its operations are being put in place. The initiative remains open and can be joined by any new European industry involved in robotic activities.

The next important steps will be to:

- Create the so-called “mirror group”, to be composed of all those public institutions and authorities supporting robotics RTD and wishing to participate in the initiative.
- Form the academia group, to be composed of all those universities and research institutes willing to join the platform’s activities.
- Bring in other relevant actors from the private sector willing to commit to a combined strategy that is, at least, partially funded by private means.

The initiative will have as its mission to undertake the following activities:

To develop a strategic R&D agenda and technology roadmaps for robotics in Europe

- To define a funding strategy (defining and assessing options for funding)
- To coordinate and integrate all relevant European, national and intergovernmental public R&D programmes with the EUROP effort and to provide the structure for the effectiveness of the private-public partnership
- To undertake a concerted effort for a substantially increased R&D budget for robotics – from basic research to technology validation;
- To develop and promote an educational programme that will establish robotics as a major interdisciplinary topic of training;
- To promote mechanisms for collaboration between industry and academia that allow a holistic approach to research, and favours the transfer of technology. To create world-class research programmes in particular application domains;
- To launch an activity to enhance the innovation environment, producing a policy for benchmarks, standards and for open source, and stimulating new ventures and markets;
- To set up and implement a communication activities to ascertain the key role of robotics in modern economies and society.

To benchmark and link to efforts outside of the EU

To provide advice on structural, educational and regulatory matters (IPR, standards, training) for implementation of a strategic agenda

EU research activities on a stronger robotics platform can serve as an ideal means to support the strategies and targets set out at the European Councils of:

- Lisbon 2000, proposing the shift towards a knowledge-based economy and society;
- Gothenburg 2001, formulating a European strategy for sustainable development;
- Barcelona 2002, targeting funding equal to 3% of GDP for research throughout the European Union.

Indeed, by uniting all the main industrial and academic robotics stakeholders and public authorities around its common vision and approach, the ambition of the initiative is to permit Europe to maintain its leading position in robotics and develop new companies and supply networks to meet the new technology needs.

Europe has the necessary ingredients to meet successfully this ambition:

- Today, Europe is leading manufacturing robotics. It has an innovation-driven and export-oriented industry that has established itself during the last 25 years but which is now facing very strong competition from Korea and Japan.
- The very fast growing service robotic market (professional and personal robots) is, at the moment, dominated by high tech SMEs. In fact more than 100 high tech SMEs have been created in Europe the last 5 years bringing many new innovative solutions in the robotics market. Europe has also strong brand names in white goods and domestic services but at present the market leaders are US and Korean.
- Europe is well positioned in integrated robotic systems for defence and space applications, but the civil security market has still to emerge.
- Europe has also several world leading academic teams in robotics research, with more than 200 universities and research institutes offering education and research in robotics, and thus creating an unparalleled basis in qualification and knowledge.

- Furthermore, for several years now, many Member States, ESA and the EU Research Framework Programmes have supported world-class robotics research. On one hand, an improved co-ordination between European civil RTD efforts and, on the other hand, the cross-fertilisation of such efforts with similar defence-related RTD can pave the way for an accelerated development of generic underpinning robotic technologies and integrated robotic systems that would be beneficial both for civil and military applications.

Annex I. The EUROP members

List of entities that have endorsed EUROP

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