Renzo Salimbeni

SKILLMAN

Sector Skills Alliance for Adavanced Manufacturing in the Transport Sector

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Report on the state of the art of advanced manufacturing in the transport sector

Printed in Florence
CNR Publisher
IFAC - Book Series
Series Editor: Daniela Mugnai

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Disclaimer

The European Commission support for the production of this publication does not constitute endorsement of the contents, which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Acknowledgements

The author wish to acknowledge the following contributions:

— Giovanni Crisonà and Stefano Tirati,
Centro Studi "Cultura Sviluppo" (IT)

— Vibeke Nørgaard and Thomas Nørup,
Teknisk Erhvervsskole Center (DK)

— Martin Perfect and Stuart Jackson,
Jaguar Land Rover Ltd (UK)

— Pandeli Borodani and Danele Bassan,
FIAT Research Centre (IT)

— Daniel Christensen and Uffe Jacobsen,
Scandinavian Airlines Systems (DK)

— David Morgan,
Excellence, Achievement & Learning Ltd (UK)

— Giancarlo Colferai and Rosa Anna Fvorito
CEPAS (IT)

The sources of basic information from the web as Wikipedia and Google. The European Community publications as the main reference of specific information about the joint policy, the technology roadmaps and about the main European projects on the transport technologies.

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Chapter 1

PREMISES

1.1 - The European Transport Sector

Europe represents global players in the field of advanced manufacturing in the transport sector with significant worldwide market share. The transport industry itself represents an important part of the economy: in the EU it directly employs around 10 million people and accounts for about 5 % of GDP[1]. In terms of employment, the automotive, aerospace and rail industries, especially when including their extensive supply chain, represent a significant volume of job vacancies, especially in highly specialized engineering disciplines as well as for technical support staff.

From the political and social perspectives, the sector confronted with significant role of governments as market regulators and with different degrees influence as sponsor, customer and gatekeeper. The sector is frequently challenged by government regulations, a public focus on emissions, sustainability and cost. Together with the digital revolution, there is a strong need to focus on future skills requirements to remain globally competitive. The challenge is to unlink growth in the transport usage from global emissions, and improve the sustainability of the transport sector. In line with the flagship initiative 'Resource-Efficient Europe' set up in the Europe 2020 Strategy (5) and the 'Energy efficiency plan 2011', the key objective of European transport policy is to help establish a system that underpins European economic progress, enhances competitiveness and offers high-quality mobility services while using resources more efficiently.

In practice, transport must become more efficient; it has to use less and cleaner energy, improve how it uses modern infrastructure and reduce the harmful impact it can have on the environment and key natural assets like water, land and ecosystems.

New transport patterns will emerge to meet larger volumes of freight and an increase in travellers. Information technology enables simpler and more reliable process. New technologies need to come out to improve the carrier's efficiency. Consumers are certainly ready to pay[2] for the full costs of transport in exchange for reduced congestion, more information, a better service and improvements in safety standards. Various networking initiatives at European level have traced the technology forecast for the manufacturing sector. To a degree, they have interconnected, producing a roadmap for technology development in the sector.

The Manufuture European Technology Platform[3] was launched in December 2004 in Enschede, in the Netherlands, with the publication of 'Manufuture – a Vision for 2020'. This document was the product of a detailed analysis carried out by a High Level Group, formed a year earlier, which included senior representatives from European businesses and the scientific community. This document recommended the preparation of a more detailed Strategic Research Agenda (SRA), paving the way for research priorities to be defined and implemented via the EU's future RTD Framework Programs, and aligned with initiatives at Member State, regional and individual stakeholder levels.

Since 2013, EuMAT, the European Technology Platform for Advanced Engineering and Materials Technologies, has been developing a Strategic Research Agenda[4], which intends to provide,

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[1] White Paper on transport, Luxembourg: Publications Office of the European Union, 2011 ISBN 978-92-79-18270-9.

[2] See for example http://www.greentechlead.com/sustainability/consumers-ready-pay-products-delivered-eco-friendly-manner-14173

[3] Assuring the future of manufacturing in Europe, Report of the High-Level Group, Luxembourg: Publications Office of the European Union, 2006 ISBN 92-79-01026-3.

[4] EuMAT Strategic Research Agenda, 2013 Steinbeis-Edition, Stuttgart, ISBN 978-3-943356-54-0

with an appropriate input from industry and other stakeholders, a basis for identifying needs and establishing priorities in the area of advanced materials and technologies.

The European Factories of the Future Research Association, EFFRA, prepared the multi-annual roadmap[5] forecasting manufacturing challenges and opportunities. The document clarifies the role of manufacturing in the Europe 2020 strategy, and refers to the key technologies - KETs[6] in general - as the major sources of innovation that will improve Europe's position amongst global manufacturers.

In this respect, a number of critical technologies are clearly shaping the present and future of advanced manufacturing in the transport sector. They include wireless technologies to improve safety and make autonomous and smart vehicles; lightweight composite materials to optimise vehicle performance and technologies including robotics associated with automation of the production systems.

In 2011 at the Hannover Fair a new definition was introduced: Industry 4.0, or the so called Fourth Industrial Revolution. This term embraces a number of technologies including automation, data exchange and manufacturing. At the end of 2012 a Working Group on Industry 4.0 was established under Siegfried Dais (Robert Bosch GmbH) and Kagermann (Acatech) prompting the German government to make a number of recommendations to implement Industry 4.0.

Industry 4.0 is also defined as a collective term referring to technologies and the organization of the value chain bringing together multi-dimensional aspects such as Cyber-Physical Systems, Internet of Things and Internet of Services. More recently, the term Industry 4.0 has become noticeably more popular[7] - including on the internet[8] - , being associated and synonymous with the more general term Internet of Things[9], when it is applied in manufacturing.

The SKILLMAN project draws its lessons from Industry 4.0 and selects a group of technologies that are changing the skills required in transport's advanced manufacturing sector. SKILLMAN - having considered the outcomes of previous EU activity - will provide, in this report about state-of-the-art technologies, an overview of such issues, focusing on three specific technology examples:

1) Robotics
2) Lightweight Materials
3) Wireless Interactive on-board Technologies

These drive innovation in all transport sectors and are crucial for developing novel products in automotive, avionics and railways; they improve performance and reduce life-cycle, operational, and maintenance costs.

1.2 - Aims of the Report

The SKILLMAN project represents Vocational, Education and Training (VET) institutions, universities, research institutes and industries who are both European and worldwide leaders in Advanced Manufacturing in the transport sector. They have expressed commitment to foster cooperation and to develop European curricula which addresses the competencies and skills requirements arising from recent trends relating to the use of innovative technologies in the transport sector.

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[5] Factories of the Future, by EUROPEAN COMMISSION, Directorate-General for Research and Innovation, Luxembourg: Publications Office of the European Union, 2013 ISBN 978-92-79-31238-0.

[6] High Level Expert Group on Key Enabling Technologies, Final Report, June 2011.

[7] See for example http://www.allaboutlean.com/industry-4-0/

[8] https://www.google.co.uk/trends/explore#q=industry%204.0

[9] The Internet of Things and the future of manufacturing, http://www.mckinsey.com/insights/business_technology

The main problem areas which the Sector Skills Alliance intends to answer focus on three challenges. These are cross-cutting and relevant for h automotive, aerospace and train companies. . They include:

- Advanced production processes including robotics;
- Advanced lightweight composite materials;
- Wireless interactive on-board technologies for safety and user commodities.

This WP1 Report on the State-of-the-Art of Advanced Manufacturing, which are going to be more and more widely employed in the transport sector, aims to be a useful source identifying technical skill gaps that SKILLMAN will aim to match with appropriate curricula development targeting many levels of the production process.

This report will provide necessary information for the Observatory on Advanced Manufacturing for the Transport Sector. On the basis of technical indications a relevant pan-European curricula will be designed and validated.

This report also reviews the worldwide emerging trends of research and development following the advancements achieved in robotics, wireless technologies and lightweight materials. Specific examples report on their application in automotive and avionics, in order to determine future competencies and skills requirements.

Chapter 2

THE ECONOMIC SITUATION IN THE TRANSPORT SECTOR

2.1 - Automotive

The automotive industry is crucial for Europe's prosperity. The sector provides jobs for 12 million people and accounts for 560 billion EUR. The EU[10] is among the world's biggest producers of motor vehicles and is the sector with the greatest share of private investment in research and development. To strengthen the competitiveness of the EU automotive industry and preserve its global technological leadership, the European Commission supports global technological harmonisation and provides funding for R&D.

An adverse economic situation created unfavourable conditions for almost all European industry sectors not sparing vehicle manufacturers. For five consecutive years (2008 – 2012) sales and registration fell significantly declined in Europe, taking the automotive sector back to the volumes of the year 1995, almost a quarter lower compared to its highest recorded figures in 2007. Falling sales have affected vehicle manufacturers in Europe in an inhomogeneous manner. Volume producers, with a product range focused on small and medium-size cars, were affected the most. Considerable pressure for cutting costs was placed on these companies, resulting in several restructuring operations across Europe (PSA, Ford, GM and FIAT).

The fall in car sales in Europe reached its peak in 2013, rebounding since the last 2013 trimester.

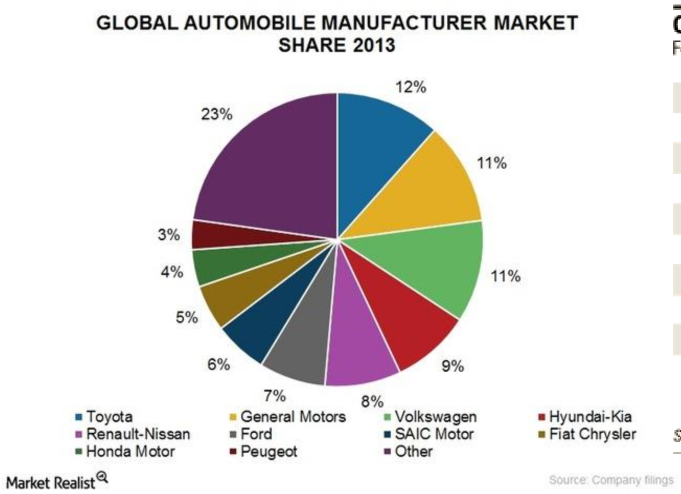

Figure 1 – Car sales in 2013. Courtesy of Market Realist [11]

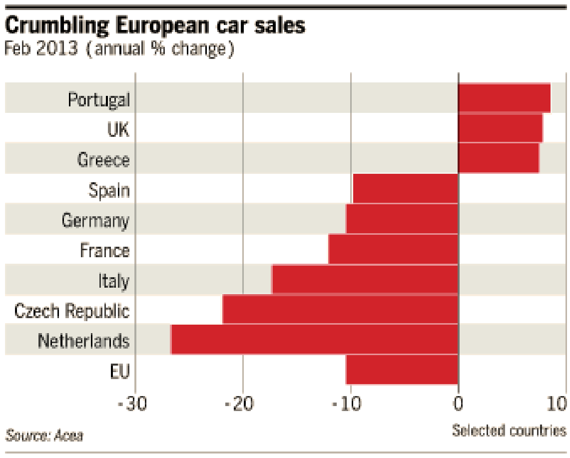

Figure 2 – European Car sales in 2013. Courtesy of European Automobile Manufacturers' Association - ACEA

[10] CARS 2020 Report on the state of play of the outcome of the work of the High Level Group, EUROPEAN COMMISSION, Directorate-General for Enterprise and Industry, 2014 Brussels

[11] http://marketrealist.com/2014/04/companies-like-toyota-lead-global-automobile-market-share

On the contrary luxury cars market found in the same period a positive trend, with increasing sales in emerging countries as China, Brazil, India and Middle East.

This trend verified in all segments, with a peak in the super-car segment.

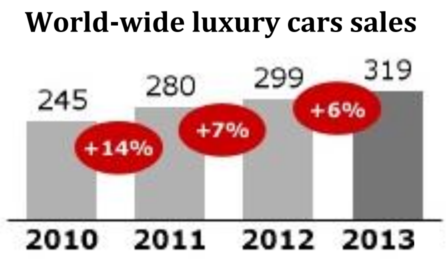

Fig. 3 - Luxury cars market trends

On 8 November 2012 the European Commission adopted the Communication: CARS 2020: an Action Plan for a competitive and sustainable automotive industry in Europe[12]. The Commission indicated the importance of specific actions in the following areas:

- Promoting investment in advanced technologies and innovation for clean, energy efficient and safe vehicles;
- Improving market conditions by - among others - strengthening the single market for vehicles, consistent application of the smart regulation principles and application of competitiveness proofing;
- Supporting the European automotive industry in approaching global markets by means of balanced trade policy, assessment of cumulative impacts of the free trade agreements (FTAs), bilateral dialogue with major third markets and the promotion of international harmonization in laws and regulations relating to vehicles. ;
- Promoting more investment in skills and training in order to meet the needs of the industry in terms of producing a highly skilled workforce.

The Commission - together with stakeholders - has made a considerable attempt to address persistent problems and respond to the global and structural challenges the industry is currently facing:

- Pillar I - Investing in advanced technologies and financing innovation;
- Pillar II - Improving market conditions;
- Pillar III - Enhancing competitiveness in global markets.

2.2 - Avionics

Avionics is one of the EU’s key high-tech sectors in the global market:

- It employs more than 500,000people and generated a turnover of close to 140 billion Euro in 2013. Civil aeronautics shows an important increase with a turnover amounting to EUR 89.2 billion in 2013, compared to EUR 81.3 billion euro in 2012;
- EU is a world leader in the production of civil aircraft, including helicopters, aircraft engines, parts and components;
- The EU has a trade surplus for aerospace products, with exports all over the world.

The industry is highly concentrated, both geographically (in particular EU countries) and in terms of the few large enterprises involved.

Employment in the aerospace sector is particularly significant in the United Kingdom, France,

Germany, Italy, Spain, Poland and Sweden. In 2013, the AeroSpace and Defence Industries Association of Europe wrote a report[13], in which the aerospace sector is divided into three sub-sectors and their employees are quantitatively evaluated as follows:

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[12] CARS 2020 Report on the state of play of the outcome of the work of the High Level Group, EUROPEAN COMMISSION, Directorate-General for Enterprise and Industry, 2014, Brussels

[13] Facts and Figures 2013, Aero Space and Defence Industries Association of Europe, 2013, Brussels

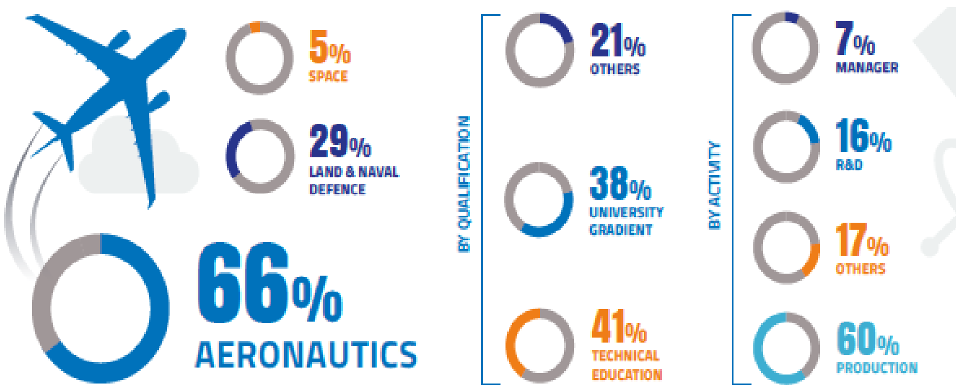

Figure 3 – Trends in aeronautics. Courtesy of ASD, AeroSpace and Defence Industries Association of Europe.

The European Commission implements a number of policy actions, to address key issues influencing influence the aeronautics industry, including:

- The Commission promotes the sustainable competitiveness of European aeronautics industries, focusing in particular on emerging sectors such as Remotely Piloted Aircraft Systems (RPAS - also known as drones).
- Accessing markets outside the EU is crucial for jobs and growth within the EU. The Commission works to keep markets and trade open by providing information on EU civil aviation exports. The most important barriers faced by EU producers of civil aircraft are the substantial subsidies paid by the US Government to their main competitor – Boeing - in the United States. The Commission represents and defends the EU aeronautics industry in dispute settlements at the World Trade Organisation.
- Investment in research, development and innovation (RDI) is vital for the competitiveness of the EU aeronautics industry. RDI expenditure represents 10% of industry turnover, one third of which is financed by the public sector. The Strategic Research and Innovation Agenda (SRIA) is the roadmap developed by the European industry through the Advisory Council for Aeronautics Research in Europe (ACARE) providing a guide to future public and private RDI programs. The Commission also supports the European RDI effort in aeronautics through Horizon 2020 under the “Smart, Green and Integrated Transport challenge” and two Joint Technology Initiatives, Clean Sky and the SESAR Joint Undertaking.
- The Commission has taken several measures to mitigate the growing impact of aviation on the environment. Aircraft emissions affect the global climate and impact on local noise and air quality.
- The common EU aviation policy aims to make Europe the safest air space in the world.

To exploit the economic potential of the sector the European Commission develops policy initiatives on several key issues: safety, single market, Single European Sky, External Aviation policy.

An evaluation of how European Aeronautics rank in the global market is derived from the Aerospace & Defence figures in various industrial countries:

%	Europe	USA	Canada	Brazil	Russia	Japan
Employment	31	34	10	1	22	2
Revenues	40	47	5	1	3	4

2.3 - A perspective on the future demand

The economy crisis challenges European industry[14]:

- The profit of 12 major European airlines dropped 8% in the period 2011-2012.
- Since 2005, a lack of expert employees in technical activities has grown by to 50%.
- Bigger investment is needed and 80-100 new aircrafts will be bought for each of forthcoming years.

The International Civil Aviation Organization forecasts that in the next 20 years, airlines will have to add 25,000 new aircrafts to the current 17,000-strong commercial fleet, and by 2026, we will need 480,000 new technicians to maintain these aircrafts.

[14] Scandinavian Airlines System communication

Chapter 3

REPOSITORY OF RECENT TECHNOLOGIES ADVANCEMENTS IN TRANSPORT INDUSTRY

3.1 - Robotics in production

3.1.1 - Robots work better

Industrial robots are on the verge of revolutionizing manufacturing[15]. As they become smarter, faster and cheaper, they're being called upon to do more well beyond traditional repetitive, onerous or even dangerous tasks such as welding and materials handling. They are taking on more capabilities that are human and traits such as sensing, dexterity, memory, trainability, and object recognition. As a result, they are taking on more jobs such as picking and packaging, testing or inspecting products, or assembling minute electronics. In addition, a new generation of "collaborative" robots ushers in an era shepherding robots out of their cages and literally hand-in-hand with human workers who train them through physical demonstrations. As costs of advanced robotics continue to fall (from several hundreds of thousands of dollars down to tens of thousands) and application broadens, industries beyond automotive - such as food and beverage - are adding them to their ranks.

One major robotics company[16] refers to its new-generation robot as an "intelligent industrial work assistant."

For many years, the automotive industry has intensively used industrial robotics. Since the implantation of the first industrial robots in the 1960s, many things have changed. These days, the production lines need to be more efficient, flexible and precise.

Many enhancements have been made[17] on production lines over the last few years to help workers in their daily tasks.

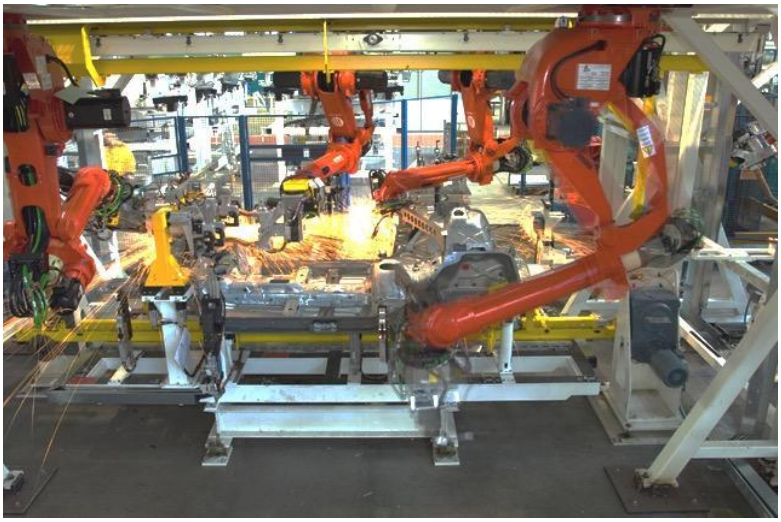

Figure 4 – Automated robotic production line.

During the production of the 2013 Ford Escape, the company decided to introduce a robotic arm with "eyes". The laser and camera, placed in an array on the robot wrist, are able to see exactly where to install the parts on the car body. By giving instant feedback to the robot the windshields, door panels and fenders can be applied more precisely. The big innovation of this technology is that industrial robots are now able to adjust case-by-case the installation of a part. Therefore, if there is any variation in the production, the robot can adapt its installation procedure to fit the part perfectly. This application reduces the gap between the assembled parts, which means a significant reduction in noise caused by wind.

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[15] The new hire: How a new generation of robots is transforming manufacturing, PWC & Manufacturing Institute, 2014

[16] KUKA communication in Hannover Messe 2015

[17] RobotiQ, The official blog of the RobotiQ company, 2015

The process of painting a car body with industrial robotic arms is not new, but it is still an important application to highlight. In fact, since highly qualified painters are hard to find these days and considering the size of a car, it is much easier for a company to use robots for this application. In addition, painting is a very complex process. It is hard work and toxic, as well as needing consistent results throughout the whole production. Another great aspect of using a painting robot is the reduction of waste material. Since the robots are equipped with a flowmeter, the same exact amount of paint is distributed on each part.

Although recent exposure of robot collaboration mostly concerns human-robot collaboration, this case deals with more of a robot-robot collaboration. In fact, in the Chinese automotive plant, Great Wall Motors (GWM), the welding line is considered to be one of the most productive lines ever made. When 27 ABB robots work at 30 different workstations, collaboration happens between handling robots and welding robots. The ABB IRB 7600 places the panel precisely at the right location, while an ABB IRB 6640 performs the welding operations. This robotic line performs more than 4,000 welding operations on the car body in an 86 seconds cycle time, including the transferring operations.

As collaborative robotics becomes more and more efficient and easy to use, the automotive industry tends to use them more frequently. Tasks performed solely manually over multiple hours risks lower quality and efficiency due to human factors such as fatigue, health, motivation, ergonomics etc. For such reasons some automotive industries (for example BMW) have introduced collaborative robots to its assembly line. These human-friendly robots perform the final assembly of the car doors. The robots work with a door sealant that keeps sound and water out of the car. The goal of this implantation is not to replace human workers, but to help them in their daily tasks. Introducing these new robots right beside workers is now safe and if it can also help enhance productivity, value is also added.

Presently, for manufacturing in general there are an estimated 1.5 million robots in operation globally, with about 230,000 in the US alone. Global shipments hit about 180,000 in 2013, an all-time high, with 200,000 forecasted for 2014, estimates the International Federation of Robots (IFR)[18,19].

3.2 - Lightweight materials

3.2.1 - Technical Overview of Aircraft A350XWB

It's no surprise that the development moves from heavy all-metal aircraft to light all-composite aircraft, with the only restriction being that the engines, landing gear, instrumentation / computers will probably be metal well into the future.

In civil aviation the 1980s gave us a new generation of aircraft including many access panels, engine cowlings, fillets and fairings, speed brakes and control surfaces made of composite /hybrid materials . This has constantly evolved as the Airbus models: A320, A330 and A340 also got a carbon tail section and floor beams of carbon. This all helps to reduce aircraft weight and thus fuel consumption and environmental issues, and together with more fuel-efficient engines and optimized aerodynamic designs, an A320 which roughly uses 25% less fuel than the MD-80.

The A350, the aircraft materials reach a composites fraction of 52%. By comparison, the original version B747 had only 1% and B777 has 11-12%. The Airbus A350 is an aircraft developed to meet the 2015 market expectations. A350 improves the performance of previous models with several technical modifications regarding an extensive use of carbon composites and advanced materials, of advanced engines and of advanced aerodynamics.

[18] "Outlook on World Robotics 2014," IFR, June 4, 2014.

[19] "Global robotics industry: Record beats record," IFR statistical department press release, June 4, 2014.

A high level of structural commonality has reinforced the aircraft's robustness. Fuselage has been resized; leading and trailing edges of the wings have common structure; outer and centre wings have a common box structure; forward fuselage has common pylon and nose; rear fuselage has common vertical and horizontal tail-planes. The changes allow:

- to reinforce structure, to increase design weights, to increase payload,
- to use a new generation of powerful engines Rolls Royce Trent XWB, with up to 94 Klbs thrust, an improved maintenance economy.

A suitable combination of materials with advanced properties has been employed. A large part of fuselage is built by Carbon-Fibre-Reinforced Polymers (CFRP) in both monolithic and stratified geometries. Limited amount of structural elements (front fuselage, central wing box, fuselage frames etc.) remain built by aluminium alloys. The radar dome (Radome) on the fuselage apex is protected by dust erosion by means of a quartz cover layer fibre reinforced polymer.

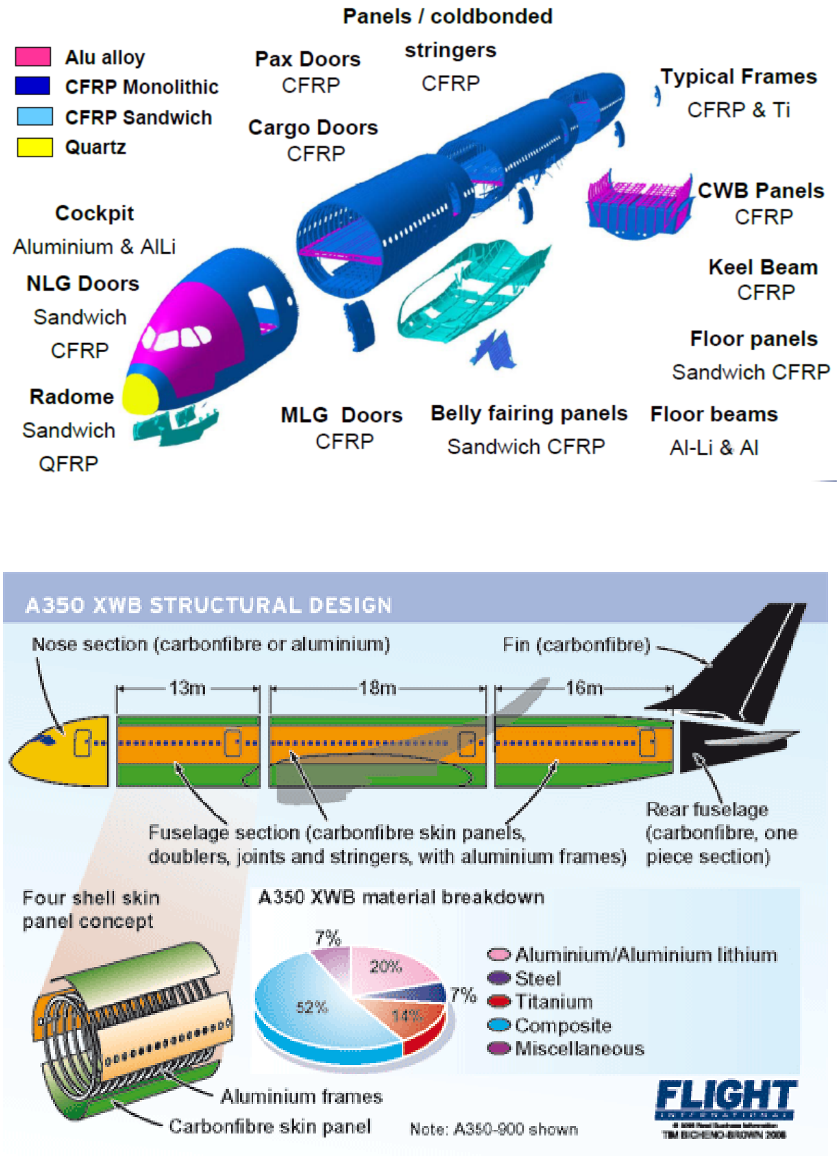

Figure 5 – Composite materials within aircraft structures. Courtesy of Airbus[20]

The composite material (CFRP) is employed normally as a secondary structure in items like floor panels, cargo liners and radomes. These solutions came with MD80, B737 and B767, a new generation aircraft also including access panels, engine displays, power monitors, air brakes and control surfaces of the composite.

In the A350 the selection of different materials according to their structural function has reached a record. Up to 52% are composite made out of Carbon fibre panels, 20% Aluminium alloy, 14% Titanium and 7% steel.

[20] www.airbus.com

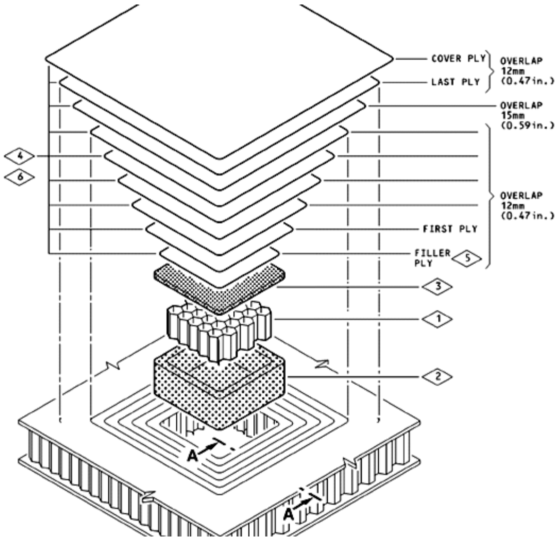

Figure 6 – Multilayer structure of composite materials. Courtesy of Scandinavian Airlines Systems.

The growing use of multi-layered carbon fiber panels has on the other hand revealed an important drawback: repairing localized damage becomes complicated and time-consuming. The carbon fiber panel has several layers stuck together to form a plate. A honeycomb separates two plates to form a panel. When, for example, part of a plate becomes delaminated, the lost material has to be finely replaced layer by layer, and restuck to the honeycomb. Typically, experts have to carry out this operation in a hangar, working out the pieces in a humid uncontrolled environment, which makes fixing even more critical.

This drawback needs to be properly addressed in all future developments of composite materials in structural utilization for an airplane body, in order to be consistently used and become dependable.

3.3 - Internet of things

3.3.1 - General concepts

The development of electronics in the 20th century brought about an exponential growth in computing power, mainly due to the discovery of transistors and the start of solid-state electronics. The opportunity of increasing transistor density on an integrated circuit by high-resolution photolithography started the age of microelectronics and gave rise to the so-called “Moore law”. According to Gordon Moore, co-founder of INTEL, the junction density had to double each year (until the 1980s) or every two years (after the 1980s).

The exponential growth in computing power made a number of technical achievements possible which were going to radically change societies across the globe, with portable computers, artificial intelligence, international network INTERNET; in short what we now call ICT.

3.3.2 - Internet of Things

The Internet of Things (IoT) is generally thought of as connecting things to the Internet and using that connection to provide some kind of useful remote monitoring or control of those things[21]. This definition of IoT is limited, and references only part of the IoT evolution. It can be seen, for the purposes of the SKILLMAN project, that IoT is a rebranding of the existing Machine to Machine (M2M) market of today.

A better definition is:

- The IoT creates an intelligent, invisible network fabric that can be sensed, controlled and programmed.

- IoT-enabled products employ embedded technology that allows them to communicate - directly or indirectly - with each other or the Internet.

[21] The Evolution of the Internet of Things, Texas Instruments, Jim Chase, 2013.

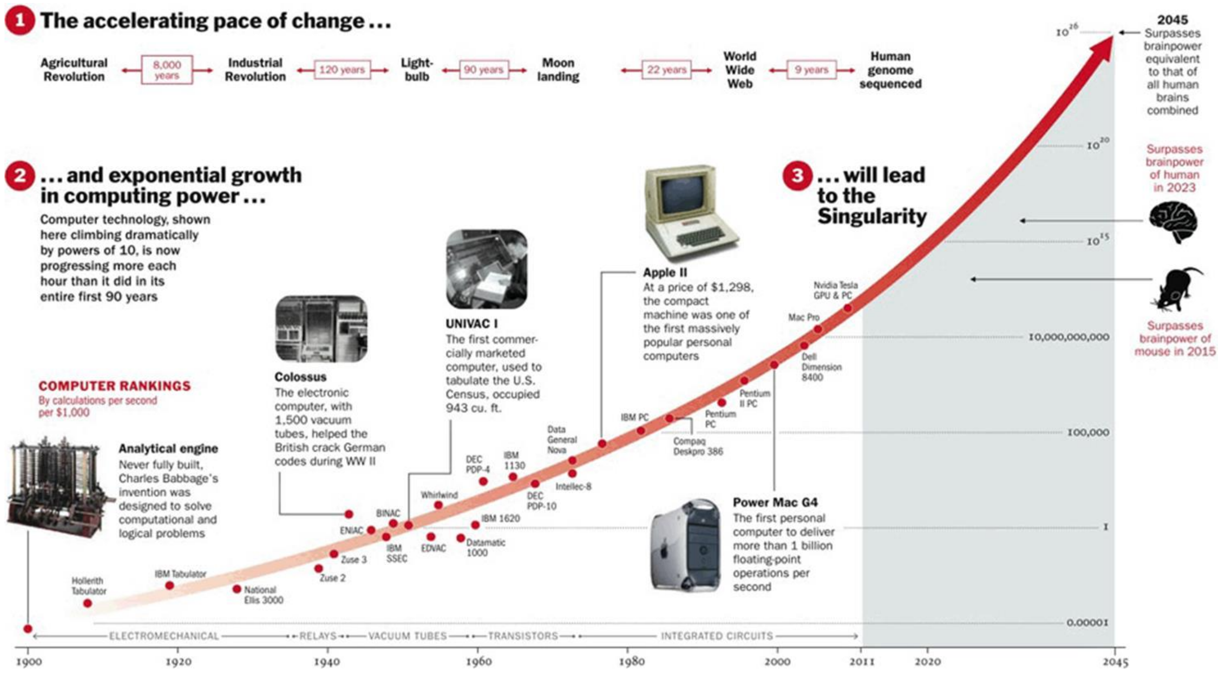

Figure 7 – Exponential growth of the computing power.

In the 1990s, internet connectivity began to proliferate in enterprise and consumer markets, but was still limited in its use because of the low performance of the network interconnect.

In the 2000s internet connectivity became the norm for many applications and is today expected to be widely used in business, industrial and consumer products to provide access to information. However, these devices are still primarily things on the Internet that require more human interaction and monitoring through apps and interfaces. The true promise of the IoT is just starting to be realised when invisible technology operates behind the scenes dynamically responding to how we want "things" to act.

To date, the world has deployed about 5 billion "smart" connected things. It is predicted that there will be 50 billion connected devices by 2020 and in our lifetime we will experience life with a trillion-node network. Those are really big numbers. How things are fundamentally deployed today is a barrier to achieving those numbers. The industry will only achieve the reality of 50 billion connected devices by simplifying how things connect and communicate today.

Preparing the lowest layers of technology for the horizontal nature of the IoT requires manufacturers to deliver on the most fundamental challenges, including:

- Connectivity: There will not be one connectivity standard that "wins" over the others. There will be a wide variety of wired and wireless standards as well as proprietary implementations used to connect the things in the IoT. The challenge is getting the connectivity standards to talk to one another with one common worldwide data currency.
- Power management: More things within the IoT will be battery powered or use energy harvesting to be more portable and self-sustaining. Line-powered equipment will need to be more energy efficient. The challenge is making it easy to add power management to these devices and equipment. Wireless charging will incorporate connectivity with charge management.
- Security: With the amount of data being sent within the IoT, security is a must. Built-in hardware security and the use of existing connectivity security protocols is essential to secure the IoT. Another challenge is simply educating consumers to use the security that is integrated into their devices.

3.3.3 - IoT in Avionics

The Internet of Things (IoT) is a powerful force within the aerospace and defense (A&D) industry today. Unlike some industry sectors that are early in the IoT maturity spectrum, A&D companies have been successfully implementing sensors and computerized automation for decades in their manufacturing operations and products.

The IoT will redefine not only manufacturing processes but also what a product is. It will change global competition with the increased co-location of design, manufacturing, and servicing.

Successful aerospace and defense companies of the future are creating new products and services today. They are transforming their businesses with new processes that fulfill the IoT approach. They are upgrading their technology infrastructure – with Big Data, mobile, cloud, analytics, and other applications – to gain the flexibility they will need to thrive.

Leading aerospace and defence companies that invested early in IoT technologies are now achieving returns that range from overall product cost reduction due to manufacturing automation to delivering a better customer experience with preventive maintenance (resulting in higher product reliability and higher customer satisfaction). They are beginning to transform their business practices and recognize that, in time, the IoT will have impact on nearly every area of manufacturing operations and customer engagement.

The connected aircraft

Adding sensors to the “smart” equipment OEMs offers huge opportunities for hardware design improvements and new service offerings. New IoT technologies bring capabilities such as:

- Real-time response to quickly diagnose and act on operational disruptions
- Condition-based maintenance and prognostics to detect trends and conditions before they lead to failure
- Reliability programs to build long-term strategies to improve equipment reliability
- Performance-based logistics to expand insight into equipment performance.

The Connected Factory

As machines and robotics become smart and communicative, production units will become more active, autonomous, and self-sufficient.

Machines and robotics will make decisions together about tools, parts, and production steps. Machines will report their status to manufacturers’ business resource planning systems.

With a real-time view of production, plant managers will be able to react quickly if problems occur.

The Connected People

As machines become smarter, production lines can be enriched and humanised. Workers can be assigned as needed to co-ordinate automated production processes and intervene when machines call for action. New ways of working will emerge. For example, smart glasses and 3D visualization can help workers fulfill tasks without long training sessions. Maintenance technicians can get visual instructions and historical data from machines on their mobile devices.

The Connected Supply Chain

Complex global supply channels have contributed to an increase in counterfeit products. Many countries have enacted serialized traceability directives to prevent fraud, particularly in A&D.

IoT technologies allow complete visibility into the location and condition of serialized products over their lifecycle.

Use of auto-ID technologies supports improved data quality and transparency. You can expect more efficient operations with automated data discovery and processing, and higher customer satisfaction with faster, more accurate shipping and handling.

IoT Innovations for Aerospace and Defense

The main trends are:

Design and Building of Complex Programs

- RFID-enabled sensors on products
- Wearable technology for plant workers
- Automated and predictive asset maintenance and optimization
- Optimal energy management in real time

Responsive Supply Network

- Security, fraud, and counterfeiting controls
- RFID-enabled sensors on containers
- Real-time supply chain visibility

Aftermarket Services

- Aircraft health monitoring
- Wearable devices for service technicians
- Real-time machine and sensor integration
- Fleet operations monitoring
- Real-time alerts
- Warehouse management and location insight.

Global market forecast for aircraft health monitoring systems by 2018 is 1.044 billion $[22].

The manufacturing, production, and subassembly of Airbus aircraft parts are distributed among 15 sites in Europe. Airbus uses innovative digital tracking and monitoring RFID technology to help streamline and increase the efficiency of its industrial operations[23].

Northrop Grumman leverages SAP® 3D Visual Enterprise applications across half of its business in support of manufacturing, training, and technical documentation[24].

3.3.4 - IoT for automotive

Technology is evolving so rapidly it has become an integral component of everyday life. Having uninterrupted connectivity is necessary, even while driving. In fact, analysts predict that by 2016 in-vehicle connectivity and basic online content will become critical buying factors in consumers' car-buying decisions in mature markets[25]. This dramatic convergence of technology in the car is quickly making it a key device in the Internet of Things with the ability to both receive data and feed it to the cloud, to the traffic infrastructure, to other vehicles and more. As a result, automakers are increasingly turning to leading technology companies such as Intel to explore new ways to inform, entertain and assist drivers to create a safer and more enjoyable driving experience.

Intel[26] partners with the automotive industry to apply its technology and expertise to the development of innovative applications, services and safety features, some of which already exist in today's vehicles. With a mix of automotive, IT and consumer electronics expertise and research and development, Intel is helping car manufacturers reduce the time-to-market, create new driving experiences, and more quickly adapt to changing consumer demand.

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[22] TechNavio, "2014–2018 Global Aircraft Health Monitoring System Market Report," February 14, 2014.

[23] www.airbus.com/newsevents/news-events-single/detail/airbus-moves-forward-with-its-factory-of-the-future-concept.

[24] SAP Solution Overview: Aerospace and Defense

[25] Gartner: Automobile of the Future: The Ultimate Connected Mobile Device

[26] Intel Drives In-Vehicle Innovation for the Internet of Things

Chapter 4

REPOSITORY OF RESEARCH ADVANCEMENTS AND TECHNOLOGY FORESIGHT

4.1 - Potentially transformative enabling technologies

Advanced manufacturing is closely connected to what are known as 'key enabling technologies', which provide some of the main sources of innovation for a wide range of industries (see note 5, European Commission, 2011). These innovations are not confined to the manufacturing sector per se, and have potential impacts in sectors as diverse and agriculture and health. However, there are close links with production processes, creating both opportunities and challenges for manufacturing employers. Looking to the future, one of the issues in trying to make sense of the impact of enabling technologies on jobs and skills is that the pace of technological advancement is fast and unpredictable. There is also a difference between the cutting-edge development of enabling technologies and the widespread application of those technologies. Relevant current enabling technologies that could have profound future implications for advanced manufacturing are summarized in the following table presenting current enabling technologies that could have profound future implications for advanced manufacturing.

Table 4.1 Current enabling technologies relevant for advanced manufacturing

Technology	Summary
Additive manufacturing	The development of products using digitally controlled machine tools. Products are built through layering rather than traditional methods of moulding, casting or welding.
Composite manufacturing	The joining of two materials together to produce one material with superior mechanical properties. Composites are increasingly being used to replace metal due to their high-tensile strength and low weight.
Nanotechnology	The manipulation of materials at a sub-atomic level to create new materials. It is used for both organic and non-organic materials.
Plastic electronics	Electronics built using semi-conducting plastic polymers. Diodes and transistors are 'printed' on plastic substrates using inks of semi-conducting plastic materials.
Silicon electronics	The development of electronic circuits built on a single layer of single-crystal silicon. It is considered advantageous because it consumes very little power.
Industrial Biotechnology	The industrial manufacture of chemical products using biological rather than oil-based materials.
Robotics and artificial intelligence	The use of machinery to automate parts of the production process. A potential recent development in this area is artificial intelligence, which is software that make decisions on optimizing the production process

Although manufacturing employment as a whole is expected to decline up to 2022, recent forecasts have predicted that advanced manufacturing is expected to grow significantly in the coming years, particularly in Western Europe. The European Competitiveness Report (European Commission, 2013b) predicts the global advanced manufacturing market will double in size to £750 billion by 2020. This will be driven by growth in 3D printing (expected to grow globally by 13.5 per cent) and robotics and robot-related products (expected to grow by 36.4 per cent).

Industry snapshot[27]

Robotics and autonomous systems (RAS) are already influencing all sectors of industry from automotive and transport to healthcare and manufacturing. Experts estimate that the global market for service and industrial robots will be worth US$59.5 bn by 2020.

When discussing the robotics sector, it is more common to talk about how many jobs it will lose than generate. Last year a report by Deloitte and Oxford Martin School academics, Carl Benedikt Frey and Michael Osborne hit the headlines with its claim that around 35% of UK jobs would be lost to robots in the next 20 years.

While robotics is all about using machines to do human tasks, someone, of course, has to create the robots. The International Federation of Robotics (IFR) reckons that for the one million industrial robots currently in operation, three million jobs has been created to build, operate and maintain them and these will mainly be highly skilled engineering and technical professionals. An IFR study: Positive Impact of Industrial Robots on Employment[28], conducted by Metra Martech, predicts that more than two million jobs will be created in the next eight years because of the use of robotics in industry. In terms of robot sales, automotive remains the biggest sector in many countries but according to figures released in 2014 by the IFR, chemical, rubber & plastics and the food sectors continue to increase as does the electrical and electronics industry.

4.2 - Robotics

The term Robot is of a Czech origin from the term *Robota* (heavy work) and was created by a Czech writer, Karel Capek, in a drama written in 1920. Three years before his brother Josef Capek, a cubist painter, coined the term *Automat* in a novel. The meaning of the two terms fluctuated with the meaning of a mechanism substituting human being for heavy works, and some social and political understatement due to the meaning of Robotnik (factory worker) in several slavic languages used in former Socialist Republics e.g. the USSR, Poland, Ukraine .

George Devol applied for the first robotics patents in 1954 (granted in 1961). The first company to produce a robot was Unimation, founded by Devol and Joseph F. Engelberger in 1956, and was based on Devol's original patents. Unimation robots were also called programmable transfer machines since their main use at first was to transfer objects from one point to another, less than a dozen feet or so apart. They used hydraulic actuators and were programmed in joint coordinates, i.e. the angles of the various joints were stored during a teaching phase and replayed in operation. They were accurate to within 1/10,000 of an inch. Unimation later licensed their technology to Kawasaki Heavy Industries and GKN, manufacturing Unimates in Japan and England respectively. For some time Unimation's only competitor was Cincinnati Milacron Inc. of Ohio. This changed radically in the late 1970s when several big Japanese conglomerates began producing similar industrial robots.

An industrial robot is defined by ISO 8373 as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. The field of robotics may be more practically defined as the study, design and use of robot systems for manufacturing (a top-level definition relying on the prior definition of robot). Typical applications of robots include welding, painting, assembly, pick and place (such as packaging, palletizing and SMT), product inspection, and testing; all accomplished with high endurance, speed, and precision.

In 1969, Victor Scheinman at Stanford University invented the Stanford arm, an all-electric, 6-axis articulated robot designed to permit an arm solution. This allowed it accurately to follow arbitrary paths in space and widened the potential use of the robot to more sophisticated applications such as assembly and welding. Scheinman then designed a second arm for the MIT AI Lab, called the "MIT arm." Scheinman, after receiving a fellowship from Unimation to develop his designs, sold those

[27] Engineering and Technology Magazine 2015

[28] http://www.ifr.org/uploads/media/Metra_Martech_Study_on_robots_02.pdf

designs to Unimation who further developed them with support from General Motors and later marketed it as the Programmable Universal Machine for Assembly (PUMA).

Industrial robotics took off quite quickly in Europe, with both ABB Robotics and KUKA Robotics bringing robots to the market in 1973. ABB Robotics (formerly ASEA) introduced IRB 6, among the world's first commercially available all electric micro-processor controlled robot. The first two IRB 6 robots were sold to Magnusson in Sweden for grinding and polishing pipe bends and were installed in production in January 1974. Also in 1973 KUKA Robotics built its first robot, known as FAMULUS, also one of the first articulated robots to have six electromechanically driven axes.

Interest in robotics increased in the late 1970s and many US companies entered the field, including large firms like General Electric, and General Motors (which formed joint venture FANUC Robotics with FANUC LTD of Japan). U.S. startup companies included Automatix and Adept Technology, Inc. At the height of the robot boom in 1984, Unimation was acquired by Westinghouse Electric Corporation for 107 million U.S. dollars. Westinghouse sold Unimation to Stäubli Faverges SCA of France in 1988, which is still making articulated robots for general industrial and cleanroom applications and even bought the robotic division of Bosch in late 2004.

Only a few non-Japanese companies ultimately managed to survive in this market, the major ones being: Adept Technology, Stäubli-Unimation, the Swedish-Swiss company ABB Asea Brown Boveri, the German company KUKA Robotics and the Italian company Comau.

Trends of research in Robotics

Research is currently underway into the following trends:

- Improvements of sensing capability in regard of precise motion, targeting, aiming the tools, directing the tools, controlling grabbing force, speed of execution etc.
- Improvements of artificial intelligence available, introducing on board the fastest microprocessors and the widest solid-state memories, or connecting the on board processors with a Cloud of computers.
- Improvements of the collaborative capability of Robots to work safely and effectively close to human beings.

In the following, these topics will be described in terms of their future expectations, their impact in the transport sector and the time scale it is going to happen.

4.2.1 - Sensors Improving Robots

Most robots of today have few sensing capabilities. Sensors can provide some limited feedback to the robot so it can do its job. Compared to the senses and abilities of even the simplest living things, robots have a very long way to go.

The sensor sends information, in the form of electronic signals back to the controller. Sensors also give the robot controller information about its surroundings and let it know the exact position of the arm, or the state of the world around it.

Sight, sound, touch, taste, and smell are the kinds of information we get from our world. Robots can be designed and programmed to get specific information that is beyond what our five senses can tell us. For instance, a robot sensor might "see" in the dark, detect tiny amounts of invisible radiation or measure movement that is too small or fast for the human eye to see. The table below shows the physical properties to be monitored and the types of sensors that are used for.

Table 4.2 – Physical properties and sensors

Physical Property	Technology
Contact	Bump, Switch
Distance	Ultrasound, Radar, Infra Red
Light Level	Photo Cells, Cameras
Sound Level	Microphones
Strain	Strain Gauges
Rotation	Encoders
Magnetism	Compasses
Smell	Chemical
Temperature	Thermal, Infra Red
Inclination	Inclinometers, Gyroscope
Pressure	Pressure Gauges
Altitude	Altimeters

Sensors can be made simple and complex, depending on how much information needs to be stored. A switch is a simple on/off sensor used for turning the robot on and off. A human retina is a complex sensor that uses more than a hundred million photosensitive elements (rods and cones). Sensors provide information to the robot's brain, which can be treated in various ways. For example, we can simply react to the sensor output: stop if the switch is open; go if the switch is closed.

4.2.2 - Improving Robots Smartness

What if robots and automatic systems were not limited by on-board computation, memory, or software[29] ? Rather than viewing robots and automated machines as isolated systems with limited computation and memory, "Cloud Robotics and Automation" considers a new paradigm where robots and automatic systems exchange data and perform computation via networks[30]. Extending earlier work that links robots to the Internet, Cloud Robotics and Automation builds on emerging research in cloud computing, machine learning, big data, open-source software, and major industry initiatives in the "Internet of Things", "Smarter Planet", "Industrial Internet", and "Industry 4.0."

Consider Google's autonomous car: it uses the network to index maps, images and data on prior driving trajectories; weather, and traffic to determine spatial localization and make decisions. Data from each car is shared via the network for statistical optimization and machine learning performed by grid computing in the Cloud. Another example is Kiva Systems approach to warehouse automation and logistics using large numbers of mobile platforms to move pallets using a local network to coordinate platforms and share updates on floor conditions.

Google's James Kuffner coined the term "Cloud Robotics" in 2010. Cloud Robot and Automation systems can be broadly defined as any robot or automation system that relies on data or code from a network to support its operation, i.e., where not all sensing, computation, and memory is integrated into a single standalone system.

There are at least four potential advantages to using the Cloud:

1) Big Data: access to updated libraries of images, maps, and object/product data;

[29] Ken Goldberg, University of Berkeley, 2015, http://goldberg.berkeley.edu/cloud-robotics/

[30] IEEE Transactions on Automation Science and Engineering (T-ASE).Special Issue on Cloud Robotics and Automation (11 papers). Vol. 12, no2, Apr 2015.

2) Cloud Computing: access to parallel grid computing on demand for statistical analysis, learning, and motion planning;

3) Collective Learning: robots and systems sharing trajectories, control policies, and outcomes, and 4) Human Computation: use of crowdsourcing to tap human skills for analysing images and video, classification, learning, and error recovery.

The Cloud can also provide access to a) datasets, publications, models, benchmarks, and simulation tools, b) open competitions for designs and systems, and c) open-source software. It is important to recognize that Cloud Robotics and Automation raises critical new questions related to network latency, quality of service, privacy, and security.

The term "Singularity" is sometimes used to describe a punctuation point in the future where Artificial Intelligence (AI) surpasses human intelligence. The term was popularized by science fiction author Vernor Vinge and Ray Kurzweil. Superintelligence, a 2014 book by Nick Bostrom, explored similar themes that provoked Stephen Hawking, Elon Musk and Bill Gates to issue warnings about the dangers of AI and robotics. Singularity is distracting attention from a far more realistic and important development that we might call "Multiplicity". Multiplicity characterizes an emerging category of systems where diverse groups of humans work together with diverse groups of machines to solve difficult problems. Multiplicity combines the wisdom of crowds with the power of cloud computing and is exemplified by many Cloud Robotics and Automation systems.

4.2.3 - Human Robot Interaction (HRI)

Humans have interacted with robots since the 1950s from the early beginning of industrial robotics. This behavior was unfocused and specific consisting mainly of simple on-off control (e.g. using joysticks) for operating manipulator joints and remote vehicles.

Telerobotics or supervisory control of remote space or nuclear-plants robots has contributed to develop further HRI; the goal of teleoperation is to support a human to control a robot in an environment where it is inconvenient or unsafe to place a human and difficult to program a robot to autonomously perform complex operations. The telerobots represent robotic systems with own sensors, drives and computer/decision control, however, capable of receiving supervision and tele-operation commands of human through the mediation of computers. Various interfaces have been developed in telerobotics such as various master-arms, parallel-robot masters, 6D space mice, instrumented data gloves, haptic devices (impedance displays), optical tracking systems, speech control etc.

The seminal master-slave teleoperation, tele-assistance and tele-manipulation, has evolved to more sophisticated HRI paradigms such as tele-presence, haptic rendering teleoperation with force-feedback, force-reflection etc., with improved transparency and fidelity of remote robot-environment interaction. Recent sophisticated robots and applications in minimal-invasive surgery (e.g Da-Vinci), for space (e.g. Robonaut), under-water and aerial robotics etc., include various forms of shared human-robot control in which both human and robot perform specific control functions in a dynamic communications. In presence of the human, the robot control provides stability and support through active constraints defined in four regions: safe, close, boundary and forbidden. For instance, after entering forbidden region the robot control provide haptic feedback amplifying the soft-tissue resistance and rendering it to the human.

Since the early development of advanced interactive robotic systems, there has also been more development in other specific fields, rather than in industry, such as rehabilitation and physical assistive robotics. Powered lower and upper extremity active exoskeletons, active suites (i.e. wearable robots), human extenders and amplifiers, etc. all belong to these groups. Specific for the initial prototypes, developed to assist disabled people with muscular dystrophy, was the adoption of specific solutions, such as switches and limited motor power, to restrict the joint motion and protect the human from injuries.

In 1990's technology and the costs limitations to make robots more flexible, intelligent and capable to work in real unstructured and varying environments, thereby performing complex skilled operations have highly motivated rapidly emerging research studies on HRI and collaborative/cooperative robots, also for industrial applications. It was widely recognized that considerable benefits will be gained if humans and robot work together, and thus combine advantages of both partners: precision, power and path control of robots, with human's dexterity, sensing, intelligence and experience. The paradigms of autonomous and fully automatic robots have been changed by new patterns, such as: semi-automation, collaborative and assistant robots. Instead to replace human, the new robot task is to help, assist and support him.

The dynamic emergence and eventual implementation of HRI as a specific research and application field has been observed since the noughties. This period was characterized by broad and systematic studies on HRI and practical developments based on the rapid development of key enabling technologies (e.g. sensors, computation, communication, control, drives etc.). In particular, actuator technology progress, from stiff drives towards motor torque control, direct drives, serial elastic (SEA) and variable impedance (VIA) technologies, have considerably contributed to the HRI systems developments. This period also developed new robot and systems safety standards (ISO-10218, part 1 and 2 issued in a draft version in 2006 and as final standard at the end of 2011), which have principally provided the background for a wider application of HRI in industry. Namely new ISO-10218 has revolutionized robot applications in industry allowing the removal of fences (so called cage-less robots), and increasingly supporting e physical HRI (pHRI), as a most challenging interaction form in very close proximity between human and robot. ISO-10218 robotic safety standard was also innovatory in this sense in that it was the first case in robotic standardization unconstrained by regulations. On the contrary, they were avant-garde foreseeing application situations for which research had no mature solutions for applications. Even nowadays, we have more laboratory prototypes for safe HRI, than practical implemented solutions.

All these preconditions and rapidly growing research interests have contributed to develop new robotic paradigms. Instead of conventional: "robot design for precision, and control for interaction", which was shown to be costly, complex and always potentially dangerous, there is a new guideline: "robot design for interaction and safety, and control for precision" has been established as most promising. Various prototypes of intrinsically safe and dependable (through both mechatronic design and control) robots have been recently developed following this paradigm.

In the industry, however, the number of practical HRI use-cases remains still insignificant in comparison to the service robotic field. It is worth mentioning several pilot-applications of Stanley-Cobotics power-assist devices (iLift and iTrolley modules and systems) mainly in the USA (in Europe only one system has been implemented which was in Italy, before the company closed). A small number of Kobot systems developed by Schmidt-Handling and Fraunhofer IPK have been implemented in Germany (Wiesheu GmbH and Wacker Chemie AG). These prototypes were produced by enhancing power-assist handling systems with new power-assist and impedance control functionalities. In recent years, however, growing interest for HRI and power-assist devices and products was noted d in industry. The eepos-MOVE system, developed by eepos GmbH and Fraunhofer IPK and presented at MOTEK-2012 and Hannover-2013 fairs has attracted considerable interest from the automotive industry. The French company RB3D has put in 2013 a prototype of cooperative pHRI, referred to as *cobot A6-15* at the market to support cooperative grinding operations. Further products have been pursued in 2014.

The workplace sharing robot co-worker have also recently arrived in the automotive industry. Universal Robot provide a certified integrated safety mode (matching Standard EN ISO 10218), supported by redundant encoders and motor current sensors that allow to safely detect contact and collision with human or environment and stop the robot motion. These novel functions allow UR-industrial robots to work in the close vicinity of humans without using protective headgear. At BMW premises in Spartanburg (South Carolina, USA) a door sealant UR-10 was applied without fences in the proximity of human workers. . At the VW plant in Salzgitter (Germany), an UR-5 was integrated in the cylinder head assembly section of the plant for inserting glow plugs into the cylinder heads.

The positive experiences enjoyed by these seminal applications certainly open the door for more acceptance and a wider use of collaborative and cooperative robots in industry. By using robots without guards, they can work together hand in hand with the robot. In this way, the robot becomes a *production assistant* in manufacturing and, as such, can free staff from unfavorable and non-skilled work.

The general, recently envisioned status, from most car makers relative to HRI, consists of:

- The operator will have the ability to accurately guide the robot through force interaction. This means that the operator will be able to grasp the robot and either pull or push. That force will be then translated into robot movement following its direction. Through that, the robot can be positioned with accuracy and assist the human operator even if the operation is not in accordance with the taught one or in case there has been any kind of error.
- Furthermore, the operator will be able to voice emergency commands to the robot to help with the increased safety that is required when the robot is in close proximity to the human operator. The human operator will only need to say "stop" and the robot will obey and immediately stop operating.
- Moreover, the robot will have to understand and translate into motor input and thus movement easy human gestures such as "stop" and "proceed".
- For safety reasons the robot should be able to monitor the distance of the human operator from itself at all times. With the use of this distance, the robot should use this knowledge to anticipate and stop what it is doing, thus avoiding any potential collision with the person.

Numerous HRI concepts based on various interfaces and sensor technologies have been developed in the past - some of them have been implemented in industry - regarding both workplace sharing (WPS-HRI) and physical HRI (pHRI).

The most challenging physical human-robot interaction requires physical contact between human and robot to operate. e.g. to carry and position a heavy part. Current concepts include:

a) The simplest way to interact directly with robots is based on tele-operation principles, using "wired control interfaces" and various 6D devices, such as: joysticks, space-mouse, small manipulandums etc. One of the most famous devices in robotics concerns DLR space mouse, developed for the space applications and provided at market under the name Magellan. This mouse has been integrated in the KUKA KR-2 control system in the teach-pendant, and has been attached to the Reis robots structures close to the robot wrist. The operation of a 6D mouse, however, has been shown to be sophisticated, requiring an understanding of robot basic frames and /or human relative position to the robot.

ITIA-CNR and Comau have recently improved this disadvantage by Motion-Guided-Device MGD. It has been recently enhanced in the ECHORD EasyPro experiment by vision sensors. MGD supports a calibration procedure for specific tasks and thus facilitate understanding of relative guided motion.

b) Colgate and Peshkin (1998) established the concept of "collaborative robots"- Cobots as intrinsically passive and safe systems, similar to passive manipulators, providing mainly programmable motion guidance. The cobot's main function - taken from robots to enhance passive handling system - is the creation of "virtual guidance surface" (virtual walls), along which the part can be maneuvered and positioned. A cobot is further manipulated manually, according to the principle: "Human moves, cobot guides". Guiding heavy parts can considerably relieve human beings from high inertia forces (so called inertia management problem). The essential cobot elements that achieve the above working principle is the continuous variable transmission (CVT) which allows the control of relative motions among device joints.

The cobotic systems and concept, described above, produce physically passive, and consequently intrinsically safe and stable devices. The computer control is applied to redirect the operator force, rather than to produce the motion. Limited power-assist can compensate for the device not moving device and relatively light payloads (e.g. up to 30-50 kg) without endangering human safety. Through their basic functions (guidance and force amplification), passive cobots can reduce the physical strain put on humans to a minimum and thereby improve ergonomics and increase productivity and quality at the same time.

c) *Admittance displays* – i.e. force/impedance control based systems – provide a practical concept to perform pHRI with convenient industrial robots (with huge apparent inertia and stiffness). An admittance display takes the input forces/torques exerted by the user on a mounted sensor on the robot flange and provides motion reaction. Commonly a well understood second-order admittance (mass-spring-damper) systems has been rendered. The position-based control, in which a force external feedback loop is closed around internal robot position control, represents a simple and feasible control scheme for pHRI. For the pHRI and manual guidance it is promising to apply so called damping target model (mass plus damper, without stiffness). In the damping impedance control approach, the robot yields ("gives way") to the force exerted by the human arm, trying to keep interaction force to zero. During manual guidance in the free-space, without contact with a stiff environment, considerably smaller target damping behavior may be achieved

In the novel direct drive robotic system (e.g. Barett-WAM arm) or special robots with joint-torque sensors (KUKA LBR iiwa it is promising to implement explicit torque-based or torque-based interaction control).

d) In the system with good back-driveability (e.g. direct-drive, joint transmission with small gear ratios etc.) the motor current-measurements may be utilised to estimate external forces acting upon robot arms without an external 6d force/torque sensor attached at the robot arm (so called whole-arm sensing). This approach is not feasible in convenient industrial robots with poor back driveability and disturbed causality between external forces exerted upon the robot arms and joint motor currents (due to high friction in the transmission system).

e) As mentioned above, the new paradigm for robot design is quite the opposite to standard industrial robot developments, and reads as follows: "*Design a robot for safety and interaction, and control it for accuracy*". This concept has motivated design of new robotic systems based on intrinsically safe structures and drives. The drives technology of interactive robots has evolved from direct drives, via serial-elastic (SEA) and hybrid dual (HDA), towards variable impedance (VIA) and bionic (e.g. pneumatic artificial muscles PAM) actuators. The novel concepts of intrinsically safe actuators provides mechanical, mechatronic and structural solutions for joint and/or arm compliance with exceptionally fast reaction to the contact, even for safe handling of mechanical impacts (happening in micro-seconds time scale). The robotic systems with compliant drives (terms also used: soft robots) are still in the phase of developments and only few systems are available at the market yet.

The above concepts achieve pHRI and manual guidance functions. Another highly potential HRI approach represents work-space sharing human-robot cooperation and collaboration. For the *workspace sharing interaction*, without a desired physical contact, the main focus is on *avoiding collision* with human beings. For this purpose, various sensors, mainly based on vision systems (e.g. safe-eye, 3D vision sensors, TOF-cameras, KINECT-like systems etc.), or RFID, WI-FI, ultra-sound, laser technology etc. indoor tracking and scanning systems have been applied. Their aim is to detect and locate a human presence in the robot working space and plan a corresponding robot reaction, such as to stop the robot motion, to reduce velocity, and/or go to a safe position.

Safety Standards

Following the evolution in industrial robots, Safety Requirements for Collaborative Robots and Applications have been drawn, which consider the Safety Standards for Applications of Industrial Robots ISO 10218-1 and ISO 10218-2[31]. Their definition originates from the previous European

[31] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=51330

Machinery Directive, and regulates the functions and design of robotic parts, the minimum gaps to avoid crushing, where safeguards should be placed, safety distances and the fixed and movable guards.

In 2011, the Italian Organisation for National Standards, UNI, published the standard UNI EN ISO 10218-2, harmonizing the requirements for using safely industrial robots in the case of robot and human workspace over-position. This standard defines three levels of space to be respected by the robot including the manipulated part:

- Grey area: a "maximum space" that may be reached by robot including the manipulated part.
- Yellow area: a "restricted space" that normally coincides with the "operating space", identifying the workspace by the work program of the robot.
- Green area: a "safeguard space" defined by safety perimeter on the basis of ISO 10218-2; it may also coincide with the "restricted space", but never may be smaller.

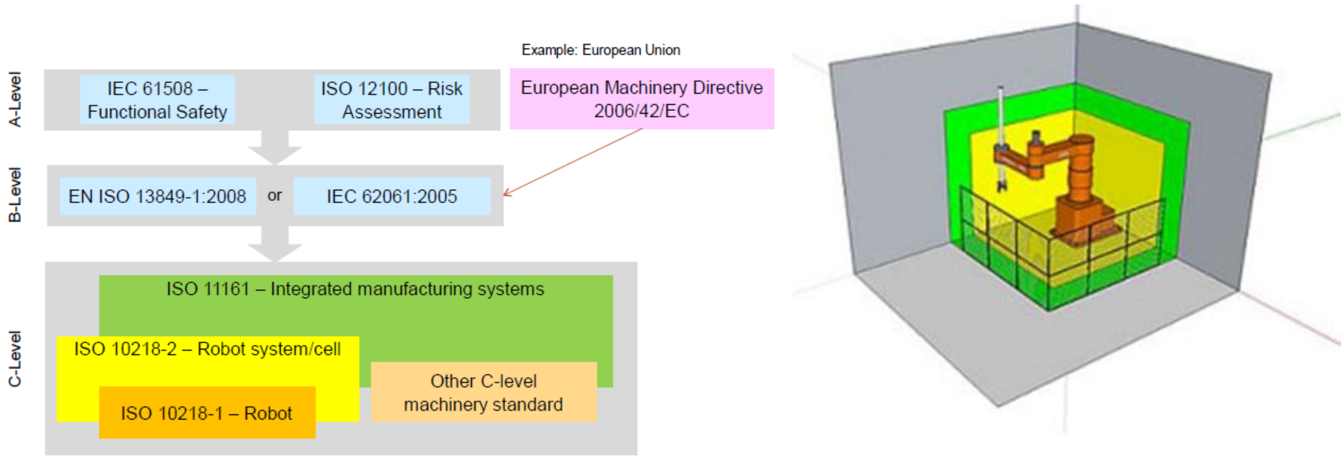


Figure 8 – ISO family of standards for Robotics and traditional fenced robot area

4.2.4 - Self-learning Robots

The combination of Robotics, Visual Recognition, Convolutional Neural Networks and their integration in a manipulation action grammar is giving an extraordinary perspective to self-learning robots. Several application examples are coming out with a variety of tasks.

Grasping

Researchers[32] at the University of Maryland and NICTA, Australia have created a robot capable of complex actions like cracking an egg and using a vacuum. Their robotic system learns processes by watching YouTube videos.

"Our ultimate goal is to build a self-taught robot that is able to enrich its knowledge about fine grained manipulation actions by watching demo videos," writes the project's lead researchers.

The robot uses object and grasping type recognition, along with a deep-learning framework that allows it to compile an ever-growing bank of skills and functions. It can recognise what a person is holding in a video, learns how they are holding it and converts their actions into repeatable steps.

It's not difficult to see how systems like this might be applied to improve automated manufacturing or bring new automation systems to areas of production that haven't yet seen much

[32] Yang, Y.; Li, Y.; Fermuller, C.; and Aloimonos, Y. 2015. Robot learning manipulation action plans by unconstrained videos from the world wide web. In The Twenty-Ninth AAAI Conference on Artificial Intelligence (AAAI-15)

automation. . An investment in a single robotic system capable of learning a variety of tasks without specialised programming would be attractive to small manufacturers, including those that do short production runs.

Self-learning Welding

A robot that can learn from watching other people could also fine tune its own actions through trial and error, essentially learning from its mistakes. That is what researchers at Lappeenranta University of Technology (LUT) in Finland had in mind when they developed a self-adjusting welding system[33].

LUT is developing an entirely new kind of welding system, which solves quality and productivity problems related to automated and mechanised welding. The system is self-adjusting, flexible and adaptable, such that it can be integrated as part of different robotic systems and different manufacturers' power supplies.

Figure 9 – Welding robot at LUT

It's self-adjusting properties are based on a new kind of sensor system which is controlled by a neutral network programme. Most often in welding a monitoring sensor is used which tracks the bevel angle, an essential part of the welding process. In the system being developed by LUT, there are also monitoring sensors for the thermal profile (the weld pool's heat values) and the weld form. The monitoring data are transferred from the sensors to the neural network, which is able to deduce and react to simultaneous changes in multiple variables.

'When a mistake is detected, the system is able, both to correct it during the welding process, and also calculate what other faults may arise. Thus the final product is flawless. The problem with welding automation systems is that certain values are set for the work, based on which the whole weld is carried out, and only then is it checked whether the result is good. Now the welding is monitored throughout the whole process', explains Project Manager Markku Pirinen.

In the gas-shielded arc welding process, factors affecting outcome quality include the welding current, the arc voltage, the wire feeding and transporting speeds, and the position of the welding gun. With the help of the neural network, a regulating window can be set for these system variables, and they can then be controlled so that they remain within certain limits, which ensures that final product is as required.

“In practice this means that when the welding values approach the boundary values set in the parameter window, the system corrects the process so that the welding values move back towards the centre of the value range and the possible defect is prevented.”

The new system works very well with high-strength steel welding, as the parameter windows for the high-strength materials are significantly narrower than those for construction steel, and the harder the steel is, the more difficult it is to weld. High-strength steel is used, for example, in arctic steel construction work, where the materials used must be light, robust, and strong.

[33] http://www.lut.fi/web/en/news/-/asset_publisher/lGh4SAywhcPu/content/the-welding-system-of-the-future-is-self-learning#sthash.zK2YlMGi.dpuf

"In the Arctic, welds must be of higher quality than in warmer regions. In the North, errors would have catastrophic consequences. For example, the welds must be able to withstand temperature of up to -60 °C, and they must be flawless. Operating safety must be so high that no accidents occur at all", says Pirinen.

The market for the new system developed by LUT is worldwide. The system can be used, for example, in the manufacture and quality verification of pressure vessels, different kinds of containers, pipes and pipe systems, booms and beam structures. In Pirinen's opinion, the welding industry has been waiting for a control system such as this ever since automated welding came onto the market.

"This system will bring significant savings to the welding industry, as resources will no longer be required for post-welding checks and repairs. However, the system can only be used for mass-welding operations, so hand-operated welding will continue to be used for the kinds of work which the robotic welders cannot do."

Adaptive Manufacturing

The potential for fully automated, self-learning and self-aware manufacturing systems led a consortium[34] of businesses and institutions led by the University of Nottingham to undertake the Fast Ramp-Up and Adaptive Manufacturing Environment project, FRAME, a few years back.

"The aim of the FRAME project is a paradigm shift from the conventional human-driven ramp-up and system integration process to fully automated, self-learning and self-aware production systems," according to a report issued at the conclusion of the investigation.

Ramp-up is necessary anytime a manufacturing device is moved, deployed, or constructed and it typically entails an intensive and person-centred process of fine-tuning and optimization. Technicians frequently rely on trial-and-error to move devices toward their maximum sustainable output and this ends up costing manufacturers significant downtime. It also adds as much as 65% to the underlying cost of a manufacturing system.

FRAME targeted the medical device, automotive and aerospace industries, which present unique manufacturing challenges and constraints. The aim of the project was to develop a system that would reduce time-to-market and time-to-volume for newly configured machines by 30 per cent.

Researchers sought to do this by creating a system first learned from humans. By matching operator actions to changes in productivity, the FRAME system could begin to solve problems without the need for further human intervention. Like LUT's welding machine, the system could also identify mistakes and take significant action on its own to correct them.

In trials, the FRAME project achieved a 30% reduction in failure rates, 64% increase in ideal outputs and 12% improvements in cycle time. The research is now being adapted for use beyond the FRAME target industries.

4.2.5 - Collective organization of Robot Swarms

Researchers have recently focus at exploiting the potential of physically connected robotic modules to accomplish tasks, which cannot be achieved by the same modules separately. In such a configuration, a group of robots may navigate a terrain that proves too difficult for a single robot. On the contrary, a group of independent robots can accomplish many collective tasks more efficiently. This collective

[34] http://www.diad-srl.com/DIAD_srl/News/Entries/2011/12/14_Newsletter_FRAME_IP_-_n.2_files/NEWSLETTER%20FRAME%20Issue%202.pdf

organisation is defined swarm-bot[35], a robotic system that can operate in both configurations and autonomously switch from one to the other.

Swarm-bots is a project sponsored by the Future and Emerging Technologies programme of the European Commission (IST-2000-31010), aimed to study new approaches to the design and implementation of self-organizing and self-assembling artefacts. This project aims to contribute to the economic development of the Community by providing a new approach to the design, construction and control of robotic systems.

The objective of the SWARM-BOTS project is to study a novel approach to the design, hardware implementation, test and use of self-assembling, self-organizing, metamorphic robotic systems called swarm-bots. This novel approach finds its theoretical roots in recent studies in swarm intelligence, that is, in studies of the self-organizing and self-assembling capabilities shown by social insects and other animal societies.

The project, that lasted 42 months, was successfully completed on March 31, 2005. Since October 1, 2006, the Swarmanoid project is extending the work done in the Swarm-bots project to three dimensional environments. Dr. Marco Dorigo, the project coordinator and one of the founders of the swarm intelligence and swarm robotics research fields, was awarded the First EU Marie Curie Award in November 2003, and the prestigious FNRS Prize - Prix Dr. A. De Leeuw-Damry-Bourlart, in November 2005, for his contributions to artificial intelligence and robotics.

The new framework of the swarm approach has been of increasing interest, with projects aiming to control up to thousands of robots toward a common task and to sound application.

Examples include the project Kilobots and the project AVERT.

Kilobots

In nature, vast groups of individual elements can co-operate and assemble to create highly complex global behaviour through local interactions from multi-cellular organisms to complex animal structures such as army ants bivouacs and flocks of birds. In the field of robotics, researchers use inspiration from collective intelligence in nature to create artificial systems with capabilities observed in natural swarms. Researchers have designed tiny robots, inspired by ants, bees and cells, envisioned to work together in large swarms or as programmable materials. Nevertheless, there still exists a substantial gap between the conceptual designs and the implemented systems. Creating engineered systems with similar abilities poses challenges in the design of both algorithms and physical systems that can operate at such scales. There is a vast body of work on algorithms meant to control collectives of hundreds or even thousands of robot however, for reasons of cost, time, or complexity, they are validated in simulation only, or on a group of a few tens of robots.

The Kilobot swarm[36] is a thousand-robot swarm designed to allow one to programme and experiment with collective behaviour in large-scale autonomous swarms. Each robot has the basic capabilities required for an autonomous swarm robot (programmable controller, basic locomotion, and local communication), but is made with low-cost parts and is mostly assembled by an automated process. In addition, the system design allows a single user to easily operate a large Kilobot collective, such as "hands-off" programming, powering on, and charging all robots. Our goal is to make experimental research on collective possible behaviours, and widely accessible and to enable deeper

[35] Swarm-Bot: a New Distributed Robotic Concept, Mondada F., Pettinaro G.C., Guignard A., Kwee I., Floreano D., Deneubourg J.-L., Nolfi S., Gambardella L.M., Dorigo M., Autonomous Robots, 17 (2-3):193-221, 2004

[36] Programmable Self-Assembly in a Thousand-Robot Swarm, Michael Rubinstein, Alejandro Cornejo, Radhika Nagpal, Science, Vol. 345, no6198, Aug. 2014

understanding and new algorithmic insights into robustness, scalability, self-organisation, and emergence in collectives of limited individuals.

AVERT

The Autonomous Vehicle Emergency Recovery Tool (AVERT)[37] started as a research project in 2012 to provide a unique capability to Police and Armed Services to rapidly deploy, extract and remove both blocking and suspect vehicles from vulnerable positions such as enclosed infrastructure spaces, tunnels and low bridges as well as basements and underground car parks. Vehicles can be removed from confined spaces with delicate, swift handling, and in any direction to a safer disposal point to reduce or eliminate collateral damage to infrastructure and personnel.

A demonstration of AVERT in March 2015 to five potential user nations and industrial partners was well received. It is expected that AVERT could enter production in early 2016.

4.3 - Materials

The EU is the home to the world's leading manufacturing industries, game changing innovative technologies and an entrepreneurial infrastructure, facilitating transition to a resource efficient and sustainable, society as envisioned in the EU 2020 agenda[38]. Providing the sustainable supply of raw materials is vital, but the EU is highly dependent on imports of raw materials that are crucial for these core industrial activities[39].

Several European initiatives have been developed to tackle this challenge through increasing resource efficiency of current processes and products and re-thinking the current linear economic model in favour of a more circular approach[40]. Increasing the supply of materials from all types of sources requires a range of technologies, infrastructures, trade measures and policies that can dynamically adjust to different resource types, availability and product compositions.

Besides the previously cited EuMAT and Manufuture, in 2014 this challenge was taken up by the European Institute of Technology. It started the Knowledge Innovation Community, Raw Materials[41], in order to fully utilise the potential of industrial symbiosis by applying a systemic perspective and to revitalise the human capital in the raw materials sector.

4.3.1 - Materials science

The basis of materials science involves studying the structure of materials, and relating them to their properties. The major determinants of the structure of a material and thus of its properties are its constituent chemical elements and the way in which it has been processed into its final form. These characteristics, taken together and related through the laws of thermodynamics and kinetics, govern a material's microstructure and thus its properties.

[37] http://new.avertproject.eu/

[38] European Commission, EUROPE 2020: A strategy for smart, sustainable and inclusive growth, COM(2010)

[39] European Parliament and Council, Strategic Innovation Agenda of the European Institute of Innovation and Technology (EIT), Factsheet 2: Raw Materials – Sustainable Exploration, Extraction, Processing, Recycling and Substitution, Decision No 1312/2013/EU

[40] European Commission, Towards a circular economy: A zero waste programme for Europe, COM(2014) 398 final

[41] http://eit.europa.eu/eit-community/eit-raw-materials

Materials science has evolved— since the 1960s—because in order to create, discover and design new materials, one had to approach it in a unified manner. Thus, materials science and engineering emerged at the intersection of various fields such as metallurgy, solid-state physics, chemistry, chemical engineering, mechanical engineering and electrical engineering.

The field is inherently interdisciplinary, and the materials scientists/engineers must be aware and make use of the methods of the physicist, chemist and engineer. The field, therefore, maintains a close relationship with these fields. Many physicists, chemists and engineers also find themselves working in materials science.

The overlap between physics and materials science has led to the offshoot field of materials physics, which is concerned with the physical properties of materials. The approach is generally more macroscopic and applied than in condensed matter physics.

The field of materials science and engineering is important from a scientific perspective, as well as from an engineering one. When discovering new materials, one encounters new phenomena that may not have been observed before. Hence, working with materials there is lot of science to be discovered.

4.3.2 - From metals to lightweight materials

The study of metal alloys is a significant part of materials science. Of all the metallic alloys in use today, the alloys of iron (steel, stainless steel, cast iron, tool steel, alloy steels) make up the largest proportion both by quantity and commercial value. Iron alloyed with various proportions of carbon gives low, mid and high carbon steels. An iron carbon alloy is only considered steel if the carbon level is between 0.01% and 2.00%. For the steels, the hardness and tensile strength of the steel is related to the amount of carbon present, with increasing carbon levels also leading to lower ductility and toughness.

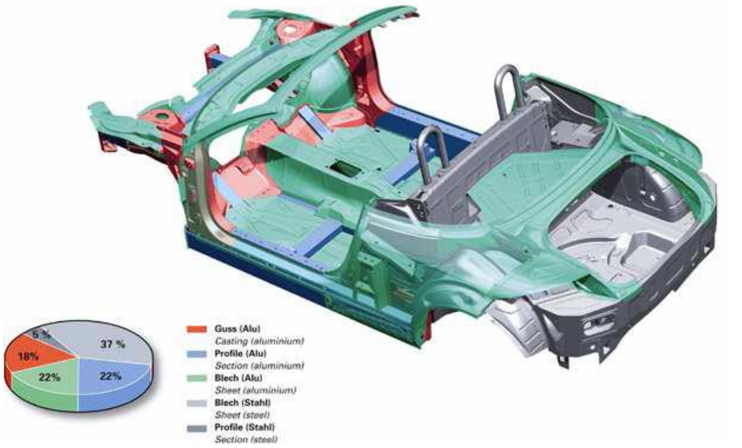


Figure 10 – New materials in vehicle structures

Heat treatment processes such as quenching and tempering can significantly change these properties however. Cast Iron is defined as an iron–carbon alloy with more than 2.00% but less than 6.67% carbon. Stainless steel is defined as a regular steel alloy with greater than 10% by weight alloying content of Chromium. Nickel and Molybdenum are typically also found in stainless steels.

Other significant metallic alloys are those of aluminium, titanium, copper and magnesium. Copper alloys have been known for a long time, while the alloys of the other three metals have been relatively recently developed. Due to the chemical reactivity of these metals, the electrolytic extraction processes required were only developed relatively recently. The alloys of aluminium, titanium and magnesium are also known and valued for their high strength-to-weight ratios and, in the case of magnesium, their ability to provide electromagnetic shielding.

These materials are ideal for situations where high strength-to-weight ratios are more important than bulk cost, such as in the aerospace industry and certain automotive engineering applications.

Over the last decade, a recent trend in the development of industry materials included substituting metals with composite materials.

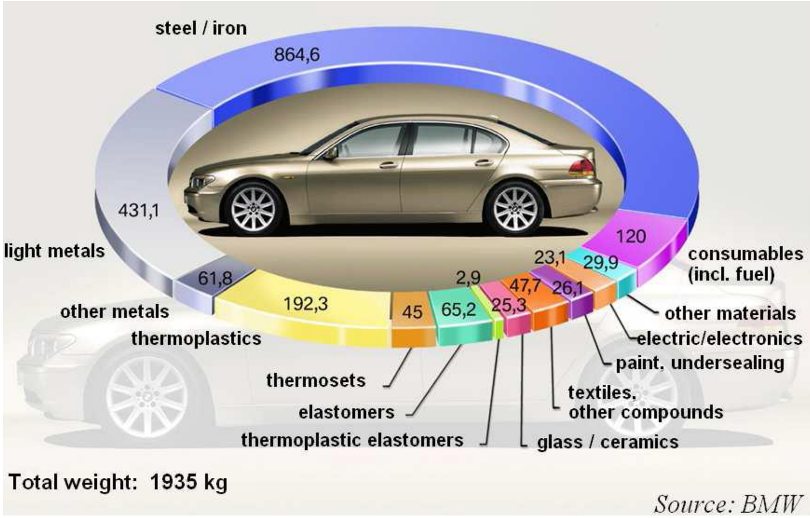


Figure11 - Overview of different materials in cars. Source BMW

Composite materials are structured materials composed of two or more macroscopic phases. Applications range from structural elements such as steel-reinforced concrete, to the thermally insulative tiles which play a key and integral role in NASA's Space Shuttle thermal protection system which is used to protect the surface of the shuttle from the heat of re-entry into the Earth's atmosphere. One example is reinforced Carbon-Carbon (RCC), the light gray material which withstands re-entry temperatures up to 1510 °C (2750 °F) and protects the Space Shuttle's wing leading edges and nose cap. RCC is a laminated composite material made from graphite rayon cloth and impregnated with a phenolic resin. After curing at high temperature in an autoclave, the laminate is pyrolized to convert the resin to carbon, impregnated with furfural alcohol in a vacuum chamber, and cured/pyrolized to convert the furfural alcohol to carbon. In order to provide oxidation resistance for reuse capability, the outer layers of the RCC are converted to silicon carbide

Figure 12 – Composite materials

A more recent trend of evolution pursued by scientific research is toward substitution of metals and macro composite materials with micro and nano composites materials.

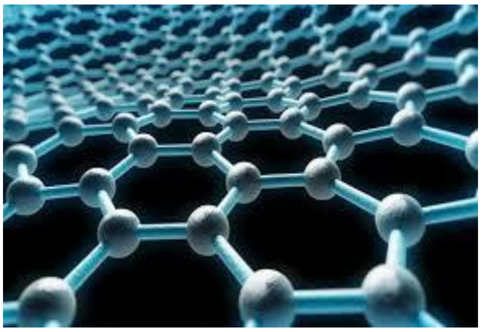
Microstructure is defined as the structure of a prepared surface or thin foil of material as revealed by a microscope above 25× magnification. It deals with objects from 100 nm to a few cm. The microstructure of a material (which can be broadly classified into metallic, polymeric, ceramic and composite) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behaviour, wear resistance, and so on. Most of the traditional materials (such as metals and ceramics) are microstructured.

Nanostructure deals with objects and structures that are in the 1—100 nm range. In many materials, atoms or molecules agglomerate together to form objects at the nanoscale. This leads to many interesting electrical, magnetic, optical and mechanical properties.

In describing nanostructures it is necessary to differentiate between the number of dimensions on the nanoscale. Nanotextured surfaces have one dimension on the nanoscale, i.e., only the thickness of the surface of an object is between 0.1 and 100 nm. Nanotubes have two dimensions on the nanoscale, i.e., the diameter of the tube is between 0.1 and 100 nm; its length could be much greater. Finally, spherical nanoparticles have three dimensions on the nanoscale, i.e., the particle is between 0.1 and 100 nm in each spatial dimension. Materials whose atoms/molecules form constituents in the nanoscale (i.e., they form nanostructure) are called nanomaterials. Nanomaterials are the subject of intense research in the materials science community due to the unique properties that they exhibit.

4.3.3 - The Graphene example

Graphene is the most recent and most promising of carbon-based nanostructured materials. It is formed by a sheet of carbon atoms, one atom thick, arranged in a honeycomb lattice. Thanks to its peculiar structure, graphene features outstanding properties with high charge mobility, excellent mechanical properties and good chemical tenability that make it easily processed in a wide variety of thin coatings or composites with polymers, metals and inorganic materials.



Graphene has been widely used as a nano-additive in polymer composites to enhance mechanical properties, electrical conductivity, and resistance to temperature or solvents. It is a promising candidate to create high-performance composite materials for metal replacement, as example for applications in the aeronautic and aerospace sector, where carbon-based composites can allow significant reduction of weight as compared to their metals counterparts.

Graphene was discovered in Europe, and several European groups are at the forefront of grapheme research.

Worldwide production is already on the tens of kilograms scale. Graphene-based products have been already commercialised by Austrian, Italian and Spanish companies.

However, an industrial production and application is very much underway and ongoing in Asia and USA, who have the lead on graphene-related patenting activities. To keep Europe at the centre of this technologically relevant sector a strong international activity and a good network of infrastructures will be needed, relying on industrial involvement, top-level research and training of researchers on processing and applying graphene.

Technologies, and our economy in general, usually advance either by incremental developments (e.g. scaling the size and number of transistors on a chip) or by quantum leaps (transition from vacuum tubes to semiconductor). Disruptive technologies, behind such revolutions, are usually characterised by universal, versatile applications, which change many aspects of our lives simultaneously, penetrating every corner of our existence.

GRMs are expected to have a major impact in several technological fields, due to the new applications that their properties propose. E.g., potential electronic applications include high-frequency devices, touch screens, flexible and wearable devices, as well as ultrasensitive sensors, nano electromechanical system s (NEMS), superdense data storage, photonic devices, etc.

In the energy field, applications include batteries and supercapacitors to store and transport electrical power, and solar cells. However, in the medium term, some of graphene's most appealing potential lies in its ability to transmit light as well as electricity, offering improved performance for light emitting diodes (LEDs), flexible touch screens, photodetectors, and ultrafast lasers.

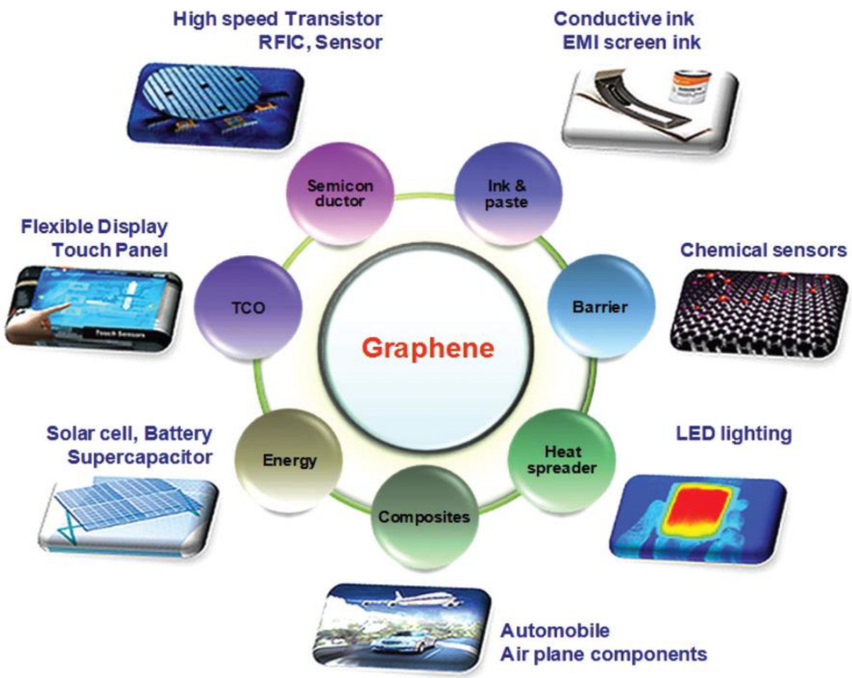


Figure 13 – Graphene potential deployment strategies

In the energy field, applications include batteries and supercapacitors to store and transport electrical power, and solar cells. However, in the medium term, some of graphene's most appealing potential lies in its ability to transmit light as well as electricity, offering improved performance for light emitting diodes (LEDs), flexible touch screens, photodetectors, and ultrafast lasers.

The Flagship Project GRAPHENE[1] is collecting the most advanced European research about this topic and is the EU's biggest ever research initiative. With a budget of €1 billion, it represents a new form of joint, coordinated research on an unprecedented scale.The Graphene Flagship is tasked with bringing together academic and industrial researchers to take graphene from the realm of academic laboratories and introducing it into European societies in the space of 10 years, thus generating economic growth, new jobs and new opportunities.

Figure 14 – Examples of polymer/graphene nanocomposites prototypes produced by ISOF-CNR and SMEs located in the Emilia-Romagna region.

4.4 - Wireless and IoT

4.4.1 - Marconi cut wiring

Guglielmo Marconi is recognised as the inventor of the Radio waves Communications - as demonstrated by his experiments in 1895 - and for his first patent "Implementations in telegraphy and related devices" introduced in London in 1896. Since its discovery, radio communications has consequently been a revolutionary technology that wipes away all the wiring of telegraph, and allows astonishing long distances to be overcame by using data and voice signals.

Somehow, the terms wireless and planetary data communications were developed during this period. Their impact consequences that we are now experiencing were unforeseen in regard of the importance they had on economic, military, social and political scale. In the 21st century, science and technology has developed and the heritage of Marconi's discoveries have become enormous, with the spread of Information and Communications technologies, mobile phones, and Gbits/sec of wearable computing intelligence, which people carry with them every day.

Internet of things is an increasingly important tool for everyday use. It creates changes in the home, when travelling and in our general experience with things in many situations and environments. It is based upon the tremendous developments made in information and communication technologies toward the following achievements:

1) Development of very compact Subscriber Identity Modules, SIM, a card capable to identify a transmitting mobile emitter;
2) Development of a global satellite network capable of connection anywhere of a GPS referenced thing from the sky;
3) Development of logistic antennas networks capable to link a SIM almost anywhere on the planet to Internet.
4) Development of a variety of protocols to manage interconnections between things.

The term "Internet of Things" was coined by British entrepreneur Kevin Ashton in 1999[42].

The Internet of Everything (IoE) creates $14.4 trillion in Value at Stake — the combination of increased revenues and lower costs that is created or will migrate among companies and industries from 2013 to 2022.

- The five main factors that fuel IoE Value at Stake are: 1) asset utilization (reduced costs) of $2.5 trillion; 2) employee productivity (greater labor efficiencies) of $2.5 trillion; 3) supply chain and logistics (eliminating waste) of $2.7 trillion; 4) customer experience (addition of more customers) of $3.7 trillion; and 5) innovation (reducing time to market) of $3.0 trillion.
- Technology trends (including cloud and mobile computing, Big Data, increased processing power, and many others) and business economics (such as Met-calfe's law) are driving the IoE economy.
- These technology and business trends are ushering in the age of IoE, creating an unprecedented opportunity to connect the unconnected: people, process, data, and things. Currently, 99.4 percent of physical objects that may one day be part of the Internet of Everything are still unconnected.

[42] Wood, Alex. The internet of things is revolutionizing our lives, but standards are a must, The Guardian. Retrieved 31 March 2015.

Typically, IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications (M2M) and covers a variety of protocols, domains, and applications. The interconnection of these embedded devices (including smart objects), is expected to usher in automation in nearly all fields, while also enabling advanced applications like a Smart Grid, and expanding to the areas such as Smart city.

The Global Standards Initiative on Internet of Things (IoT-GSI) concluded its activities in July 2015 following TSAG decision to establish the new Study Group 20 on "IoT and its applications including smart cities and communities". All activities ongoing in the IoT-GSI were transferred to the SG20. For more information see SG20 webpage[43].

IoT-GSI aimed to promote a unified approach in ITU-T for development of technical standards (Recommendations) enabling the Internet of Things on a global scale. ITU-T Recommendations developed under the IoT-GSI by the various ITU-T Questions - in collaboration with other standards developing organizations (SDOs) – will enable worldwide service providers to offer the wide range of services expected by this technology. IoT-GSI also aimed to act as an umbrella for IoT standards development worldwide.

The Internet of Things (IoT) has been defined in Recommendation ITU-T Y.2060 (06/2012) as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

4.4.2 - IoT in Transport sector

Forecasts by telecom players predict massive traffic growth, in the realm of 1000 time greater global wireless-traffic volumes in
020 than seen in 2010, and primarily driven by the increased usage of mobile multi-media services.

The revolutionary introduction of the latest versions of ICT in cars, planes and in almost every type of transport has exceeded the old radio receiver for a more pleasant journey. Today the driver may be assisted by GPS to find the correct target on the routes net. He may wish to remain connected to the internet as a source of information for passengers.

Figure 15 – Communication nodes. Source GoGo

It is quite common to be asked to turn off any electronic device, such as a mobile phone, on an airplane. The warning is due to the remote possibility of interference with the local e.m. connections aboard the airplane itself. Today in-flight Wi-Fi is now accessible on around 40% of US flights and on international long haul flights with Lufthansa, Emirates and Qatar Airways. Norwegian and Turkish airlines and the Scandinavian airline SAS are currently trialling this.

US provider GoGo has built a network of 3G ground stations all across the US, and planes communicate with these as they fly overhead. Bandwidth limited to as little as 3.1Mbps. The alternative approach is to connect via satellite. Ku-band (12-18GHz) satellites are the mainstream; they are relatively economical and delivering good performance. Lufthansa's FlyNet system claims download speeds up to 50Mbps, including in the middle of the ocean.

[43] http://www.itu.int/en/ITU-T/studygroups/2013-2016/20/Pages/default.aspx

In a car, the driver is warned not to use the telephone in order to avoid misunderstanding of sound alarms. Most car accidents are determined to be due to driver error. About 41% of the driver-related critical reasons were recognition errors that include inattention, internal and external distractions, inadequate surveillance, etc. Of these, the most frequently occurring critical reason was inadequate surveillance that refers to a situation in which a driver failed to look, or looked but did not see, when it was essential to safely complete a vehicle manoeuver. This critical reason was assigned to drivers in about 20% of crashes. Internal distraction as a critical reason was assigned to drivers in about 11% of cases. About 34%of the driver-related critical reasons were decision errors that included driving too fast for the conditions (8.4%), too fast round a curve (4.9%), incorrect assumption of others' actions (4.5%), illegal manoeuver (3.8%), and misjudgment of gap or others' speed (3.2%). In about 10% of cases, the major reason for accidents was performance errors such as overcompensation (4.9%), poor directional control (4.7%), etc.

A solution may be provided by mobile and wireless systems such as HSPA, LTE/LTEA. The IEEE802.11 family of technology is expected to dominate the wireless-communication arena for the next decade. The aims include assessing:

- Navigation and traffic information systems
- Voice recognition and wireless Internet
- Safety systems
- Security systems
- Diagnostics and maintenance services.

The communication frameworks may be three :

- VANET Vehicle Ad hoc Network
- MANET Mobile Ad hoc network
- SATNET Satellite Ad hoc Network.

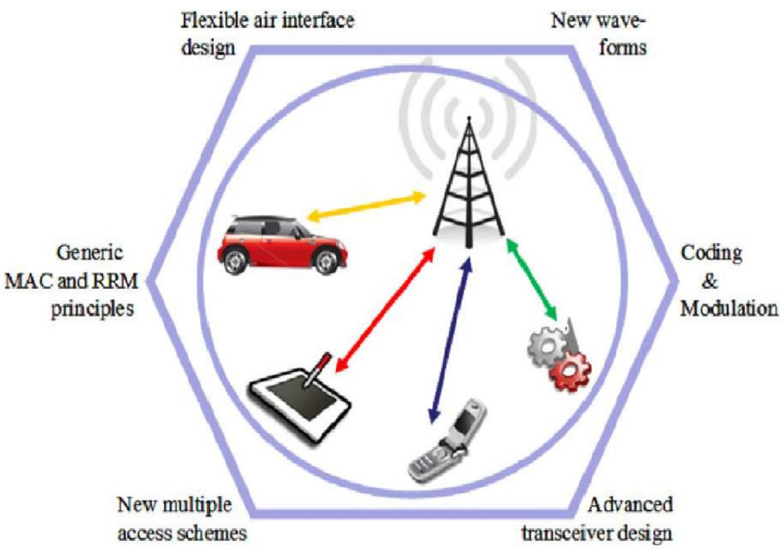


Figure 16 – Communication structure. Courtesy of Afif Osseiran [44]

[44] www.metis2020.com/wp-content/uploads/publications/VTC_2013Oss_et_al_MobileSystem2020.pdf

Drivers are continuously supported by local wireless communication with steady emitters, with other cars, with the web through satellites, in order to activate commands and control speed.

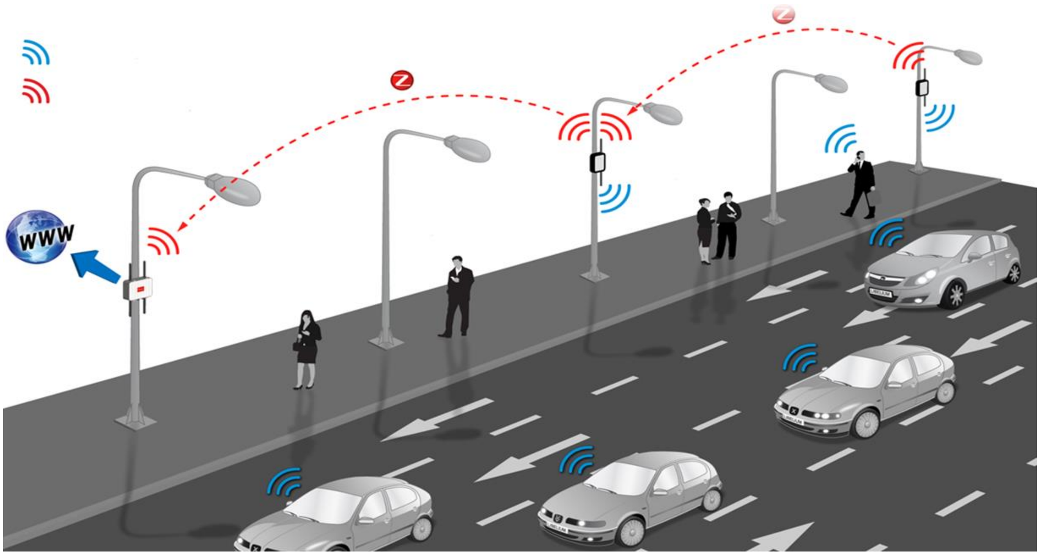


Figure 17 – Example of connected road

4.4.3 - Wireless aboard means connected cars

In the near future the risks to car travel will be radically reduced due to wireless interconnections and automated operation of the car. This task has hardly been pursued in research and industry labs and today the option for a self-driven car has become a reality.

Cars equipped by radio emitters will be continuously connected to Vehicle-to-vehicle (V2V) and vehicle-to road infrastructure (V2I) protocols, in order to exchange data for steering, braking and speed command, for a Cooperative Traffic Safety Applications. The requirements for this application of IoT are:

- Real-time with low latencies (sub 100 ms)
- High reliability: no undetected errors
- Scalable: support for many vehicles in the same area.

Current standards for V2V and V2I are based on IEEE 802.11p, which is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE), a vehicular communication system. In Europe, 802.11p was used as a basis for the ITS-G5 standard, supporting the GeoNetworking protocol for vehicle to vehicle and vehicle to infrastructure communication.[3] ITS G5 and GeoNetworking is being standardised by the European Telecommunications Standards Institute group for Intelligent Transport Systems[45]. The European profile standard for the physical and medium access control layer of Intelligent Transport Systems operates in the 5 GHz frequency band, as it is set by the "Intelligent Transport Systems (ITS)".

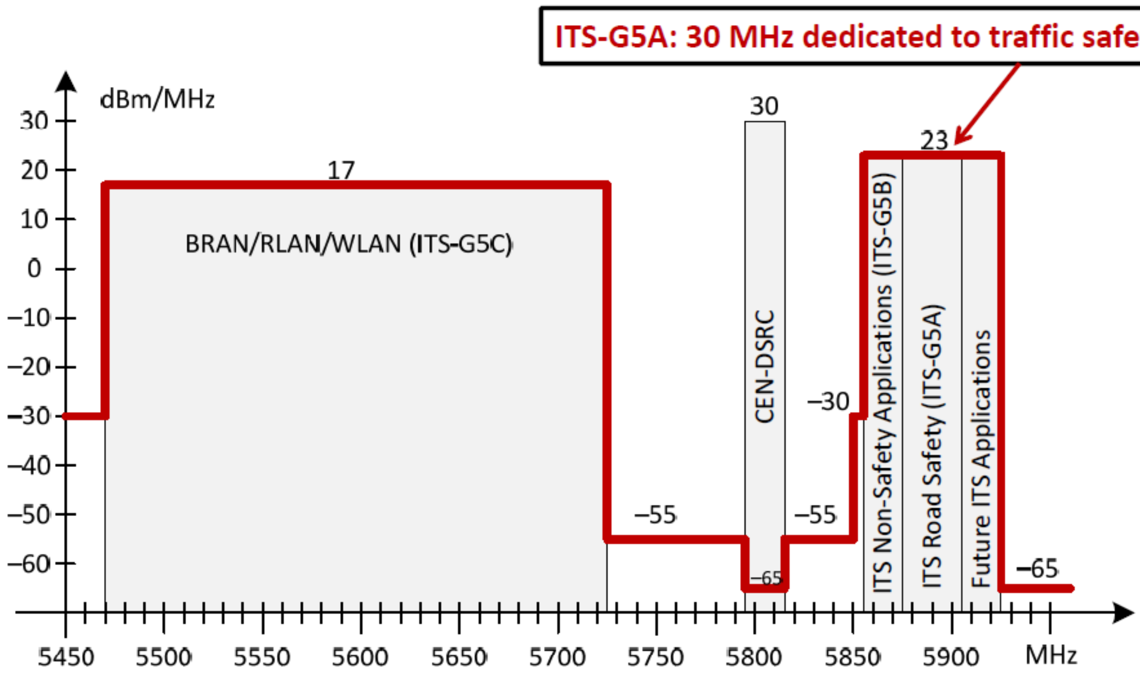


Figure 18 – Frequency band of Intelligent Transport Systems. Courtesy of Prof. Erik Strom, University of Chalmers Sweden.

The European profile standard for the physical and medium access control layer of Intelligent Transport Systems operates in the 5 GHz frequency band, as it is set by the "Intelligent Transport Systems (ITS)".

At about 6 GHz the wavelength is 5 cm long, which ensures appropriate propagation limit and a sufficient spatial resolution for the car typical dimension. Research studies[46] have analyzed problems and solutions, such as Doppler-effect due to car speed difference in both V2V and V2I frames.

4.4.4 - Latest self-driving car developments

Google Self-Driving Car

The commonly abbreviated as SDC is a project by Google involving the development of technology for autonomous cars, mainly electric cars. Lettering on the side of each car identifies it as a "self-driving car". Legislation has been passed in four U.S. states and Washington, D.C. allowing driverless cars. The state of Nevada passed a law on June 29, 2011, permitting the operation of autonomous cars in Nevada, after Google had been lobbying in that state for robotic car laws. The Nevada law went into effect on March 1, 2012, and the Nevada Department of Motor Vehicles issued

[45] "Intelligent Transport Systems". Web site. ETSI. Retrieved September 9, 2013.

[46] Mecklenbräuker, et al., "Vehicular channel characterization and its implication for wireless systems design and performance," Proc. of the IEEE, July 2011

the first license for an autonomous car in May 2012, to a Toyota Prius modified with Google's experimental driverless technology.

Figure 19 – Google driverless car. Courtesy of Google and FRG-LAW[47].

In April 2012, Florida became the second state to allow the testing of autonomous cars on public roads, and California became the third when Governor Jerry Brown signed the bill into law at Google HQ in Mountain View. In December 2013, Michigan became the fourth state to allow testing of driverless cars in public roads. In July 2014, the city of Coeur d'Alene, Idaho adopted a robotics ordinance that includes provisions to allow for self-driving cars.

In May 2014, Google presented a new concept for their driverless car that had neither a steering wheel nor pedals, and unveiled a fully functioning prototype in December of that year that they planned to test on San Francisco Bay Area roads beginning in 2015. Google plans to make these cars available to the public in 2020.

Dual electric motor TESLA car with autopilot

Tesla is a car producer that focuses on the fast growing market of electric cars. The company introduced several concept innovations, such as dual engine on both wheels axes, long-range battery, high peak current for higher acceleration, self-driving capability based on complementary sensors.

Tesla is committed to developing and refining the technologies to enable self-driving capability[48] of an electric drive car. In October of last year, Tesla started equipping Model S with hardware to allow for the incremental introduction of self-driving technology: a forward radar, a forward-looking camera, 12 long-range ultrasonic sensors positioned to sense 16 feet around the car in every direction at all speeds, and a high-precision digitally-controlled electric assist braking system. Today's Tesla Version 7.0 software release allows those tools to deliver a range of new active safety and convenience features, designed to work in conjunction with the automated driving capabilities already offered in Model S.

This combined suite of features represents the only fully integrated autopilot system involving four different feedback modules: camera, radar, ultrasound, and GPS. These mutually reinforcing systems offer real-time data feedback from the Tesla fleet, ensuring that the system is continually learning and improving upon itself.

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[47] http://www.frg-law.com/truck-accident-blog/driver-alert-self-driving-cars-hit-road/

[48] https://www.teslamotors.com/blog

Figure 20 – Representation of the display of Tesla autopilot system. Source Tesla Motors

Autopilot allows Model S to steer within a lane, change lanes with the simple tap of a turn signal, and manage speed by using active, traffic-aware cruise control. Digital control of motors, brakes, and steering helps avoid collisions from the front and sides, as well as preventing the car from wandering off the road. The car can also scan for a parking space, alerting the driver when one is available, and parallel park on command.

Chapter 5

CONCLUSIONS

The multiannual roadmap prepared by EFFRA, Factories of the Future[49], provides a view on the long term Manufacturing vision 2030. Four long-term paradigms will guide the transformations that European manufacturing needs to undergo:

Factory and nature -> green/sustainable

- Lowest resource consumption energy — lean, clean, green
- Closed loops for products/production and scarce resources
- Sustainability in material, production processes/workers

Factory as a good neighbour -> close to the worker and the customer

- Manufacturing close to people (in cities/metropolitan areas)
- Factory integrated and accepted in the living environment
- Event-oriented production/integration of customers

Factories in the value chain -> collaborative

- Strive for highly competitive distributed manufacturing (flexible, responsive, high speed of change)
- European production system: design-oriented products, mass customised products
- Integration of the product and process engineering — agile and demand driven Mastering the collaboration from simple to sophisticated products in the value chain

Factory and humans -> human centred

- Human-oriented interfaces for workers: process-oriented simulation and visualisation
- Products and work for different type of skilled an aged labour, education and training with IT support
- Regional balance: work conditions in line with the way of life, flexible time- and wage-systems
- Knowledge development, management and capitalisation

In response to the megatrends European manufacturing sectors need to undergo innovation-driven transformations towards the Manufacturing 2030 vision.

The Factories of the Future PPP identifies and realises these transformations by pursuing a set of research priorities along the following research and innovation domains:

- advanced manufacturing processes
- adaptive and smart manufacturing systems
- digital, virtual and resource-efficient factories
- collaborative and mobile enterprises
- human-centred manufacturing
- Customer-focused manufacturing.

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[49] Factories of the Future, by EUROPEAN COMMISSION, Directorate-General for Research and Innovation, Luxembourg: Publications Office of the European Union, 2013 ISBN 978-92-79-31238-0.

Each of these domains embodies a particular aspect of the required transformations towards the factories of the future.

The research and innovation activities undertaken within the domains should focus on a concrete and measurable set of targets, described as the following manufacturing challenges and opportunities:

- **Manufacturing the products of the future**: Addressing the ever-changing needs of society and offering the potential of opening new markets.
- **Economic sustainability of manufacturing**: Combining high performance and quality with cost-effective productivity, realising reconfigurable, adaptive and evolving factories capable of small-scale production in an economically viable way.
- **Social sustainability of manufacturing**: Integrating human skills with technology
- **Environmental sustainability of manufacturing**: Reducing resource consumption and waste generation.

Addressing these challenges and opportunities is at the core of what the Factories of the Future PPP is determined to achieve.

Overall, the achievement of the identified transformations requires a coordinated research and innovation effort, where manufacturing challenges and opportunities are addressed by deploying successively the following set of technologies and enablers:

- advanced manufacturing processes and technologies, including photonics;
- mechatronics for advanced manufacturing systems, including robotics;
- information and communication technologies (ICT) 31;
- manufacturing strategies.

SKILLMAN classification of Advanced Manufacturing and maintenance technical processes in the Transport sector

The SKILLMAN project partakes of and share the over mentioned indications by EFFRA, in particular for what concerns the increasing use of Robotics, Advanced materials and Internet of things (or Industry 4.0).

The planning of professional courses in view of Joint European Curricula for professional technician and engineers of the Transport sector will be the subject of another SKILLMAN Work Package.

The conclusion of this Report will focus on indications about the basic background and the specific skills that SKILLMAN will consider for the over mentioned professional courses. The following Tables intend to provide a track to translate the trends of advancement of technologies into a segmented set of basic background and skill needs for the employee qualification in the transport sector.

Tab. 5.1. - Examples of Basic background and Skill Needs in Robotics

Advanced Technology	Main Technical Components	Technical know-how	Basic background	Skill needs
Robotics	Motorized motion	Electric Motors	Electro-technical engineering	AC/DC Motors
				3D Rotation & Translation
				Motorization design
	Multi-axes systems	Translation encoding	Power auxiliary equipment	Motion control programming
		Rotating joints		Multi-axes design
	Sensors	Pressure, temperature transducers	Micro electromechanical system Infrared spectroscopy Thermo-graphy	3D scanning
				Infra Red emission
				Frame grabbing
	Vision	Light detectors, CCD/CMOS, image grabber	Optics Photodiodes PD matrix	Photon detection
				Imaging systems

Tab.5.2 - Examples of Basic background and Skill Needs in Lightweight Materials

Advanced Technology	Main Technical Components	Technical know-how	Basic background	Skill needs
Lightweight Materials	Carbon composite	Carbon fibres	Carbon chemistry Chemical-physical properties Bonding materials Nano-materials Light-weigth materials	Composite design
		Resins		
	Nano-composite	Bi-dimensional composite		Composite assembling
		Tri-dimensional composite		
	Multilayered sandwich	Composite		Composite fixing
		Honeycombs Realization	Tri-dimensional structuring Additive machining	
		Fixing		
	Trabeated structures	Additive machining		

Tab. 5.3 - Examples of Basic background and Skill Needs in Wireless Interactive On-board ICT

Advanced Technology	Main Technical Components	Technical know-how	Basic background	Skill needs
Wireless Interactive On-board ICT	Radio communication	Transmitter/Receivers	Electromagnetic waves Satellite comm. Photonics Microelectronics ICT systems Electro-Mechanical engineering	Wireless Communication systems
		GPS		
	Sensors	Proximity		
		Imaging		Electronics maintenance
		3D Distance		
	Microprocessors	Data elaboration		
		Data storage		Processor programming
		Data exchange		
	Actuators	Internal wireless controls		
		Infotainment on-board		Digital devices
		Auto-pilot		
		Driving command		

This Report on the State of the Art of Advanced Manufacturing in the Transport sector has indicated the main trends of research devoted to improvements and new discoveries in Robotics, Lightweight materials and Internet of Things. The project SKILLMAN will build on these findings through its activities and Work Packages included in its Work Plan.