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Ethical Aspects of Cyber-Physical Systems

Scientific Foresight study

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Ethical Aspects of Cyber-Physical Systems

Study

June 2016

The Scientific Foresight project 'Ethical Aspects of Cyber-Physical Systems' was requested by the Science and Technology Options Assessment Panel (STOA). The main part of the study was conducted by Technopolis Group and managed by the Scientific Foresight Unit within the Directorate-General for Parliamentary Research Services (DG EPRS) of the European Parliament.

This report is a compilation of the findings of the different phases of study. The document was compiled by Lieve Van Woensel, Christian Kurrer and Mihalis Kritikos, with the contribution and assistance of Brian Kelly, Philip Boucher, Sarah McCormack and Rachel Manirambona of the Scientific Foresight Unit of DG EPRS.

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Abstract

Cyber-physical systems (CPS) are intelligent robotics systems, linked with the Internet of Things, or technical systems of networked computers, robots and artificial intelligence that interact with the physical world.

The project 'Ethical aspects of CPS' aims to provide insights into the potential ethical concerns and related unintended impacts of the possible evolution of CPS technology by 2050. The overarching purpose is to support the European Parliament, the parliamentary bodies, and the individual Members in their anticipation of possible future concerns regarding developments in CPS, robotics and artificial intelligence.

The Scientific Foresight study was conducted in three phases:

1. A 'technical horizon scan', in the form of briefing papers describing the technical trends and their possible societal, ethical, economic, environmental, political/legal and demographic impacts, and this in seven application domains.
2. The 'soft impact and scenario phase', which analysed soft impacts of CPS, on the basis of the technical horizon scan, for pointing out possible future public concerns via an envisioning exercise and using exploratory scenarios.
3. The 'legal backcasting' phase, which resulted in a briefing for the European Parliament identifying the legal instruments that may need to be modified or reviewed, including — where appropriate — areas identified for anticipatory parliamentary work, in accordance with the conclusions reached within the project.

The outcome of the study is a policy briefing for MEPs describing legal instruments to anticipate impacts of future developments in the area of cyber-physical systems, such as intelligent robotics systems, linked with the Internet of Things.

It is important to note that not all impacts of CPS are easily translated into legislation, as it is often contested whether they are in effect harmful, who is to be held accountable, and to what extent these impacts constitute a public rather than a private concern.

Table of Contents

These annexes are available in a separate publication:

Annex 1: Technical briefing papers on cyber-physical systems in seven application areas

Annex 2: Four exploratory scenarios in a future in which cyber-physical systems have developed and matured in various aspects of our lives

Annex 3: Methodology used for the assessment of possible future concerns regarding cyber-physical systems

Executive Summary

Cyber-physical systems (CPS) are defined as technical systems of networked computers, robots and artificial intelligence that interact with the physical world. The aim of the project *Ethical aspects of CPS* was to

(i) examine future development paths of CPS technology up to the year 2050,
(ii) highlight potential unintended impacts and ethical concerns; and
(iii) support the European Parliament, the parliamentary committees and other parliamentary bodies, as well as the individual Members, in their anticipation of possible future concerns regarding developments in CPS, robotics and artificial intelligence.

Context

The study was launched by the STOA Panel upon the request of the European Parliament's Committee on Legal Affairs (the JURI Committee) to provide evidence for its Working Group on legal questions related to the development of robotics and artificial intelligence, which should feed into the reflection of Members on the need for civil law rules by facilitating specific information, providing for an exchange of views with experts from many fields of academic expertise and enabling Members to conduct an in-depth analysis/examination of the challenges and prospects at stake. The input gathered by the Working Group will be the basis for an INI report and possible future legislative activities. The INI report will also be discussed by other Committees before being voted upon in plenary. The present STOA study will lead to a final policy briefing paper which aims to support these parliamentary bodies by providing an analysis of legal instruments available for dealing proactively with possible future concerns regarding developments in CPS, robotics and artificial intelligence.

Methodology

The Scientific Foresight study was conducted in three phases[1]:

1. a 'technical horizon scan', in which briefing papers described the key technical developments, including short- and long-term trends with a reflection upon their societal, ethical and other impacts;[2]

2. a 'soft impacts and scenario development phase', which analysed soft impacts[3] of CPS to highlight possible public concerns. Two workshops were organised to identify these soft impacts, to develop a set of possible future scenarios, and to identify areas of possible public or ethical concern;

3. a 'legal backcasting' phase, which identified the legal instruments that may need to be modified or reviewed and, where appropriate, areas where anticipative parliamentary work may be required. In this phase, the outcomes from the previous steps were transformed into a forward-looking strategy to support the legislative activities of the European Parliament, the parliamentary committees and the Members of the European Parliament.

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[1] The process is described in the report *Towards Scientific Foresight in the European Parliament*.
http://www.europarl.europa.eu/RegData/etudes/IDAN/2015/527415/EPRS_IDA(2015)527415_REV1_EN.pdf

[2] This follows a 'STEEPED' checklist of social, technological, environmental, economic, political, ethical and demographic aspects.

[3] Soft impacts are those impacts that are not easy to measure – e.g. affecting health, environment, and safety – and for which it is not easy to distribute responsibility.

Process summary

Step 1: **Request** for the study: 'Ethics of Cyber-Physical Systems', for the JURI Committee

Step 2: **Technical Horizon Scanning**, unravelling the complexity of CPS in seven areas;

Step 3: **Envisioning phase** ('Soft impact' phase), identifying possible future impacts of CPS;

Step 4: **Scenario Phase**, resulting in areas of societal concern raised by CPS;

Step 5: **Legal backcasting**, identifying legal instruments that may need to be reviewed or modified and, where appropriate, areas where anticipatory parliamentary work may be required, anticipating the future concerns identified;

Step 6: **Sense-making phase** in which the outcomes are transformed into briefings supporting the Members of the European Parliament in their anticipation of possible future concerns regarding developments in CPS, robotics and artificial intelligence.

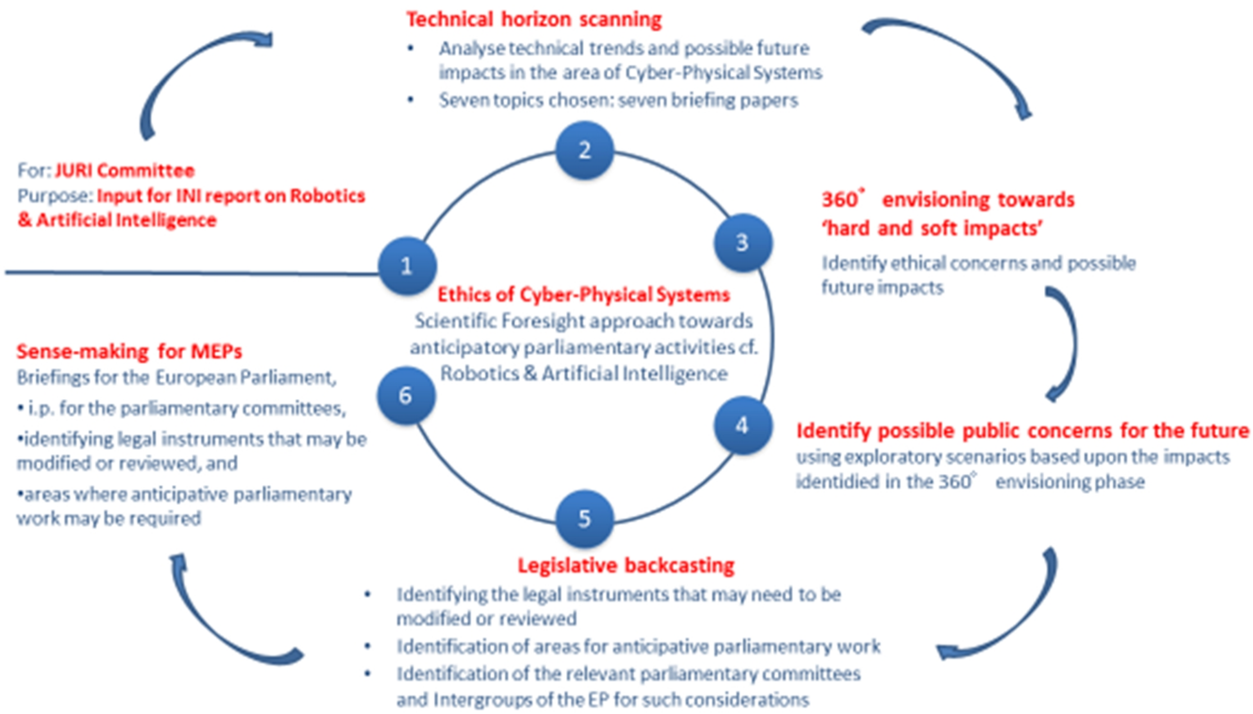

Figure 1.1 Visualisation of the steps and phases of the study

1 Lay summary

The present Scientific Foresight study on 'Ethics of Cyber-Physical Systems' was conducted for the European Parliament's STOA Panel (Science and Technology Options Assessment Panel).

What are cyber-physical systems?

Cyber-physical systems (CPS) are technical systems in which networked computers and robots interact with the physical world. By 2050, these systems may interact with us in many domains, driving on our roads, moving alongside us in our daily lives and working within our industries. Due to the wide range of situations where we will be interacting with CPS, understanding the impacts of these systems is essential.

Expected benefits and core promises

The integration of CPS into society promises many benefits, including increasing the efficiency and sustainability of many of our current practices, and creating new markets and growth.

These promises include:

- automated cars that enhance traffic flow, reduce pollution and allow drivers to work or relax while in transit;
- mass-customisation of products that closely match consumers' preferences and reduce waste during production;
- telecare alarm systems and CPS treatment tools that help to care for sick and elderly people while enabling them to live with more independence;
- smart technological aids for disabled citizens that enable them to become more active members of society;
- CPS in agriculture that reduces the need for pesticides, prevents food waste, and optimises food production, all the while reducing water and energy footprints;
- drones and search-and-rescue robots that perform missions in hazardous environments, thereby reducing the risk for the operating personnel.

Unintended impacts and policy implications

While many potential benefits of CPS systems raise high expectations, past experience has taught that the effects of newly introduced technologies can never be completely predicted. There are always unintended effects, some of which are good, some bad, and others that are never truly realised.

One such unintended consequence may be that 3D printing changes consumer habits, making production so easily obtained that we start producing more, and become less attached to our goods. As a result, maybe we become more inclined to discard goods, and thus generate more waste.

We need to think ahead and avoid such possible unintended consequences while ensuring that these technologies can benefit everyone.

Employment and delegation of tasks

As we delegate more tasks to CPS, old jobs will be lost while new ones are created, such as repairing robots, and mediating between robots and humans. In these circumstances, will humans leave routine decisions to robots to remain focused on tasks that demand creative thinking and decision-making? If so, will we be able to integrate our knowledge with data from these systems? Is it desirable to delegate meaningful tasks to robots when robots can do these tasks better than humans, or at least as well as them? Such as taking care of our loved ones: If robots perform these tasks, would we lose a certain degree of meaning in our lives? Do we want to live our lives without experiencing the satisfaction deriving from the altruism of unconditionally helping others? These are the sort of possible effects we need to keep in mind.

Safety, responsibility and liability

Safety aspects, i.e., finding ways for robots and humans to work together without accidents, should be one of our primary concerns. This is especially important as robots increasingly operate in close proximity to humans.

CPS systems are large and complex, intelligent and self-learning. But who should be held responsible when the system fails? Moreover, finding the initial cause and attributing liability will prove very difficult. Who can we hold accountable should these systems malfunction?

In healthcare, is it the doctor, caregiver or patient who is responsible for failure? Or is it the developer or producer of the CPS?

As factories, energy grids and transport systems become digital networks, how can we prevent outsiders from hacking and infiltrating these systems for nefarious purposes?

Privacy concerns

CPS require vast amounts of data to operate effectively, and this poses several privacy questions. For instance, in order to optimise energy usage, smart home systems might want to keep track of the times residents are away, which is also valuable information for burglars. Or will robots be spying on the working habits of their human co-workers, maybe even manipulating them to work harder? Should the code of conduct on medical professional secrecy be reviewed, concerning the health data stored on connected parts of medico-technical systems—data that third parties can also access?

Collecting data on a person's lifestyle and physical parameters can definitely improve their health, but as we proceed, should we discuss how to prevent others from taking advantage of the data shared on medico-technical systems?

Social relations

CPS will influence our relations with machines, and might even lead to new controversies: Should robots acquire some form of moral sense if they are to interact with us in our comfort zone? And as we humanise the robot, how will this affect our self-understanding? And what if robots one day become emotionally — or even affectionately — involved with humans, how should this be managed?

Also, with CPS we can build smart prostheses for the disabled. At what point will they turn into cyborgs, possibly even exceeding human abilities? And how will we define 'disabled' or 'able-bodied' in the future?

Conclusion

Exploring the future effects of CPS shows that it could have considerable impacts on various areas in our personal and professional lives. The deployment of interconnected autonomous working machines in complicated data environments involves a number of legal areas, such as responsibility, liability, data ownership and privacy. Designing CPS for operation in proximity to humans means that current safety regulations need to be updated to ensure that individuals are not harmed and that the desired benefits outweigh the potential unintended consequences.

2 Technical Horizon Scanning of CPS

Introduction

The following sections summarise the briefing papers prepared in the first phase of the study, a 'technical horizon scan' of seven domains of CPS, including short- and longer-term trends and their societal impacts. The full briefing papers can be found in Annex I of this report. The briefing papers deal with the following domains:

1. Disabled people and daily life of elderly people
2. Healthcare
3. Agriculture and food supply
4. Manufacturing
5. Energy and critical infrastructures
6. Logistics and transport
7. Security and safety

In each case, the summaries highlight key technical developments, short- and long-term trends, and reflections upon the most important social, technological, environmental, economic, political, ethical and demographic impacts identified (STEEPED – see Figure 3.1).

Figure 3.1 STEEPED Scheme for reflection on possible impact during Horizon Scan[4]

[4] 'STEEPED' checklist: social, technological, environmental, economic, political, ethical and demographic aspects.

2.1 CPS for disabled people and daily life of elderly people

Summary of the technical briefing paper written by Professor Adriana Tapus (ENSTA-ParisTech, FR) and Chiel Scholten, MSc (Technopolis Group, NL)

CPS for the disabled and elderly include homes equipped with sensors (Smart Homes), wearable sensors and robotics. The adoption of these technologies will result in major benefits for the disabled and the elderly, including better patient care and better health results, leading to increased life expectancy, and shifting medical emphasis from treatment to prevention.

In the **short term** we will see an increase in the use of sensors to provide medical professionals with real-time data on their patients through smart homes and smaller or wearable CPS devices. Additionally robots with specialised tasks will make their entry.

- The expected impact on **patient care** is the increased effectiveness of treatment as the increased data flows to medical professionals will facilitate prevention and treatment via the use of data mining tools providing better diagnosis and better insights into treatment, care and rehabilitation options.

The **long-term trends** points to the prospects of more powerful and capable CPS becoming ubiquitous in patient care with growing levels of autonomy. The increased autonomy of CPS systems will eventually stand in contrast to the reduced autonomy of disabled or elderly people. Under what conditions should we allow CPS systems to take decisions on behalf of its patients? Furthermore, the increased use of sensors and robotics will allow greater levels of data sharing between robots and medical professionals.

- The resulting impact on **patient care** will be profound as the medical profession will be able to shift its focus from treatment to prevention through the increased use of CPS and increased data flows.
- By 2050, the population of adults over the age of 85 is expected to triple as a result of **increased life expectancy**. The combined effects of lower birth rates and longer life expectancy will result in **a fundamentally different balance between generations within our societies**.

Impacts will include:

- The data collected by CPS units could lead to **infringements of privacy** as increased autonomy of CPS will move decisions on personal information away from the patient and towards the CPS units.
- **Jobs will change** as CPS units will augment the number of, not replace, medical professionals. The increase in demand for CPS units will **create many highly skilled jobs** and the demand for smart homes both for new construction and renovation will result in **further economic growth**.
- Greater use of CPS will **result in environmental pressures** through an overall increase in the demand for power and greater need for rare and precious materials.
- As CPS units become more autonomous, making decisions for themselves, we may find **legal issues of responsibility.**
- **The ageing society** with a larger number of old people and lower number of young people will further drive up demand for CPS for patient care.

Key issues:

- **Medical professional secrecy and data**: CPS share private patient data with other systems, medical professionals, caregivers and the disabled individual. Who owns the data? Can and should the data gathered in this way be used to develop better medical treatments for other patients with similar medical conditions? Will CPS systems go as far as gathering data that will not enable the condition of the patients at hand to be improved, but will benefit other patients exclusively? Could increased data sharing cause the patient to lose trust in medical professionals?
- **Robotic autonomy**: CPS developments will increase the capability of robots to act independently. When should a robot make a medical decision on behalf of the patient? Should a robot act paternalistically towards the patient, or allow the patient to make life choices that might lead to negative health outcomes? When should the CPS notify the appropriate medical personnel? Should the robot be able to override the wishes of the patient? Would this decrease trust in CPS, lowering the number of positive patient outcomes?
- **Legal responsibility**: When CPS makes a decision, where does legal responsibility lie? If a decision is made via a combination of CPS, medical professionals and the patient, who bears responsibility, and should the responsibility be shared or assigned to one individual? Should the manufacturer of the CPS bear responsibility, what about the software programmer?
- **Technological acceptance:** CPS will change the relationship between the patient and the caregiver. Will patients want to be taken care of by CPS? Will this affect the level of trust with the patient?

Conclusion:

As the development and implementation of CPS in healthcare for the disabled and the elderly continues, we will continue to see greater amounts of data collection, and a shift in the focus of medicine from treatment to prevention. This shift will help relieve the burden on medical professionals, allowing for more time to focus on patient care, and lowering the cost of medicine. These changes will require a discussion on privacy and data ownership, legal responsibility and the appropriate level of robotic autonomy.

2.2 CPS in healthcare

Summary of the technical briefing paper written by Professor Bram Vanderborght (Vrije Universiteit Brussel, B) and Chiel Scholten, Msc (Technopolis Group, NL)

CPS are quickly becoming an integral part of modern healthcare with profound changes in patient treatment, care and outcomes.

In the **short term** we will see CPS in the form of smart devices and alarms providing medical professionals with more accurate real-time information, in addition, we will see an increased use of robots in surgery and human enhancement.

- The expected impact on patient care is increased accuracy of real-time medical data leading to fewer false alarms and quicker recovery times. We will also see a decrease in recovery times as robots become smarter and support surgical procedures, resulting in fewer medical errors and more positive patient outcomes.

In the **long term** we will see major advances in CPS and artificial intelligence that will allow for real-time, rapid machine learning, resulting in an increase in robotic automation. In addition we will see the miniaturisation of robots to the micro and nano-scale.

- The increased autonomy of CPS systems will have a fundamental impact on patient care. Since the diagnostic process is highly structured, CPS will increasingly make these decisions and suggest evidence-based treatment, potentially outperforming doctors.

Impacts will include:

- Increased use of CPS will result in a **healthier society** as procedures become less invasive, leading to a **quicker recovery times**, and **reducing health-related absenteeism**.
- Medical CPS is a **growing market**. Its impact on jobs in the medical field is expected to be significant; however, CPS is expected to be mainly **complementary to existing jobs**.
- Increased use of CPS will **result in environmental pressures** through an overall **increase in the demand for power** and the **increased need for rare and precious materials**.
- Medical CPS will necessitate the need to **reconsider laws on patient privacy and medical professional secrecy** to find an appropriate **balance between patient privacy and medical prevention**.
- **Certification and approval procedures** will need to be adapted to accommodate medical CPS, and **incremental certification should be introduced**.

Key issues:

- A discussion is needed as to the ethics of improving healthcare outcomes at the expense of **patient privacy and medical professional secrecy**. In addition, possible inequalities in access to medical data and improved prevention strategies will pose ethical questions.
- A further discussion that needs to be addressed is whether patients will welcome CPS that partly replace **patient-doctor care relationships** with **patient-machine relationships**.
- **Medical professional secrecy and data**: CPS share private patient data with other systems, medical professionals, caregivers and the disabled individual. Who owns the data?
- **Legal responsibility**: CPS will advance to make their own decisions. When CPS make a medical decision, who will be responsible in the event of failure? If a decision is made via a combination of CPS, medical professionals and the patient, who will bear liability, and how should the responsibility potentially be shared or assigned between individuals? What sort of responsibility should the manufacturer of the CPS bear, what about the software programmer or provider?

Conclusion:

CPS will bring about major changes in the healthcare sector. With the increase of more autonomous CPS, we will see major benefits in the form of healthier societies, fewer medical mistakes and more accurate medical decisions. These changes will necessitate clarifications of a number of issues relating to patient privacy, medical professional secrecy, data ownership and patient acceptance of CPS.

2.3 CPS for agriculture and food supply

Summary of the technical briefing paper written by Professor Eldert J. van Henten (Wageningen University, NL) and Dr Christien Enzing (Technopolis Group, NL)

CPS are changing the face of agriculture. The development of these technologies is expected to have both long and short-term implications.

In the **short term**, food production will increasingly use sensors to scan for disease, assess the freshness of a product and, ultimately, improve food safety. The use of autonomous machines in food processing will also assist in hygiene in this industry. Drones, sensors and other farming machines will be used to gather the data necessary for precision farming.

In the **long term**, it is expected that crop establishment, scouting and care and selective harvesting through the use of autonomous machines will be possible. We will also see advancements in pattern recognition and artificial intelligence for the interpretation of the data and decision-making. Smart food labels will be able to communicate with the whole production chain giving us a better understanding of where our food comes from.

Impacts will include:

- CPS will have a **positive impact on the environment** through the reduced size of machinery (which can damage soil structure) and reduced use of fertilisers, energy and water. CPS enables effective **precision farming** which can use resources more efficiently and reduce waste.
- The introduction of CPS into agriculture and food production will bring about **a loss in the number of jobs as technologies replace human workers**. However the robots will need highly skilled robot engineers to operate them. Additional high-skilled jobs will arise in the industries developing autonomous agricultural machines.
- These new technologies might attract more **young people into this field**, as an automated farm may enable farmers to do their job remotely and therefore be more compatible with more urban life styles, and providing more free time for engaging in tasks outside of the farm. These technologies may also influence daily quality of life. They will also take over unhealthy, heavy or dangerous work, making this a safer industry.
- With the introduction of the **Internet of Things,** we may see in food production the development of **packaging that can communicate** with other devices such as fridges, and conveniently alert the supermarket when something needs to be replaced. At the same time, this raises ethical concerns as to whether this is will **infringe upon our privacy**.

Key issues:

- The main question will be **who is responsible for these technologies**. For example if autonomous machines end up causing harm to plants, animals or humans, where will the responsibility lie? This also ties in with the issue of safety.
- We will also need to see whether or not modifications to the environment are needed to safely introduce robots into agriculture. This has been seen in industry where autonomous machines and often separated from humans.
- If robots continue to replace the work of the farmers, e.g. as machines have replaced farmers in milking, **what will happen to the relationship between farmers and their animals**?
- Will these technologies improve the working lives of farmers? Will they actually attract younger generations back into this sector? How can we make it a more inviting area to work in?

Conclusion:

CPS will result in greater food safety and hygiene. The introduction of the Internet of Things, and the increased use of autonomous robots and sensors will improve working conditions, optimise harvests and increase production. These changes will require discussions on liability, the relationship between farmers and machines, and on young people employed in this industry.

2.4 CPS for manufacturing

Summary of the technical briefing paper written by Professor Fred van Houten (University of Twente, NL) and Chiel Scholten, MSc (Technopolis Group, NL)

CPS will fundamentally change the manufacturing sector. The use of CPS in manufacturing is commonly referred to as the fourth Industrial Revolution, or Industry 4.0.

In the **short term**, we will see three main drivers further promoting the introduction of CPS in manufacturing processes: **the continuous miniaturisation of actuators and sensors** driven by developments in nanotechnology, the **constant reduction in prices of sensors and actuators**, and **the introduction of the IPv6 internet protocol** in 2012.

In the **long term**, CPS will change the manufacturing process as **products become customised**, through the development of **smart factories**, which will be organised in networks of companies, each specialising in a specific manufacturing capability.

Impacts will include:

- CPS will contribute to **the individualisation of modern society** by giving consumers a greater role in the design of products and their production processes (end-to-end engineering).
- **The labour market will profoundly change as the share of high-skilled jobs will greatly increase**. While it is **hard to quantify the net effect of CPS in manufacturing**, some have estimated a **value-added potential of €1.25 trillion** for Europe in 2025. Previous industrial revolutions have greatly increased both jobs and wealth.
- CPS will **radically change the business model for manufacturing**, as integrated networks of companies will appear, with each company specialising in its core competencies while the rest of the manufacturing process will be outsourced to other companies within the network.
- As a result of product customisation and industry specialisation, **data will become a key competitive asset**.
- As customisation and additive manufacturing replaces subtractive manufacturing, **resources will be conserved**; CPS however are expected to result in an **overall net increase in power consumption**.
- CPS will result in more **flexible career paths, less physically demanding work, resulting in healthier workers, increased life span, and an increase in worker productivity at older ages.**

Key issues:

- **Safety standards and certification** of products need to be considered in the context of increased customisation. If a product doesn't comply with safety standards, who is liable, the manufacturer or the designer?
- **Data ownership**, who will own the designs of products that are custom designed by the customer?
- With customised design, **how can governments prevent individuals from creating harmful, dangerous or illegal products**? Who in the production chain would be liable if one was manufactured?
- With CPS enabling the creation of unique, customer designed products, **will our conception of uniqueness change**? Should smart factories be **legally bound to some ethical principles** in the customisation and individualisation of products?

- **Privacy will become a critical issue** with the rollout of CPS. Large amounts of data will be gathered at all stages of the manufacturing process. How will the data gathered be protected? What data should companies be allowed to capture on customers and employees?

Conclusion:

As CPS continue to be developed and deployed in manufacturing, with smart factories, we will see a radical change in the way manufacturing occurs primarily through new business models and the customisation of products. The changes will have profound implications for the economy, therefore legal issues concerning data ownership, privacy, certification and safety will need to be addressed.

2.5 CPS for energy and critical infrastructure

Summary of the technical briefing paper written by Dr Stamatis Karnouskos (SAP, Karlsruhe, DE) and Joost van Barneveld, MSc (Technopolis Group, NL)

CPS will create profound changes in both energy and the infrastructure systems that control the flow of electricity from producer to consumer. The changes will result in the creation of energy prosumers, individuals who both produce and consume energy, and the development of smart grids to accommodate the increasing decentralisation of energy.

CPS technology in the **short term** will imply the increased use of smart technologies, which will change the traditional, linear energy grid, into a **smart grid** through the **'Internet of Energy'**. Smart grids will give both producers and consumers more information about their energy use, allowing grid management to be optimised.

In the **long term**, we will see CPS technologies result in greater and more profound changes in the energy system, and the infrastructure system underpinning it. Automation will be a key feature of future energy systems, achieved through the **global Internet of Energy**. Communities of prosumers will emerge, creating **virtual power plants (VPP)**.

Impacts will include:

- CPS energy systems will enable the empowering of communities to allow them to **create self-sustaining communities**.
- CPS energy systems may lead to a **digital divide** between those who have the technical abilities and the financial resources to implement them and those who do not.
- Smart grids should **reduce economic inefficiencies and resource waste** in current energy grids; however these developments will not necessarily result in a net economic return.
- Smart grids **will allow for major environmental benefits** as they will allow energy consumers to monitor their energy consumption in real time, allow for the rapid implementation of renewables, especially at the individual level, and allow for a reduction in power losses from power transmission and distribution.
- CPS will result in **far more information about consumers being collected**, potentially intruding upon the privacy of individuals and communities.
- CPS for energy systems will provide the infrastructure and **ability for remote communities to provide for their own energy needs** allowing the movement of people from mega cities to more rural communities.

Key issues:

- The **question of liability** is a key issue that must be addressed at the political and legal level in order for CPS energy systems to reach their full potential. In a system with multiple stakeholders and decisions being made by artificial intelligence, it will be important to identify who is responsible – and liable – for failures.

- With increasing amounts of data being collected, **ethical questions emerge regarding what the data is used for, what level of detail of data is allowed to be collected, and who is allowed to use it.**
- Automated actors will be increasingly connected to the grid, which raises **political and legal issues concerning reliability**. What incentives will be put in place for individual actors to contribute to improved grid stability?

Conclusion:

CPS will become a key component of future energy systems, and the critical infrastructure underpinning the energy grid. However it is important to discuss the areas of liability, data collection and ownership of that data to ensure that the rollout of the new energy systems can achieve positive benefits while mitigating and potentially eliminating the negative side effects.

2.6 CPS for logistics and transport

Summary of the technical briefing paper written by Professor Haydn Thompson (Haydn Consulting Ltd, UK) and Dr Christien Enzing (Technopolis Group, NL)

CPS are expected to revolutionise logistics and transport systems sectors across Europe, with profound implications for safety, emissions and overall efficiency in the transportation of goods and people.

In the **short term**, we will see the continued automation of automobiles. Current manufacturers are introducing **Advanced Driver Assistance Systems (ADAS)**, which help to make a car 'smarter' through automated assistance for the driver. Logistics will fundamentally change as robotic technologies are deployed to solve last-kilometre problems (traffic congestion and lack of loading and unloading areas in urban areas), while automation for **storage and retrieval systems** in warehouses will further increase, with the first autonomous robotic material handling systems currently being built.

In the **long term**, we will see the **deployment of fleets of fully autonomous vehicles** in both logistics and transportation sectors. Warehouses and shipping centres will automate their storage and retrieval systems, while also automating the handling and manipulation of goods.

Impacts will include:

- CPS will have a **major impact on the daily lives of Europeans**; road safety will increase as a result of automation, however the trust in, and the integrity of, the system is paramount in order to achieve this.
- The implementation of autonomous and robotic technologies will bring **a key competitive advantage to Europe**; although the implementation of CPS will alter and disrupt current business models, it will allow for completely new types of service to exist.
- The adoption of CPS in transportation and logistics will result in an **overall reduction in emissions**; in addition CPS will optimise efficiency in transportation resulting in greater savings in fuel consumption.
- The implementation of autonomous vehicles **will remove some of the insurance barriers for younger drivers**, and make driving more attractive for families as a result of increased road safety. Additionally, the same advancements in road safety and automation will allow the ageing population to continue to safely enjoy the mobility provided by vehicles.

Key issues:

- **Regulatory policies will need to be implemented in a stepwise fashion**. As early regulatory action carries risks, some level of regulatory flexibility will be necessary in order to achieve the rollout of autonomous vehicles.
- **Non-uniformity in laws** across Europe as regards data obtained by infrastructure will need to be addressed.
- The **issue of responsibility** with autonomous vehicles is a key issue that needs to be addressed, including **legal liability** if an autonomous vehicle is involved in an accident.
- The **ethical issue of privacy** is a very important issue that needs to be discussed, as CPS will collect large amounts of data on individuals, while the legal provisions for using that data vary across Europe; for example, technology may not be used for tracking cars in Germany, while this is allowed in France.

Conclusion:

CPS are already changing the transport and logistics sector. In the future, these changes will profoundly impact the way we move both goods and people with major impacts on safety, emissions, and the mobility of older citizens. The introduction of CPS will require appropriately timed regulatory measures, standardisation of laws, and clarification of liability and privacy aspects.

2.7 CPS for security and safety

Summary of the technical briefing paper written by Professor Michael Henshaw (Loughborough University, UK) and Joost van Barneveld (Technopolis Group, NL)

The increasing numbers of CPS in this area will undoubtedly have an impact on the security and safety of individuals, both in the short and long term.

In the **short term** we can see that CPS will bring about new challenges for safety and security. Security could be compromised by hackers or criminals that exploit vulnerabilities in order to corrupt operating systems. Safety issues could emerge through the inability to predict the behaviour of machines, affecting our ability to interact safely with them. Disaster relief is likely to improve with the development of CPS which will **increase the safety of relief workers** and the individuals they help.

In the **long term,** potential **vulnerabilities will be reduced** through the development of quantum 2.0 technologies. The use of CPS will allow better collection of data on potentially dangerous individuals. The misinterpretation of signals from CPS by humans will still remain a **safety issue**.

Impacts will include:

- CPS will monitor borders **to reduce the number of illegal immigrants** and thereby have an impact on demographic developments.
- CPS allow the **gathering large amounts of personal data** on individuals for security surveillance purposes. Increasingly, **continuous monitoring** is also an ethical issue and may change the way individuals behave.
- The further implementation of **CPS will lead to a loss of jobs**, e.g. as standard taxis are replaced with driverless cabs.
- We will also see widespread use of CPS to assist the elderly, which will enable them to carry out a wider range of tasks for longer, giving them the ability to work and **contribute to society and work for longer**.

- CPS can potentially **improve the management of power and materials and help preserve the environment**. This can be seen in systems automatically switching off when not in use. This can lead to lower consumption of energy of certain systems. In other cases, CPS might be used fraudulently to defeat test procedures designed to enforce environmental standards. This will pose a challenge to legislators to ascertain that tests are not rendered inefficient by CPS.
- There is a general issue about the creation of robots functioning autonomously without ethical and operational constraints. **The lack of ethical behaviours could lead to breaches in both security** (e.g. drones used to collect private data) **and safety** (e.g. robot soldiers mistaking civilians for military personnel). We should ensure that the human choice in their usage is both ethical and falls within a legal framework of safe usage.

Key issues:

- Should manufacturers or operators be held accountable for the malfunctions of autonomous technologies, e.g. a driverless car that causes an accident? As these issues arise and become more commonplace adequate legislation will need to be put into place. With large amounts of data being collected, which in the short term may be susceptible to cyber-attacks, the need to seek **improved data protection laws** is growing. This also raises the question of who is responsible for ensuring that the data collected is being kept safe: Is it the individual, the organisation collecting the data or the political institution?
- How will we accommodate for the large number of **jobs that are potentially going to be lost**? What will be the implications when other regions of the world such as China similarly begin to reduce the number of staff?

Conclusion:

CPS might in certain ways contribute to making the world a safer and more secure place. Yet, at the same time, it will create a more complex world in which we will need to improve the way we predict and understand machines and their effect on security and safety. We need to ensure that those coming into contact with these new technologies – whether bystanders or operators – are able to understand the risks to their safety and security. These changes will require discussions on liability, data protection and the impact CPS will have on employment.

3 Assessment of possible future concerns regarding CPS

3.1 Introduction

The results of the Technical Horizon Scanning presented in the previous chapter were subsequently used to identify possible 'soft impacts' of future CPS technology, and to develop scenarios that will enable the identification of **societal concerns** relating to the future use of CPS. The scenarios are presented in detail in Annex 2. Further background information on the concept of 'soft impacts' can be found in Annex 3, together with a description of how this concept guided the development of the scenarios in the context of the 'envisioning workshops'.

In this chapter, we present the main concerns that were identified as part of the envisioning exercise, and that should be brought to the attention of Members of the European Parliament. The subsequent chapter then presents - in the form of a briefing paper - the legal instruments that may need to be modified or reviewed as the use of CPS expands across our societies.

3.2 Outcomes of the 'envisioning stage' of the scientific foresight project

Here, we present a limited set of relevant findings, concentrating upon those that recurred across many CPS, rather than those that are very specific to a given application area. Some of these were foreseeable, while others were quite novel.

Unsurprising outcomes

Some concerns such as privacy/data protection and (un)employment frequently emerge when discussing data-intensive, ubiquitous technological systems like CPS that are meant to take over some of the tasks currently performed by human workers. These appeared repeatedly in the study.

Thought-provoking outcomes

Several thought-provoking ideas suggested how CPS development may destabilise the current meanings of the normative concepts that guide our practices, policies and laws. Some of these included:

- **Human**: when collaborating and living together with robots that are increasingly intelligent and, perhaps, more morally aware, the question of what makes humans truly human becomes unavoidable. Especially if artificial intelligence (AI) develops substantially, it is to be expected that the answers to questions of human identity will co-evolve with CPS technology.
- **Body**: as we start incorporating more and more smart technologies, the question of where the body ends will become increasingly important, and unanswerable in simple a priori terms. For example, is a prosthesis part of the body, or is it a device separate from the body? It will become increasingly impossible to define the body in a 'naturalistic' way. This question has deep ramifications, for example, concerning ideas about self-determination, physical integrity, and property rights.
- **Dis/abled:** connected to the previous issue, our conceptions of what it means to be able or disabled, will prove to be relative to our increasingly technological environment. Assuming a future of widespread human enhancement, what we consider to be able now may be considered dis-abled tomorrow.
- **Nature**: Underlying the previous instances of meaning-destabilisation, is the idea that normative conceptions of 'nature' will be constantly challenged, to an even greater extent than

the case that is today. However, also in the domain of agriculture, prevailing conceptions of nature as organic and interdependent may, under the influence of 'precision farming', give way to more reductionist, molecular conceptions of 'nature'.

- **Food**: Examples of destabilised meaning are found in the current discussion about what constitutes 'organic' in relation to food. Currently, the concept only denotes that farming should be devoid of chemicals. But is organic farming compatible with the use of agricultural robots? Opinions differ already.
- **Farming/Farmer**: Currently, farmers are typically close (emotional) in distance to the land they are farming. However, CPS may enable long-distance farming, which would allow the farmer to live most of the time in a city environment. Also, farming will be increasingly high-tech. Due to these changes, popular images of farmers/farming are bound to change, which could make it more or less attractive for young people.
- **Security**: Currently, this value is most often applied to questions regarding physical health and safety, and to a lesser extent to employment and finances. With CPS and the Internet of Things, data streams become ubiquitous, making all domains of life a possible candidate for security risks. As a possible consequence, it is foreseen that debates will occur about how much security in which domain it is reasonable to expect or claim, and what is seen as (ir)responsible behaviour.
- **Public-private:** Where the border is drawn between these two domains is of utmost relevance to policy-making. However, CPS technology is bound to bring these borders constantly into question, because it shifts responsibility from the collective to the individual and back again. For example: is human enhancement a private or a public responsibility?

These examples illustrate how entrenched meanings may be challenged by technological developments in the domain of CPS, raising subsequent questions about how to act.

More novel outcomes

There are a number of examples where CPS may invite novel behaviour more directly, e.g.:

- If something gets easier, more people do it. An example of this mechanism would be drones, or military robots. If you are the only one to have them, that gives you a competitive edge. However, other parties are bound to acquire the technology too, and then what seemed 'smart for one' may become 'dumb for all'.
- If something gets cheaper, more people buy & use it. If we make energy cheaper through the use of CPS, this may well lead to a net increase in energy use, with for example devastating effects for global warming. Or, more in the domain of soft impacts: maybe scarcity is a good thing? If energy is cheap and clean, do we still need to be conscientious about using it? Are there other positive practices that we have developed in light of scarcity?

Illustrative examples

Care robots promise us more quality time with our loved ones by taking over the hard and dirty work. However, it was also imagined how such care robots can perversely lead to less caring, e.g. because caring is partly done by doing the hard and dirty work for one's loved ones, or because care becomes so un-demanding that we delegate it all to the robots. Caregiving can be a very meaningful practice for family members / friends. No longer having to do it can lead to a loss of identity. A more general instance of this mechanism is the following: many CPS promise to do their beneficial work quietly and unseen in the background. Think of a smart energy grid. However, will this not lead to a form of disengagement between us and the world? Will these black-boxed technologies not take so many things out of our hands – and control – that we will be left impoverished?

This last example brings us to a special category of concerns dealing with us delegating tasks, skills, and responsibilities to CPS. Of course, because CPS perform some of our tasks, learn some of our skills, and take over some of our responsibilities, they set us free for (presumably) more worthwhile endeavours. However, there are also concerns about this delegation, which are taken up in the exploratory scenarios for the next phase, as well as other soft impacts and concerns, which are described in further detail later in this report.

Some considerations

A final reflection worth making here is on legislation and soft impacts. By definition soft impacts are hard to legislate for as they usually are morally ambiguous and produced by a heterogeneous network of human and non-human influences, which makes it difficult to hold particular parties accountable. Also, as soft impacts are difficult to quantify, it often remains a matter of contention whether they in fact occurred.

That being said, it is also true that soft impacts/soft concerns to a large degree determine whether and how a technology is societally embedded. So, legislation and policy do have a role to play here, but adequate measures are in all likelihood often found in the domain of soft law, soft governance, education, information campaigns, raising of awareness, etc. One more concrete measure is the counterbalancing of negative incentives by new CPS. For example, if we know from experience that lowering the price of a product tends to invite increased consumption, then this can be countered by using taxes to compensate for decreasing costs thanks to more efficient technologies.

3.3 More specific concerns arising from the four scenarios developed

The four scenarios have been developed to help understand the possible social, ethical and social tensions that could arise in connection with CPS systems. The scenario reports, which are included in Annex 2, focus on our specific contexts:

1. CPS for health and for people with a disability
2. CPS in farming
3. CPS in manufacturing & for transport and logistics
4. CPS for energy and critical infrastructures and for community security and safety

While the scenarios are speculative and ultimately fictional, they have been based upon substantial research and analysis. Every detail of the scenarios presented – from the habits, hopes, fears and values of the characters to the social, legal and ethical tensions evident in their lives – has been carefully chosen to highlight a particular way in which technological development might affect society in the longer term perspective. The scenarios do not aim to predict the future, but to provide an accessible means for the reader to understand the social, ethical and legal tensions that were identified in the foresight process. They were designed to help the policy makers explore, anticipate and respond to potential CPS development paths and their associated impacts, and to aid reflection on anticipatory policy and agenda setting at the European Parliament.

The extent to which our society will resemble these scenarios depends upon various factors, some of which are outside what is possible to anticipate or control, but some of which remain in the hands of the reader – be they a policymaker, technology developer or citizen.

The aim of the developed scenarios is specifically to provoke further reflection about issues that might already need to be addressed at an early stage. The scenarios were thus presented to the participants of a workshop, where they led to the identification of the following issues and concerns:

Scenario 1: CPS in the domain of health and disability

Feedback provided by the workshop participants: comments and questions

- The automatic collection of data by robots and sensors offers great promise, but people might react by manipulating them to create the impression of a better or worse health condition.
- We need to detach ourselves from thinking in terms of traditional gender roles when designing scenarios for the future of the healthcare sector.
- Will we be surrounded by external carebots, or rely more on less visible, implanted robots?
- What will be the price of the new CPS-based services, and who will be able to afford these services; will the increasing reliance on sophisticated robots turn the medical professions into lower paid service personnel, or lead to even higher specialist job profiles?
- Will insurance companies be able to effectively prescribe to patients what robots they will have to use, and be able to punish patients that turn off their robots by increasing the insurance premiums?
- Social media might play a central role in a future CPS-dominated healthcare sector. But will elderly people continue using social media when they grow older, and will the next generation develop different social media preferences?
- Who will have access to the data? Will the patient have access to his or her own data and be able to self-manage it? What balance will we find between the public interest in reliable community health data, versus individual concerns for privacy?
- How will the emergence of authoritative AI information systems change the current distribution of authority between doctors and patients? In the future, we might absorb information though augmented reality systems rather than from traditional screen displays.
- What rights should children have in claiming access to parents' data?
- How will we make different data-privacy regimes in different Member States work in harmony in an increasingly interconnected world?
- In the age of cloud computing, will we still be able to decide which data will remain with doctor or patient?
- Who owns cloud-data? What uses will governments or health insurance systems be allowed to make of the data they have paid for? What will companies like Google be allowed to do with all these data?
- Will patients still have the possibility to opt out of certain programmes – or will governments investing in keeping people healthy be able to prescribe compulsory measures? Or will it be left to insurance companies to hold patients liable? How can we ensure sufficient levels of anonymisation as diagnostics and treatment become more and more personalised?
- Individualised drugs hold promises but might in the end be so expensive that they will only benefit the few.
- Medical mishaps could occur because a CPS algorithm made a mistake. What sort of tasks will we allow to be delegated to robots?

- To what degree will a patient be allowed access to family data in order to refine his or her personal diagnostic and treatment options?
- What will be the role of algorithms operating largely independently in analysing the data they find in the cloud?
- What policy measures do we need to help avoiding monopolies in the data sphere?
- Health service is becoming a business – what place will there be for 'new' business models?
- What rights will employers have to track employees' medical data and life styles, including the use of medical detectives?
- Scarcity of resources – what choices will we be faced with?
- Policy-framework for health insurance – what will be the implication of these developments for the way health insurers operate?
- Changing authority of doctors – how will this impact their self-image and their relationship with patients?
- With new technological developments, people will increasingly start self-monitoring. How will they find the right balance between self-diagnosis and reliance on professionals?

First reflections on relevant policy areas towards the next phase:

- Who in the future will issue the necessary certificates for sick leave? Doctors or CPS systems?
- Who is responsible for the reliable operation of a lab-on-a-chip?
- Question of expertise: who is the highest authority? In cases of divergent opinions between doctors and robots, how do we decide whom to trust?

Scenario 2: CPS and farming

Feedback provided by the workshop participants: comments and questions

- Will there be enough food for everyone? Will we need less pesticide to produce our food, thanks to micro farming (precision farming)?
- One could imagine that certain technologies could be embedded in the animal to steer its behaviour – such as cyborg-cows. Can *theranostics* be used to steer the animals back to their stable as soon as the system detects a need for their farmer's intervention?
- Fences around farmland go against current consensus in Europe. Aesthetics of countryside are an important part of why we pay for agriculture. In Europe, people want to retain the open fields. How to reconcile recreational and productive nature? How much will agricultural activity in the future be driven by the desire to beautify landscapes?
- Food might increasingly be produced in factories, e.g., using insects, transforming organic waste, recycling other biomaterials. Rather than growing food in a field, food might increasingly be printed in factories using basic biomaterials as ingredients. (Such factories might even operate in underground spaces). In the future, will normal food be 3D-printed, or engineered, while only luxury food will still be grown in fields?
- What is the robustness of the system through seasons? CPS systems need to be weatherproof, cope with varying weather conditions.
- Financial aspects of farming while market prices fluctuate: Will CPS be able to help farmers obtain better market prices?
- Will there be continued justification in the future for giving out subsidies? Today we give subsidies because farmers also take care of nature. If you increase the efficiency of production,

will farmers still need subsidies? How will we make sure in the future that farmers get a fair income?

- Will we use precision farming to increase production and fight world hunger, or will we rather aim at improving the quality of food for customers who can afford to pay for higher quality products?

First reflections on relevant policy areas towards the next phase:

- Animal welfare and animal rights issues might need to be revisited to take account of increasing reliance on CPS systems.
- Access to food as a basic right – how will CPS systems help provide food for the underprivileged?
- Subsidies to agriculture (38% of EU budget) – how will CPS systems impact on the need for agricultural subsidies and the way they are allocated?
- Skilling: How will we ensure that future farmers are sufficiently skilled to use all the different CPS systems efficiently? What other new professions will emerge to support farmers using CPS systems?
- What if robots cause damage to the farm environment, or if robots are damaged during farming?
- How can CPS help farming become more sustainable without relying on subsidies? Will farming activity one day turn into just another business?
- What would be the effects on regional policy? Will we need to adapt CPS policies to regional specificities? Will CPS help reduce disparities between regions, or further accentuate them?

Scenario 3: manufacturing and security

Feedback provided by the workshop participants: comments and questions

- Will robots continue to be considered as mere machines, or will they one day be considered as human beings? Will they develop some sort of emotional intelligence?
- Will robots one day appear to show empathy, without actually feeling it. How will humans deal with robots that manage to generate the appearance of feelings, and how can those be distinguished from true feelings?
- Will robots one day truly be emphatic and emotional? How will they feel, and what does 'feeling' mean? How will we distinguish between robots showing empathy and humans feeling empathy? How much will we project into robots, and how attached will we get to them. How will humans be able to deal with the confusion of their emotions? Will there be a need for policy or regulation in this area?
- As the robots become increasingly person-like, what kind of 'rights' will they eventually acquire?
- If we want robots to share our space with us, this will destabilise our perception of what we our-selves are? What kind of pressure will they exert on humans, and will we manage to exert some sort of pressure on them? What sort of pain will they create, and will certain things make robots feel the equivalent of pain and react to such a feeling?
- As companies increasingly use robots instead of workers, will we somehow tax the work they perform? What impact will they have on labour relations?

- As more and more products will be printed by the customer, what will the place of the manufacturer be? If you can print locally, will we still need factories?
- Not everyone will want to print everything, not every customer will ask for customised products. What will be the place for standardised products in the future?
- Who is the owner of the intellectual rights stemming from customer designed products?
- What will be the role of intellectual property rights as customers increasingly customise products rather than copying them?
- What are the implications in the area of consumer protection, and built-in obsolescence? What kind of entitlements will the purchaser have?
- How much specification by the customer will be allowed? How will we handle cases where customers try to modify specifications beyond what is safe or legal?
- In the past, we purchased products based on physical performance properties covered by warranties. As product properties are based increasingly on the algorithms that drive them, and as such algorithms start to learn or auto-modify themselves, how do we deal with CPS that evolve in an undesirable way?

First reflections on relevant policy areas towards the next phase:

- The right to know that you are working with an artificial being: Will there be a right to know whether one is dealing with a robot or a human being?
- Should there be tax on robots?
- Consumer protection / Objects becoming out of date: How can the purchaser be protected not only against the physical deterioration of a product but also against the risk that its adaptive software algorithms evolve in such a way that they are no longer fit for purpose?
- How will we prevent customers from printing products that are not up to standards, or illegal?
- Who owns the intellectual property associated with the customisation undertaken by customers?

Scenario 4: CPS and energy and security

Feedback provided by the workshop participants: comments and questions

- What about producing your own energy and selling it back to the national grid when you have a surplus? Who is allowed to be an actor in this market? How will we ensure that these actors don't render the grid unstable?
- Advertising will be much more sophisticated than what happens now with targeted adverts. In 2050, advertising will be much more efficient. The new ads will say: the fridge you have now is 10 years old; a newer fridge would be better for you (and calculate exactly how much you'll be saving).
- Energy poverty – will the energy consumer or the tax payer have to shoulder the cost of managing the increasingly complex national grids?
- Insurance issues – when you temporarily use / rent a product, who will ensure that you will be able to operate it safely?
- Will CPS allow customers to buy energy that is, for instance, only from alternative sources? And how can that be verified? What impact will this have on the way energy is being produced?
- What responses will the EU have to develop as CPS systems further facilitate the transport and trade of energy across borders?

First reflections on relevant policy areas towards the next phase:

- How could CPS systems help us reach our sustainability goals
- How will we defend privacy in the face of the increasing use of CPS systems?

4 Legal reflections regarding cyber-physical systems

By Dr Mihalis Kritikos, Legal expert at the Scientific Foresight Unit, European Parliamentary Research Service, European Parliament

Introduction

The overarching purpose of this 'legal backcasting' phase is to provide the Members of the European Parliament with some preliminary legal insights on the basis of the scenarios and trends identified in the previous sections. This step of the foresight process, which will result in special briefings, aims at translating the findings of the foresight phase into legal and regulatory terms so as to pave the way for possible parliamentary reflection and work.

This phase transforms the outcomes from the previous steps into a forward looking instrument for the European Parliament, the parliamentary committees and the Members of the European Parliament.

It consists of the following phases:

1. Identification and analysis of areas of possible future concern regarding CPS that may trigger EU legal interest
2. Identification of those relevant EP committees and intergroups that may have a stake or interest in these areas
3. Identification of those legal instruments that may need to be reviewed, modified or further specified
4. Identification of possible horizontal issues of a legal nature (not committee-specific, wider questions to think about).

The final section of this chapter draws attention to some broader ethical aspects of cyber-physical systems that might have to be discussed and dealt with beyond the purely legislative approach.

Committees concerned

- AGRI Agriculture and Rural Development
- EMPL Employment and Social Affairs
- ENVI Environment, Public Health and Food Safety
- IMCO Internal Market and Consumer Protection
- INTA International Trade
- ITRE Industry, Research and Energy
- JURI Legal Affairs
- LIBE Civil Liberties, Justice and Home Affairs
- TRAN Transport and Tourism

A. Legislative aspects of cyber-physical systems in selected policy areas

1. Cyber-physical systems and transport

Committees concerned: LIBE – Civil Liberties, Justice and Home Affairs
TRAN – Transport and Tourism

Areas of interest or concern and possible issues and challenges

- Privacy, data protection, cyber-security and human dignity issues arising from the growing use of surveillance systems and monitoring procedures in the fields of transport and logistics
- Assessment procedures to ascertain the functionality and safety of automated systems – including standardised test procedures for pilot tests, recording of data, infrastructure requirements, cross-border testing, etc.
- Safety aspects of operating CPS in public spaces, and in particular safety and liability issues of self-driving vehicles and rules governing the testing, licencing and operation of this technology on public roads
- Risk that increased connectivity and integration of vehicles and complex logistics networks may lead to exposure to potential criminal or malicious attacks or misuse, which could result in significant financial loss, gridlock across Europe and, in the worst case scenario, injury and fatalities
- Review of the rules for truck and bus drivers on driving and resting times and digital tachygraphy in the age of increasingly autonomous transport systems

Legal instruments and provisions that might need to be reviewed or updated (indicative list)

EU legislative acts

- Regulation (EC) 561/2006 and Regulation (EEC) 3821/85 regarding driving and resting times and digital tachygraphy (for truck platooning)
- Directive 2014/45/EU on Roadworthiness
- Directive 2010/40/EU on Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport
- Directive 2009/103/EC on motor vehicle insurance
- Directive 2007/46/EC on vehicle approval
- Directive 2006/126/EC on requirements for driving licences
- Directive 2003/59/EC on training and initial qualifications of professional drivers
- Directive 85/374/EEC on product liability

Relevant international legal acts and documents

- United Nations Convention on Road Traffic, 19.9.1949
- United Nations Vienna Convention on Road Traffic, 8.11.1968
- United Nations Economic Commission for Europe (UNECE) acts, in particular:
  - UNECE regulation R13 on braking systems, to take account of automatically commanded braking
  - UNECE regulation R79 on steering equipment for automatically commanded steering functions beyond the threshold of 10 km per hour
- United Nations Economic Commission for Europe (UNECE) – Inland Transport Committee– documents:

- Report of the 68th session of the Working Party on Road Traffic Safety, Geneva, 24-26.3.2014
- Status of the implementation of the Road Map on Intelligent Transport Systems, Geneva, 15.12.2015
- UNECE and automated vehicles – Informal document WP.29-167-04, November 2015

2. Trade of dual-use technology

Committees concerned: INTA – International Trade
ITRE – Industry, Research and Energy
JURI – Legal Affairs

Areas of interest or concern and possible issues and challenges

- How to implement fail-safe cyber security measures in the context of CPS for the protection of European Citizens
- The legal concerns raised by the availability and constantly improving sophistication of CPS for criminal or terrorist purposes
- Asymmetric risks from dual-use, mission creep and misuse of security related research
- Opening up of new vulnerabilities that may be exploited by hackers either to corrupt the operation of systems, or to extract commercial or other sensitive data
- Potential misuse of robotics and artificial intelligence should be considered; need to consider the introduction of additional safeguards (e.g. access restrictions, use of less dangerous substances, training, safe disposal, ethics management, an ethics advisory body)

Legal instruments and provisions that might need to be reviewed or updated (indicative list)

- Council Regulation 428/2009 setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items
- EU explanatory note on the potential misuse of research[5]
- EU guidance note – Research involving dual-use items[6]

3. Civil liberties (data protection, privacy, etc.)

The protection of privacy and of personal data is a major ethical and legal concern in the field of robotics given that CPS extract, collect and share information of a particularly sensitive nature with a wide range of stakeholders, especially in the fields of homecare and health.

Committees concerned: IMCO – Internal Market and Consumer Protection
ITRE – Industry, Research and Energy
JURI – Legal Affairs
LIBE – Civil Liberties, Justice and Home Affairs

Areas of interest or concern and possible issues and challenges

[5] http://ec.europa.eu/research/participants/portal/doc/call/h2020/fct-16-2015/1645168-explanatory_note_on_potential_misuse_of_research_en.pdf

[6] http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/guide_research-dual-use_en.pdf

- Data practices in relation to homecare robots, such as obtaining and ensuring informed consent especially by disabled and/or vulnerable people when using or interacting with service, homecare or healthcare robots
- Ensuring transparency of the process by which domestic robots collect, process, and make use of personal data, including the terms of use of algorithms
- Privacy and integrity risks associated with the emergence of new forms of access to domestic sphere
- Concept of privacy beyond a data protection perspective
- Concept of privacy by design and by default in robotics applications
- Concepts of sensitiveness and vulnerability – the collection of sensitive personal data, especially from vulnerable patients and/or under constant direct observation or surveillance
- Data ownership, control, storage and security issues, especially regarding interconnected robots
- Sharing of private patient information collected by robots with other systems, medical personnel, caregivers and the disabled person and preventing the potential misuse of data
- Division between data processors and data controllers and the terms under which third parties' information is processed
- Data collection during the research, development and testing of CPS
- Accessibility of robots especially for elderly people and people with disabilities
- Possible need for compulsory insurance covering pecuniary and non-pecuniary damages which can be caused by the illicit treatment of personal data

Legal instruments and provisions that might need to be reviewed or updated (indicative list)

- Regulation (EU) 2016/679 of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data
- Directive 2009/136/EC amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services, Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector and Regulation 2006/2004 on cooperation between national authorities responsible for the enforcement of consumer protection laws
- Directive 2002/58/ of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector
- Council Framework Decision 2008/977/JHA of 27 November 2008 on the protection of personal data processed in the framework of police and judicial cooperation in criminal matters

4. Safety (including risk assessment, product safety, etc.)

Committees concerned: **EMPL - Employment and Social Affairs**
ENVI - Environment, Public Health and Food Safety
IMCO - Internal Market and Consumer Protection
ITRE - Industry, Research and Energy
JURI - Legal Affairs

Areas of interest or concern and possible issues and challenges

- The need to address the safety aspects of the operation of CPS, as they will operate in public settings with potential harmful impacts

- The need to introduce multiple safeguards to ensure that the robot itself is safe for users and does not infringe on their right to physical integrity
- Certification and approval of individualised (or custom) products
- Certification (e.g. ISO safety standards)
- Certification amidst increasing complexity and interconnectivity of devices including component upgrades
- The need to build effective verification and certification in at the design stage of CPS
- The need for an overall assessment of the safety and effectiveness of CPS
- The liability of manufacturers and designers should customised products not comply with safety standards
- Feasibility studies and the development of solutions for the safe implementation of planned mobile robot applications
- Individual risk assessment during the development of a new robot solution and assistance with CE label certification
- Research into and identification of safety requirements for new and emerging application fields in robotics
- The overall application may also need to be considered (process, fixtures, gripper technology, robot), i.e. not only the robot itself
- Ensuring transparency in the operation of a tele-presence robot in terms of its control functions and safeguards
- Distribution of tasks, roles and responsibilities among robots and operators
- Varying degree of automation and varying degree of development of the various application areas
- High variety of types of user interface, handover, conveying, etc.
- Frequency of changeover, typical lot sizes
- Identification of keys for acceptance of partial automation or a mixed human-robot environment
- The need for new tests for application design and ergonomics, accompanied by tailored training programmes for designers and users
- Considering making ex-ante risk assessment compulsory for all kinds of human-robot collaboration
- The potential need to introduce special safety safeguards and testing protocols for the research into and development of the new generation of robots
- Possible need for risk assessment procedures to take non-technical parameters (i.e. psychosocial factors) into account, i.e. indirect impacts of machine-machine communication
- The need to implement safety functions using suitable components in accordance with pre-determined requirements
- Lack of specific international safety standards for robotic prostheses including risky and unsafe activities of autonomous robotics
- Possibility for long-term care insurance contracts for assistive robots
- Need to update security measures on a constant basis
- Robot-specific safety clauses for autonomous industrial robotics
- Safety concerns stemming from possible data security threats
- The need to ensuring and manage systems' predictability, and increase human understanding of the increasing complexity of automated safety

Legal instruments and provisions that might need to be reviewed or updated (indicative list)

- Directive 2009/104/EC concerning minimum safety and health requirements for the use of work equipment by workers at work
- Directive 2006/95/EC (Low Voltage Directive (LVD))

- Directive 2006/42/EC on machinery (henceforth Machinery Directive (MD)
- Directive 2004/108/EC (Electromagnetic compatibility Directive (EMC))
- Directive 2001/95 on general product safety (GPS)
- Directive 99/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres
- Directive 92/58/EEC on minimum requirements for the provision of safety and/or health signs at work
- Directive 89/656/EEC on minimum health and safety requirements for the use by workers of personal protective equipment at the workplace
- Directive 89/654/EEC concerning minimum safety and health requirements for the workplace
- Directive 89/391 – OSH Framework Directive on the introduction of measures to encourage improvements in the safety and health of workers at work
- The United Nations Convention on the Rights of Persons with Disabilities. *Treaty Series*, *2515*, 3, (2006)

ISO standards

- ISO 10218-1 Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots;
- ISO 10218-2 Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration;
- ISO/TS 15066 Robots and robotic devices – Collaborative robots;
- ISO 12100 Safety of machinery – General principles for design – Risk assessment and risk reduction;
- ISO 13849-1 Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design;
- ISO 13849-2 Safety of machinery – Safety-related parts of control systems – Part 2: Validation;
- ISO 60204-1 Safety of machinery – Electrical equipment of machines – Part 1: General requirements.

5. Health (Clinical Trials/Medical Devices/E-health devices)

Committees concerned: **ENVI – Environment, Public Health and Food Safety**
ITRE – Industry, Research and Energy

Areas of interest or concern and possible issues and challenges

- Certification and approval (e.g. ISO safety standards), in particular a possible adaptation of current trial procedures – designed mainly for testing medicines – to the purpose of testing new medical robotic devices
- Certification for individualised (or custom) products
- Certification and setting of standards amidst increasing complexity and interconnectivity of devices including component upgrades, also taking into account the added vulnerability of patients
- The need to incorporate effective verification and certification at the design stage of CPS
- Review of codes of conduct on medical professional secrecy, including an examination of the challenges associated with the use of a robot as an 'electronic health record'
- The use of e-health devices and surgical robots needs to be discussed first within the framework of medical devices legislation, along with the respective implementing measures

- Clinical certification and approval procedures for robotics and suitability review of the current framework for healthcare robots, with special attention to their use by impaired users or in emergency situations
- Randomisation, inclusion of a control group, power calculation based on a clinically meaningful outcome, and reproducible descriptions of the intervention being tested

Legal instruments and provisions that might need to be reviewed or updated (indicative list)

- Directive 2001/20/EC on the approximation of the laws, regulations and administrative provisions of the Member States relating to the implementation of good clinical practice in the conduct of clinical trials on medicinal products for human use
- Directive 98/79/EC on in vitro diagnostic medical devices (IVDMD)
- Directive 93/42/EEC concerning medical devices modified by Directive 2000/70/EC (MDD))
- Directive 90/385/EEC on active implantable medical devices (AIMDD)

6. Energy and environment

Committees concerned: AGRI - Agriculture and Rural Development
ENVI - Environment, Public Health and Food Safety

Areas of interest or concern and possible issues and challenges

- Possible review of labelling, energy efficiency, eco-design and standard product information rules
- Clarification of whether CPS for disabled people should be defined as home appliances and/or electric motors for the purposes of energy efficiency legislation
- Applicability review of the EU rules on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances
- Minimisation of the possible environmental or ecological footprint of (mostly industrial) robotics (improving energy efficiency, reducing waste, and adopting new environmental friendly technology)
- Examination of the conformity of the use of rare, and precious materials against EU's methodological approach and criticality assessment
- Applicability review of the REACH framework in relation to microscopic chemical robots
- The possible use of rare and precious materials may trigger the need to be evaluated against the methodological approach and criticality assessment of the European Commission (Raw Materials Initiative, etc.)
- Data-management and storage concerns and level of legal control of critical system operations including security of supply, safety, etc.
- Need to identify legal solutions for facilitating the production and transport of excess energy production to the grid
- Potential misuse or capture of the robotics infrastructure established for energy transmission or as power or energy grids
- Possible review of the European Convention for the Protection of Animals kept for Farming Purposes and of the EU acquis on farm animals and animal experimentation regarding the use and treatment of animals when testing farm robots and/or cyborgs and the terms of interaction among robots, humans and animals

Legal instruments and provisions that might need to be reviewed or updated (indicative list)

- Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC

- Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes
- Directive 2010/30/EU on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products
- Regulation 2006/1907 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
- Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes

7. Horizontal legal issues (cross-committee considerations)

Committees concerned: AGRI – Agriculture and Rural Development
EMPL – Employment and Social Affairs
IMCO – Internal Market and Consumer Protection
ITRE – Industry, Research and Energy
JURI – Legal Affairs
LIBE – Civil Liberties
TRAN – Transport and Tourism

Areas of interest or concern and possible issues and challenges

- Issues raised by these systems' integration with communication technologies in terms of control and monitoring but also in terms of the reversibility of their functions or decisions
- Legal concerns regarding access and equal opportunities for all people in need of assistance given the national character of social and healthcare policies; the need to consider the affordability/accessibility of robotics technologies/products and to coordinate national legal systems so as to reinforce the principle of equality;
- Legislative measures to boost long-term care contracts, such as tax relief or similar incentives, and applying such incentives for the use of assistive robotics for elderly and disabled people
- Legal control and power over the CPS and the respective algorithms
- Intellectual property rights
- Strict liability and insurance instruments for products/users
- Consideration of the possibility of creating a new legal category under the title e-person (electronic person) for smart robots by analogy with the category legal subjects
- Development of bounded control rules that guarantee and preserve connectivity of the overall network in applications involving mobile sensor networks and multi-robot systems
- Legal and regulatory standards for anthropomorphic projection that enhances the acceptance and use of robots and/or directly supports the main function of the robot (social robot technology)
- Laws as algorithms during the design and deployment process

Legal instruments/provisions that might need to be reviewed/updated (indicative list)

- European Charter of Fundamental Rights and the UN Convention on Disability Rights;
- Directive 2011/24/EU of the European Parliament and of the Council of 9 March 2011 on the application of patients' rights in cross-border healthcare, OJ L 88, 4.4.2011, p. 45–65;
- Communication of the European Commission, Taking forward the Strategic Implementation Plan of the European Innovation Partnership on Active and Healthy Ageing, COM(2012) 83 final;

- Council Declaration on the European Year for Active Ageing and Solidarity between Generations (2012): The Way Forward, Guiding Principles for Active Ageing and Solidarity between Generations, Brussels, 7 December 2012.

B. Complementary ethical considerations regarding of cyber-physical systems

The introduction of cyber-physical systems into our daily lives will pose not only a challenge in legislative terms but, as illustrated by the ongoing discussion about electronic personhood and the learning abilities of autonomous robots, it will poses ethical challenges as well. In fact, recent years have witnessed a wave of innovation in robotics driven by the need to move out of the industrial context and start introducing robots into unstructured environments where ethical challenges for policymakers, practitioners and participants will become much more nuanced in their nature and will effectively affect the way we approach and interpret legal concepts, human safety, privacy, integrity, dignity, intimacy, autonomy and data ownership, and intimacy.

In view of the future human-centred challenges, a governing or guiding framework for the design, production and use of robots is needed to guide and/or compliment the various legal recommendations or the existing national or EU acquis. Such a framework should take the form of a code of conduct for researchers/designers and users and should be based on the principles enshrined in the EU Charter of Fundamental Rights (such as human dignity and human rights, equality, justice and equity, benefit and harm, dignity, non-discrimination and non-stigmatisation, autonomy and individual responsibility, informed consent, privacy and social responsibility as well as the rights of the elderly, the integration of persons with disabilities, the right to healthcare, and the right to consumer protection) and on existing ethical practices and codes.

The values enshrined in the EU Charter of Fundamental Rights represent the normative framework on which a common understanding of the ethical risks associated with the operation of robots could be built. Still, judgements about the ethical soundness of robotics applications depend significantly on the specific context of application and the findings of the respective risk assessment process.

Thus, it is important to highlight that in view of the value-laden nature of the majority of the legal challenges and concerns associated with robotics and the social intensity of the latter, law and ethics should go hand in hand when designing anticipatory legal solutions and regulatory instruments.

Final reflections

As technology increases its impact on human activity, the potential for empowerment through the use of robotics is nuanced by a set of tensions and risks to human safety, privacy, integrity, dignity, autonomy and data ownership. While much of the promise held in these technological innovations remains to be fully realised, the expansion of robotics into new areas of human interaction and activity is expected to be followed by a profound set of shifts in the way individuals perceive some fundamental concepts such as companionship and intimacy. The human-centred turn in robotics technologies raises complicated legal questions that need to be addressed directly at the design phase. These questions involve the gathering and volunteering of data, and the involvement of lay people in experimentation with robotics for the programming of the necessary algorithms.

The path from the laboratory to the actual use of robots in real environments necessitates a broader look into these technologies, as robots and artificial intelligence will increase interaction with humans across very diverse fields. Robots have quickly become not only one of the most prominent technological trends of our century but also a dynamic object of legal concern. The accelerating pace of the design, creation, production, programming and use of robots is continually raising new and difficult legal questions.

The preceding legal analysis, based on a consideration of the study's scenarios, points primarily to the need to adjust the current EU legal framework on privacy, data protection and data ownership, to the dynamic flow of data that may arise when robots become more autonomous. In the near future, many risks may also be faced by consumers in terms of safety and security, requiring further legal action.

Specific provisions will need to take into consideration all the social aspects, including human and moral values, education, employment and social security.

Given the wide range of application of robotics technology, the question arises as to whether existing EU legislation can cope well with the respective legal challenges in an efficient manner and also as to the need for legal categorisation. Among these challenges, one should highlight structural differences in the way robots are approached from a legal perspective at national level and the lack of coordination, classification, sharing and validation of any information concerning the assessment and market use of robotics applications. How can EU law ensure that care robots are easily accessible to vulnerable people given the complexity of the healthcare and social systems that organise and regulate the provision of care? Can our legal system pave the way for a one-stop shop for safety and insurance purposes while remaining compatible with the various national systems for example? How can regulatory bodies and authorities secure transparent acceptance procedures for autonomous robots or even introduce standards on quality levels that could apply across all EU Member States?

Given the wide range of concerns with regard not least to setting high standards of quality and safety for robots, one might also ask whether it is feasible, in legal terms, to have uniform testing procedures for assistive technology products. Alternatively, should policy-makers move forward through softer approaches that are based on an exchange of best practice, data and experience or even through the compilation of regulatory EU-wide databases and catalogues? A further challenge stems from the absence of a horizontally accepted definition of robots and the varying autonomy of cyber-physical systems. Will the definitions provided in various technical contexts suffice also for legal contexts where robots are gradually introduced? Similarly, rapid technological developments in the field of robotics raise multiple questions regarding the shaping, application and interpretation of concepts such as autonomy, integrity and privacy.

The myriad ethical, legal and social effects of the commercial development and use of these technologies may signify a paradigm shift in tort law and insurance law or may even affect the terms of interaction between science, ethics and law. Last but not least, given the dynamic interface between market innovation and ethical considerations, EU legislators need to perform a social fitness test of the current framework. Accessibility should be a key consideration in all ongoing and future efforts to enhance standardisation and the formulation of specific standards for the improvement of the proper functioning of the internal market for robotics products and services.

Beyond the identification of the main areas of potential legal concern and the associated challenges as well as the respective pieces of EU legislation that may need to be reviewed or considered, the analysis leads to several, rather conceptual conclusions of a structural nature. The first is that every attempt to conceive and tackle the legal challenges associated with such a multifaceted technology needs to be designed in a reflective manner in order to help making individual adjustments on a case-by-case basis. Moreover, special emphasis should be placed on the need for a clear definition of CPS and, more specifically, of smart autonomous robots, for reasons of legal certainty at least at EU level.

Such a definition should be subject to future modifications, possibly by means of delegated acts. Apart from the identified points of legal reflection, a risk analysis strategy should be devised in order to provide a plausible instrument of regulatory importance that will have a horizontal and technology-driven perspective. The attempt to regulate emerging technology of this kind should be accompanied by ethical standards and with procedures that will address the needs and ethical dilemmas of researchers, practitioners, users and designers alike. This ethical framework would not need to take a legally binding form but could take the form of an EU code of conduct. Such multidisciplinary exercises can in fact facilitate the technological embodiment of law and help to shape a pluralist conception of law, ethics and technology.

Finally, it should be emphasised that not all the concerns identified in the previous steps can be translated into legislative terms. These are the affordability of CPS services, the control boundaries for the enhancement of the likely digital divide between those using CPS and those not, potential effects upon the labour market, the terms of interface between the authority of the doctor and of the patient with the AI-authority, the expected data concentration, the shortage of skills required for working with robots (e.g. as a person with a disability, as a user of an autonomous vehicle or as a farmer), the terms of emotional attachment with robots and the control of super smart, quick, strong cyborgs. Last but not least, our analysis indicates the regulatory and protective limits of law in its protective and even precautionary functions, and the fragility of traditional legal instruments.

5 Conclusions

The overarching purpose of this study is to support the European Parliament's bodies, as well as the individual Members, to strengthen their anticipatory knowledge and develop insights regarding the dynamics of change, future long-term challenges and options, in view of the rapid developments in the field of robotics. The main outcome of this foresight study is a policy briefing aiming at translating the identified the technical trends in the area of robotics as well as the respective impacts and concerns into legal and regulatory terms.

During the first phase of this study, a 'technical horizon scan' has been conducted in seven different domains of possible cyber-physical system (CPS) application, including short- and longer-term trends and their societal impacts. These domains are:

1. Disabled people and daily life
2. Healthcare
3. Agriculture and food supply
4. Manufacturing
5. Energy and critical infrastructure
6. Logistics and transport
7. Security and safety

In each case, the key technical developments, the short- and long-term trends and reflections upon the most important social, technological, environmental, economic, political, ethical and demographic impacts identified have been highlighted.

The development and implementation of CPS for the disabled and the elderly may lead to higher risks to data protection and privacy and a shift in the focus of medicine from treatment to prevention. This shift may help relieve the burden on medical professionals, allowing for more time to focus on patient care, and lowering the cost of medicine.

CPS may create major changes in the healthcare sector. These changes will trigger discussions on patient privacy including medical professional secrecy, data ownership and patient acceptance of CPS, and on civil liability for in case of medical shortcomings.

In the area of farming and food, CPS may result in greater food safety and hygiene. Through a combination of the Internet of Things, autonomous robots and sensors, we may experience an improvement in working conditions in the agricultural sector, and achieve optimised harvests and increased production. These changes will require discussions, for instance, on liability issues and the terms of the relationship between farmers and machines.

As CPS continue to be developed and deployed in manufacturing, with smart factories, we will see a radical change in the way manufacturing occurs primarily through new business models and the customisation of products. The changes will have profound implications for the economy, therefore legal action concerning data ownership, privacy, certification and safety will be needed.

CPS will become a key component of future energy systems, and the critical infrastructure underpinning the energy grid. However it is important to discuss the areas of liability, data collection and the ownership of that data to ensure that the rollout of the new energy systems can achieve the positive benefits while mitigating and potentially eliminating the negative side effects.

CPS are already changing the transport and logistics sectors. In the future, these changes will profoundly impact the way we move both goods and people with major impacts on safety, emissions, and the mobility of older citizens. A discussion towards accommodating the implantation of CPS will be needed concerning appropriate regulatory policy actions and timing, standardisation of laws, liability and privacy.

CPS will not generally make the world a more or less safe or secure place. It may however create a more complex world in which we will need to improve our ability to predict and understand the machines and their effect on security and safety. We need to ensure that those coming into contact with these new technologies – whether bystanders or operators – are able to understand the risks to their safety and security. These changes will require discussions on liability, data protection and the impact CPS will have on employment.

The next step of the study was based on and inspired by the outcomes of the technical horizon scan. Within this frame, a series of potential soft impacts[7] of CPS were taken into consideration along with some publicly expressed concerns and fears. Two workshops were organised to identify these soft impacts, to develop a set of possible future scenarios, and to identify areas of possible public or ethical concern. A list of possible societal impacts and concerns related to a future in which CPS would be integrated in society was the main outcome of this phase.

Examples of these outcomes cover both rather obvious and less likely robotics-related futures. Some of the examples below illustrate how entrenched meanings may be challenged by technological developments in the domain of CPS, raising subsequent questions about how to act in view of the following challenges/developments:

- Co-living and co-working between humans and robots, possibility of intelligent robots as a result of artificial intelligence developments
- The incorporation of smart technologies, which might raise issues as to where we will need to consider the borderlines between assistive technologies and human enhancement: will human enhancement become wide-spread? Will we consider the concept of 'disability' differently tomorrow? In this area, we are also confronted with issues such as self-determination and physical integrity.
- Normative conceptions of 'nature' will be constantly challenged, to an even greater extent than today is the case. For instance, do we perceive precision farming, using CPS, as conflicting with the concepts of 'nature'? Opinions already differ if organic farming compatible with the use of agricultural robots.
- CPS in farming may allow farmers to work further from the land they are farming. The image of farmers might change drastically. Will CPS in farming make farming more or less attractive to young farmers?
- Currently, security as a value is most often applied to questions regarding physical health and safety, and to a lesser extent to employment and finances. With CPS and the Internet of Things, data streams become ubiquitous, making all domains of life possible candidates for security risks. As a possible consequence, it is foreseen that debates will occur about how much security it is reasonable to expect or claim in any given domain, and what is seen as (ir)responsible behaviour.
- Where the border is drawn between public and private is of the utmost relevance for policy-making. However, CPS technology is bound to bring these borders constantly into question,

[7] Soft impacts are those impacts that are not easy to measure – e.g. affecting health, environment, and safety – and for which it is not easy to distribute responsibility. See also Annex 3 to this report.

because it shifts responsibility from the collective to the individual and back again. For example: is human enhancement a private or public responsibility?

There are a number of examples where CPS may invite novel behaviour more directly, for instance:

- If technologies become easier to use, more people will use them. One example of this mechanism is drones. If you are the only one to have them, that gives you a competitive edge. However, other parties are bound to acquire the technology too, and then what seemed 'smart for one' may become 'dumb for all'.
- If things or services gets cheaper, more people buy and use them. If we make energy cheaper through the use of CPS, this may well lead to a net increase in energy use, with for example devastating effects for global warming. Or, more in the domain of soft impacts: might scarcity be a good thing? If energy is cheap and clean, do we still need to be conscientious about using it? Are there other positive practices that we have developed in the light of scarcity?

For this analysis of possible future impacts and concerns, the study made use of four exploratory scenarios in which the first identified possible futures were considered. These were developed after the envisioning meeting during which a working group with technical experts, social scientists and some stakeholders brainstormed on the possible future impact of CPS. They covered:

- CPS and health and disability
- CPS and farming
- CPS and manufacturing and security
- CPS and energy and security

Each of these scenarios is an imagined account of a future in which CPS has developed and matured in various aspects of our lives. Based upon these exploratory scenarios, the study identified future concerns regarding CPS that can be considered for anticipatory action by the European policymaker.

While the scenarios are speculative and ultimately fictional, it is important to note that they are systematically based upon concrete research conducted by top experts in the field, including technical trend analysis, horizon scanning and expert workshops. As such, every detail of the scenarios presented — from the habits, hopes, fears and values of the characters to the social, legal and ethical tensions evident in their lives — is based upon substantial research and analysis.

The scenarios do not aim to predict the future, but to highlight how technology development might affect society and the public and private lives of EU citizens. These imagined scenarios (published in Annex 2 to this report) are meant to provide an accessible means for the reader to understand the social, ethical and legal tensions that were identified in the research process. They were designed to support committees and individual MEPs in exploring, anticipating and responding to potential CPS development paths and their associated impacts, and to aid reflection on anticipatory policy and agenda setting at the European Parliament.

The final step of the foresight process, called the 'legal backcasting' phase, was performed entirely in-house and aimed at translating the findings of the foresight phase into legal terms so as to pave the way for possible parliamentary reflection and work. During this phase, the outcomes of the previous steps were taken into account and were legally translated into a forward looking instrument for the European Parliament, the parliamentary committees and the Members of the European Parliament.

The analysis consisted of the following phases:

1. Identification and analysis of areas of possible future concern regarding CPS that may trigger EU legal interest
2. Identification of those relevant EP committees and intergroups[8] that may have a stake or interest in these areas
3. Identification of those legal instruments that may need to be reviewed, modified or further specified
4. Identification of possible horizontal issues of a legal nature (not committee-specific, wider questions to think about)

The legal backcasting covered the following areas:

- Transport
- Trade (dual-use / misuse)
- Data protection
- Safety (including risk assessment, etc.)
- Health (clinical trials/medical devices/E-health devices)
- Energy and environment
- Horizontal legal issues (cross-committee considerations).

The analysis looked at all stages of contact between robots, AI and humans. In this process, special emphasis was given to human safety, privacy, integrity, dignity, autonomy, data ownership and the need to provide a clear and predictable legal framework of an anticipatory nature. Special attention was given to the legal framework for data protection owing to the (expected massive) flow of data arising from the use of robotics and AI. Moreover, consumer concerns over safety and security concerning the use of robots and AI were discussed. The analysis shed light on legal concerns arising during the testing and development of robots including the risks associated with the terms of interaction with robots given their potential to profoundly impact physical and moral relations in our society.

Beyond the identification of the main areas of potential legal concern and the associated challenges as well as the respective pieces of EU legislation that may need to be reviewed or considered, the analysis leads to several, rather conceptual conclusions of a structural nature. Firstly, that every attempt to conceive and tackle the legal challenges associated with such a multifaceted technology needs to be designed in a reflective manner in order to help with making individual adjustments on a case-by-case basis. Moreover, special emphasis should be placed on the need for a clear definition of CPS and more specifically of smart autonomous robots for reasons of legal certainty at least at EU level. Such a definition should be subject to future modifications in the form of delegated acts.

Beyond the identified points of legal reflection, a risk analysis strategy should be devised in order to provide a plausible instrument of regulatory importance that will have a horizontal and technology-driven perspective.

Last but not least, the attempt to regulate emerging technology of this kind should be accompanied by ethical standards and procedures that will address the needs and ethical dilemmas of researchers, practitioners, users and designers alike. Such an ethical framework does not need to take a legally binding form but would be better established as an EU code of conduct. Finally, it should be emphasised

[8] The intergroups are not official bodies of the European Parliament, not do they represent its official view, yet they bring together MEPs from different political groups to discuss subjects ranging from human rights to economic and social issues.

that the fact is that not all the concerns identified in the previous steps can be 'translated' into legislative terms. Following such an extensive backcasting analysis and looking simultaneously at the rapid technological trends and developments at the same time, the regulatory and protective limits of law become rather evident.

In the light of some of these foresight scenarios, laws appears to be significantly inept at fulfilling their protective or even precautionary function. When carrying out these forward-thinking technological reflections, the fragility of traditional legal instruments and the limits of law and legal optimism become rather clear. At the same time, however, multidisciplinary exercises of this kind can facilitate the technological embodiment of law and help to shape a pluralist conception of law and technology.

To illustrate this, below we list some examples of concerns which, given the current EU legislative acquis and the particular status of EU competences but also the nature of some of these challenges, cannot fall within the scope of law in general or EU law in particular.

- The affordability of CPS services
- The possible digital divide between those using CPS and those not doing so
- The terms of interface between the authority of the doctor and the patient with AI-authority
- Avoiding data concentration
- The shortage of skills required for working with robots (e.g. as a person with a disability, as a user of an autonomous vehicle or as a farmer)
- Empathy with robots
- Control of super smart, quick, strong cyborgs

Cyber-Physical Systems (CPS) stands for intelligent robotics systems, linked with the Internet of Things.

The project 'Ethical aspects of CPS' aims to provide insights into the likely ethical concerns and related unintended impacts of the possible evolution of CPS technology by 2050.

This report covers the Scientific Foresight study which results in a briefing for the European Parliament identifying the legal instruments that may need to be modified or reviewed, including — where appropriate — areas identified for anticipative parliamentary work, in accordance to the conclusions reached within the project.

Annexes related to the study are available in a separate publication.

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