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Abstract:

This report gives seven proposals for concrete collaboration actions that the PICASSO Expert Groups on Big Data, IoT/CPS, and 5G have developed, based on the PICASSO opportunity report "Towards Enhanced EU-US ICT Pre-competitive Collaboration" and a variety of other activities, such as face-to-face meetings and remote discussions with internal and external experts, interactions with governmental actors and funding agencies, and a number of dissemination and community enhancement measures. The proposals are aimed at policy makers and describe strategic initiatives that should be enacted to foster EU-US collaboration.

Keywords:

Internet of Things (IoT), Cyber-physical Systems (CPS), Big Data, 5G, strategic initiative proposals for EU-US collaboration

Disclaimer

Strategic Initiatives:
Proposals and Recommendations

"Towards Enhanced EU-US ICT Pre-competitive Collaboration"

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**ICT Policy, Research and Innovation
for a Smart Society**

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Executive Summary

This report gives **seven proposals for concrete collaboration actions** that the PICASSO Expert Groups on Big Data, IoT/CPS, and 5G have developed, based on the PICASSO opportunity report "Towards Enhanced EU-US ICT Pre-competitive Collaboration" and a variety of other activities, such as face-to-face meetings and remote discussions with internal and external experts, interactions with governmental actors and funding agencies, and a number of dissemination and community enhancement measures. The proposals are **aimed at policy makers and describe strategic initiatives that should be enacted to foster EU-US collaboration**.

The Big Data Expert Group has developed the following two proposals:

- In **proposal 1 (Big Data EU-US Task Force for Enhancing Collaboration)**, the Big Data EG recommends to formally establish a task force for the enhancement of collaborations that builds on top of the collaboration between BDVA, NSF, and US Big Data Hubs that has been established in PICASSO. The task force should include subgroups on EU-US standardisation, regulation, smart cities, the environment-food-energy-water nexus, health, and data science.

- In **proposal 2 (Joint Big Data R&D Projects under the H2020 or FP9 Umbrella)**, the Big Data EG recommends to establish a joint EU-US programme or a set of projects for establishing international partnerships to jointly tackle specific challenges, arguing that such a program would give a huge boost to the Big Data industry.

The IoT/CPS Expert Group has developed the following two proposals:

- A regular exchange on technological topics for IoT-enabled cyber-physical systems is of crucial importance for the establishment of a common understanding of EU and US experts of the existing challenges and opportunities, and for the determination of the concrete benefits and synergies that EU-US collaboration actions can provide. In **proposal 3 (Joint EU-US Knowledge Exchange Initiative)**, the IoT/CPS EG recommends to establish, in the short term, an initiative that provides funding and facilitation mechanisms for regular EU-US knowledge exchange events (e.g. thematic EU-US workshops, conferences, symposia, or seminar series), as well as for fellowships and student exchanges between EU and US research institutions, in the form of a successor CSA to PICASSO or as a more permanent facilitation organization.

- In the longer term, the IoT/CPS EG recommends to set up a **Joint NSF-EC Programme on Autonomous IoT-enabled Cyber-physical Systems in FP9 (proposal 4)** that is co-funded by the EC and the NSF and that provides coordinated calls for low-TRL research & innovation projects.

The 5G Expert Group has developed the following three proposals:

- In **proposal 5**, the 5G EG recommends to establish a **5G EU-US Twinning Workshop Initiative** that focuses on organising twinning workshops that invite EU and US peer researchers/projects, with the obejectives to build an EU-US wireless research community and pair EU-US peers who have common research interests and are willing collaborate on the selected topics.

- In **proposal 6**, the 5G EG recommends to establish a **5G EU-US Twinning Coordination Project Initiative** that aims to bring (PICASSO-like) coordination projects on EU-US collaboration on the EU and US sides together.

- In **proposal 7 (5G EU-US Academia Research Collaboration Initiative)**, the 5G EG recommends to establish a pure academy research collaboration initiative with official members from universities and public research institutes from the EU and the US.

The proposals are described in more detail in section 1 of this report. Sections 2 to 4 provide background information on the proposals, such as more detailed guidelines and insights that led to the proposals.

The PICASSO Project

The aim of the 30-months PICASSO project is (1) to reinforce EU-US collaboration in ICT research and innovation focusing on the pre-competitive research in key enabling technologies related to societal challenges - 5G Networks, Big Data, Internet of Things and Cyber Physical Systems, and (2) to support the EU-US ICT policy dialogue by contributions related to e.g. privacy, security, internet governance, interoperability, ethics.

PICASSO is oriented to industrial needs, provides a forum for ICT communities and involves 24 EU and US prominent specialists in the three technology-oriented ICT Expert Groups - 5G, Big Data, and IoT/CPS - and an ICT Policy Expert Group, working closely together to identify policy gaps in the technology domains and to take measures to stimulate the policy dialogue in these areas. A synergy between experts in ICT policies and in ICT technologies is a unique feature of PICASSO.

A number of analyses will be accomplished, as well as related publications, that will for a major part be made public and contribute to the project's outreach. Dedicated communication and dissemination material will be prepared that should support the operational work and widespread dissemination though different channels (website, social media, publications …). The outreach campaign will also include 30+ events, success stories, factsheets, info sessions, and webinars.

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1. Strategic Initiative Proposals for Policy Makers

This section summarizes seven proposals that the technical PICASSO Expert Groups have developed over the project duration. The proposals are aimed at policy makers and describe strategic initiatives that should be enacted to foster EU-US collaboration.

1.1. Big Data

Proposal 1: Big Data EU-US Task Force for Enhancing Collaboration

A collaboration between BDVA, NSF, and US Big Data Hubs has been established, initiated and animated by the PICASSO project, and there is a clear opportunity of building on top of this activity. All actors engaged in the **Transatlantic Workshop on Public Private Partnerships for Big Data Research and Innovation and Workforce Development**[1] have expressed their willingness and commitment to continue working on a number of critical Big Data topics as defined in the workshop, by providing their personal time and effort in order to build a sustainable forum able to enhance EU-US collaboration in the Big Data field.

To this end, the need of establishing a formal EU-US Big Data Think Tank/Forum is vital. Our suggestion is to create a **EU-US Task Force for Collaboration**, under the BDVA, which will also include international members from the US, in order to establish a formal communication and collaboration channel between the two regions on Big Data. **This activity does not require the establishment of a new structure or programme. It only requires the critical redefinition of an existing EU structure (BDVA), to allow the inclusion of non-EU organisations into their Task Forces.** This Task Force may include both existing members from the BDVA (RTOs, Policy makers, Industrial stakeholders) and from NSF, the US Big Data Hubs, NIST, EC Big Data Unit and ESOs[2] (CEN, CENELEC, ETSI). Moreover, this task force will include a number of subgroups, each one working on topics already specific as critical by both the EU and the US Big Data ecosystems. The following subgroups can be included:

- **Subgroup A: EU-US standardisation board.** A joint EU-US standardisation board working on this subject could fill in the existing gap on Big Data standardisation and bring both regions to the technological forefront by jointly define standards able to boost both the research and the industrial landscape.

- **Subgroup B: Regulation Board.** A joint regulation board could propose a number of adjustments to existing data-related regulations in order to create a fertile and fruitful environment in which the industry could operate without having to individually overcome the burden of different policies and regulations for each region.

- **Subgroup C: Smart Cities.** A smart city subgroup could work towards the creation of smart city exemplars, both by the EU and the US, in order to drive discussions on initiatives that will benefit citizens. Moreover, the smart cities subgroup could organize EU-US conferences or workshops to advance the discussion and facilitate implementation of mentoring programs for smart city public-private partnerships.

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[1] http://www.picasso-project.eu/2017/11/27/trans-atlantic-workshop-on-public-private-partnerships-for-big-data/

[2] The European Standardisation Organisations

- **Subgroup D: Environment-Food-Energy-Water Nexus.** The role of a joint subgroup would be to a) exchange best practices between EU and US R&D projects, b) organise bilateral workshops to identify the best existing data sets to learn from and improve for training purposes, and c) organise dedicated workshops to connect principal investigators and further discussions of citizen science parameters, benchmarking, data sharing, and potential data standardizations.

- **Subgroup E: Better Health.** The specific working group should examine other industries to determine optimal models for data standardization and create a matrix that leverages various types of healthcare data, such as genetics, diagnostics, and behavioural data sources. Moreover, subgroup members should explore AI auto-encoding of EHRs to enhance data quality and ensure consistency among data entry. Both activities will lead to the development of a working guide for future healthcare data challenges, which will be distributed to policy makers in order to provide guidance and suggestions for steps and actions needed to support EU and US collaboration in this field.

- **Subgroup F: Big Data Workforce.** The role of this subgroup would be to determine data science definitions and standards, as well as the granularity and timeline for a transatlantic workforce development program. Such a program should create a data science pipeline from elementary to higher education, including vocational training and mentoring programs to promote lifelong learning.

Overall, the role of these subgroups will be a) to co-organise workshops (physical meetings) for sharing of experience and exchanging views and opinions on specific Big Data matters and, b) to produce whitepapers and roadmaps with specific propositions and measures to EU and US policy makers for jointly tackling Big Data challenges.

Proposal 2: Joint Big Data R&D Projects under the H2020 or FP9 Umbrella

The need of a joint programme or topic, cofounded both by the EU and the US side, on Big Data issues, is more than obvious. The implementation of a joint programme or set of projects for establishing international partnerships to jointly tackle specific challenges will give a huge boost to the Big Data industry. Such a Joint program/project would enable the sharing of experiences, results, and capabilities among agencies and organisation, shorten the development phase of a project, and allow agencies and organisation to assimilate and integrate new results and solutions quickly. Industry engagement in the program would demonstrate broader utility, foster better interoperability, and potentially provide long-term sustainability of solutions. Pilots and testbed infrastructure could be shared among agencies and organisation, thereby helping to maximize investments and share the benefits of projects and technologies that would otherwise remain isolated. Example of topics could be:

- Interoperability and Standardization

- Adding a semantic layer to Big Data technology

- Integrating Linked Data and Big Data technology

- Enable discovery of deeper, fresher insights from all enterprise data resources

- Improve efficiency, effectiveness, and decision-making

- Facilitate more timely, agile response to business opportunities, threats, and challenges

- Provide a single view of diverse data resources throughout the business chain

- Support tighter security, protection, and governance of data throughout its lifecycle

- Improve the scale, efficiency, performance, and cost-effectiveness of data/analytics platforms.

1.2.   Internet of Things / Cyber-physical Systems

Proposal 3: Joint EU-US Knowledge Exchange Initiative

Modern cyber-physical systems are equipped with a large number of sensing devices, and the Internet of Things will make access to the information provided by these sensors a lot simpler and more flexible. The connectivity provided by the Internet of Things will become an enabling technology for cyber-physical systems of systems in which the loop from a myriad of sensors to the way the systems are operated and also to the demands of the users is closed. Many of today's technological infrastructures, such as smart production facilities or smart energy and transportation networks, belong to this class of *IoT-enabled cyber-physical systems*, and the large amounts of real-time data from IoT-connected devices will enable new approaches for monitoring, optimization, management, and intelligent service provision that promise large improvements in performance, cost-efficiency, and safety and will thus help to solve key societal challenges.

A **regular exchange on technological topics** that are of importance for IoT-enabled cyber-physical systems is of crucial importance for the establishment of a common understanding of EU and US experts of the existing challenges and opportunities, and for the determination of the concrete benefits and synergies that EU-US collaboration actions can provide. In addition, the exchange of researchers, practitioners, and students between the EU and the US will widen horizons and will be an important part of a **comprehensive education of the future workforce in the IoT and CPS domains**.

In the short term, a **joint EU-US knowledge exchange initiative** is needed that provides **funding and facilitation mechanisms** for regular EU-US knowledge exchange events (e.g. thematic EU-US workshops, conferences, symposia, or seminar series), as well as for **fellowships and student exchanges** between EU and US research institutions. This initiative should be co-funded by the EC (supporting European experts and students) and suitable US partner organization (such as NSF and NIST) that fund US participants, but it could also be implemented using a bilateral program between a single EU member state and the US which, from our investigations, may be easier to realize that a full EU-US program. A bilateral program could be extended selectively by inviting other relevant EU member countries to join. Collaborations of regional EU entities (e.g. cities) with regional US entities (e.g. with cities or US states) may be a viable option as well, albeit with limited impact.

In addition, EU-US cross-funding elements can be included by involving EU, US, and international institutions that can provide funds to both EU and US actors, e.g. industry associations like the *Industrial Internet Consortium* (*IIC*) or the German initiative *Plattform Industrie 4.0*, or national agencies that can provide international funds at a basic research level like the Office of Naval Research, the Air Force Office of Scientific Research, or DARPA.

For the coordination of the knowledge exchange events and the student exchange programme, a facilitator must be established, e.g. in the form of a **successor CSA to PICASSO** or as a more **permanent facilitation organization** (modeled e.g. on programs like the *Intelligent Manufacturing Systems* (*IMS*) global research and business innovation program).

The exchange events should focus on the PICASSO technology themes since these were determined to have a large potential for EU-US collaboration (see section 3). They should aim at fulfilling the following objectives:

- Bring together **a diverse group of experts from academia, industry, and government** to discuss specific joint collaboration opportunities.

- Identify **specific R&I topics and concrete technology and application scenarios** that can serve as the basis for targeted collaboration programmes and calls.

- **Synthesize a list of benefits** that can be used to justify the effort of collaboration actions to all involved parties, including researchers, industry and industry-led associations, and the EU and US

funding providers (such as the EC, the NSF, or specific industrial consortia that are willing to open their funding to the outside).

- Generate **proposals for facilitation mechanisms** that can be used to identify suitable participation and funding structures within the diverse EU and US funding landscapes.

- Develop and disseminate **white papers** that concisely summarize the concrete scenarios, potential involved participants, benefits, and facilitation mechanisms and can serve as a basis for the definition of concrete R&I projects, calls, or coordinated work programmes.

The Trans-Atlantic Symposia that were organized by the PICASSO project provide suitable templates on which future exchange events can be modeled.

The knowledge exchange initiative should provide a **twinning option** so that both, the regular exchange events and the fellowship and student exchange programme can be linked to relevant R&I projects on both sides of the Atlantic, thus fostering the international exchange between national initiatives.

Proposal 4: Joint NSF-EC Programme on Autonomous IoT-enabled Cyber-physical Systems in FP9

A **joint collaboration programme on autonomous IoT-enabled cyber-physical systems** should be set up in FP9 that is co-funded by the EC and the NSF and that provides coordinated calls for low-TRL research & innovation projects to advance the state of the art in **autonomy and autonomous IoT-enabled cyber-physical systems**. The specific call topics should be based on the results (i.e. the concrete R&I topics and technology and application scenarios) that are generated by activities of a **joint EU-US knowledge exchange initiative** (see above). A list of R&I topics on autonomous IoT-enabled CPS that were identified by the IoT/CPS Expert Group is given in the following:

- Autonomy in large-scale, complex, open systems that are not domain/knowledge-"contained"

- Trust in / security of autonomous IoT-enabled CPS

- Human interactions with autonomous IoT-enabled CPS

- Collaborative decision making of humans and autonomous IoT-enabled CPS

- New engineering methods and tools for autonomous IoT-enabled CPS

- Models of autonomous IoT-enabled CPS systems and human actors

- Optimal coordination of (partially) autonomous IoT-enabled CPS

- Novel approaches for analysis, visualization, and decision support in autonomous IoT-enabled CPS

Recently established EU-US collaboration mechanisms, such as the coordinated calls on EU-US collaboration on the next-generation internet (NGI), can serve as an inspiration to design the joint collaboration programme on autonomous IoT-enabled cyber-physical systems.

1.3.   5G

Proposal 5: 5G EU-US Twinning Workshop Initiative

This initiative is specialised in organising twinning workshops that invite EU and US peer researchers/projects to participate and network. From a funding point of view, EU researchers will be funded by European public funding agencies, e.g., EC (in FP9) or national funding agencies. US researchers will be funded by US public funding agencies, e.g., NSF, NIST and DARPA. The missions of the initiative are to build an EU-US wireless

research community and pair EU-US peers who have common research interests and are willing to collaborate on the selected topics. In order to build and maintain a sustainable EU-US research collaboration relationship over wireless research, the workshop has to be held at least once per year or ideally twice per year (one time in US and one time in EU). This type of initiative has been partially envisioned in the H2020 ICT-21-2018 call[3].

Proposal 6: 5G EU-US Twinning Coordination Project Initiative

This initiative targets to bring (PICASSO-like) coordination projects on EU-US collaboration at the EU and US sides together. There are two alternatives for funding the initiative and corresponding project(s). Ideally, it will be jointly funded by public funding agencies at both EU and US sides, e.g., EC (in FP9) and NSF. If such an option is not possible, then EU and US should fund mirror coordination projects that receive funding from EU and US sides separately. The mission of this proposed strategic initiative is to provide a sustainable framework for projects from EU and US sides carrying out coordinating activities on common grounds and partially shared resources.

Proposal 7: 5G EU-US Academia Research Collaboration Initiative

So far, the only EU-US research initiative on wireless research is WIFIUS[4] that is funded by NSF and Finland (Academy of Finland and Tekes). Based on the experience of WIFIUS, it is possible to establish a pure academy research collaboration initiative with official members from universities and public research institutes in both EU and US sides. This strategic initiative should be funded by public funding agencies from EU and US sides, e.g., NSF, NIST, EC (in FP9) and national funding agencies in EU. Members of the initiative at the both EU and US sides should jointly propose research ideas and carry out collaboration research projects. All the results should be made for public access. Due to the fact that NSF or most federal agencies in US only fund pre-commercial research, direct industry participations will most likely be minimal or even not possible. However, it is possible for industry to participate indirectly, e.g., as associated members who are not funded and can provide feedback to research carried out in the initiative.

Suggestions for Designing EU-US Collaboration Initiatives

Regarding to the technology themes for the proposed initiative, the PICASSO 5G Expert Group has also provided its recommendation: Technologies that have niche market shares yet will have strong society impact. In addition, the PICASSO 5G Expert Group also suggests the following considerations while designing the EU-US collaboration strategic initiative:

- For any research initiative, researchers at EU and US should collaborate on and submit EU-US joint proposals instead of applying at EU and US sides respectively.

- For funding any strategic initiative, the review and selection process should be conducted by a joint EU-US committee, otherwise mismatches between EU and US peers will very likely occur.

- It is important to find an EU-US commonly acceptable approach to involve industry at the both sides. For example, based on past experiences, industrial advisory board that has been widely implemented in the EU H2020 projects is not of interest of NSF at the US side.

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[3] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/ict-21-2018.html

[4] http://www.wifius.org

2. Tackling Big Data Challenges via Collaboration

2.1. 1st Step: Definition & Validation of Challenges and Opportunities for Collaboration in the Big Data Sector

The first step towards defining the most important challenges and opportunities for collaboration between the EU and US, in Big Data, was the publication of the **Opportunity Report: "Towards Enhanced EU-US ICT Pre-Competitive Collaboration", published on March 2017**[5]. This report describes the major results that were obtained by the PICASSO Expert Groups in the first half of the PICASSO project on the technology sectors Internet of Things IoT) / Cyber-physical Systems (CPS), Big Data, and 5G, and on ICT policy relating to these technology sectors. The contents of this report are based on in-depth discussions with a large network of international experts, analytical research by the Expert Groups, preliminary PICASSO results and other feedback collection mechanisms such as a public consultation on the PICASSO website.

Specific to the Big Data sections, all findings and outcomes were based on various sources (i.e. from PICASSO project, deliverables, online sources, reports, etc.) and inputs deriving from the Big Data Expert Group. Roadmaps and reports produced by high level organisations and structures (i.e. **European Commission, White House Science and Technology Office, NIST**, etc.) have been extensively analysed and were also taken into account. Adding to the above, a database of more than 300 Big Data research projects (from EU and US) has been created and analysed, which enabled us to better define common application areas between EU and US.

The first draft version of the opportunity report regarding Big Data has been shared with Expert Group members and other external experts (over 16 different organizations - from EU or US) in order to collect feedback and validate the content of this report. These individuals represented the following organisations: **Big Data Value Association (BDVA), Big Data Europe, NESSI ETP, IEEE Big Data Initiative, South Big Data Regional Innovation Hub, Midwest Big Data Innovation Hub, West Big Data Innovation Hub, NSF, NIST, MIT and European Commission Media Unit**.

Key Outcomes from the Opportunity Report

The opportunity report has revealed a number of technology and application domains which can be considered as critical for both regions. From our analysis, common research and innovation topics have been identified. **Data Analytics**, **Data Protection & Privacy**, **Data Processing Architecture** and **Data Visualisation and User Interaction** are the technological priorities that are in the heart of policies and strategies for both regions. However, each region also gives emphasis to additional technological domains such Big Data Infrastructures and Ethics (for the US) and Data Management (for the EU). Moreover, the analysis has revealed that some application sectors are of extreme importance, both for the US and for the EU. **Health**, **Security**, **Smart Energy** and **Environment** are the most critical sectors for both regions. Moreover, sectors such as **Smart Transportation (Smart Cities)**, **Government**, **Manufacturing (Smart Production)**, **Finance** and **Agriculture** are also under a common microscope, although it seems that these sectors receive less support. Last but not least, what can also be seen is that the US has identified the domains of **Natural Resources and Hazards and Big Data Literacy** as extremely important while the EU has given a significant attention and support to the **Media** domain.

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[5] http://www.picasso-project.eu/wp-content/uploads/2017/03/PICASSO-Opportunity-Report_March-2017_revMar19.pdf

Adding to the above, a number of policy and technological reports have been taken into account in order to shape a clear set of technological opportunities for collaboration between the EU and US. The most important **technological opportunities** are:

- Interoperability and Standardization

- Adding a semantic layer to Big Data technology

- Integrating Linked Data and Big Data technology

- Enable discovery of deeper, fresher insights from all enterprise data resources

- Improve efficiency, effectiveness, and decision-making

- Facilitate more timely, agile response to business opportunities, threats, and challenges

- Provide a single view of diverse data resources throughout the business chain

- Support tighter security, protection, and governance of data throughout its lifecycle

- Improve the scale, efficiency, performance, and cost-effectiveness of data/analytics platforms

Adding to the technological priorities, additional collaboration opportunities exist in non-technological areas such as **standardisation, regulation and ecosystem creation**. What can also be extracted from this exercise, is that there is a great potential for EU and US universities to collaborate in order to fulfil the huge demand of **Big Data graduates**, and cooperate in order to learn from each other, mutually sharing experiences. More information regarding these themes for collaboration, can be found in the **Opportunity Report: "Towards Enhanced EU-US ICT Pre-Competitive Collaboration"**.

2.2. 2nd Step: Pilot-setting a Collaboration Mechanism between the EU and the US

Following the publication of the opportunity report, the **PICASSO Big Data Expert Group** has managed to bring together critical stakeholders from EU and US, in order to enhance collaboration and support a fruitful dialogue between the two regions, by co-organising a dedicated workshop in order to a) define the most critical points for collaboration and b) setup a mechanism for collaboration between research communities from both regions.

To these ends, the **Transatlantic Workshop on Public Private Partnerships for Big Data Research and Innovation and Workforce Development**[6] was held in Versailles, France, on November 20, 2017 as a partnership between the **US National Science Foundation (NSF) Big Data Regional Innovation Hubs, the EU Big Data Value Association (BDVA), the PICASSO project, and INRIA**. More than 50 EU and US participants from both academia and industry gathered to discuss opportunities for effectively using and learning from big data through public-private partnerships.

The workshop was **conceived as a kick-off for an ongoing collaboration** aimed at helping both the **EU and the US cultivate partnerships and develop a workforce** poised to advance and apply data science now and in the future. The workshop had three stated goals:

- To **determine best practices for supporting collaborative research programs** in data science, with a special focus on public-private partnerships and innovation in the areas of smart cities, transportation, health, and the nexus of environment, food, energy, and water;

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[6] http://www.picasso-project.eu/2017/11/27/trans-atlantic-workshop-on-public-private-partnerships-for-big-data/

- To **identify promising areas for bilateral EU-US research and data sharing**, especially among the US National Science Foundation's Big Data Regional Innovation Hubs and Spokes program and the EU Big Data Value Public-Private Partnership program; and

- To **examine ways to develop the burgeoning discipline of data science** in order to train a skilled workforce capable of keeping up with the rapid growth in opportunities to collect, analyze, and apply data.

Figure 1: Transatlantic Workshop on Public Private Partnerships for Big Data Research and Innovation and Workforce Development

The event **marked a crucial first step in establishing a productive EU-US relationship** for advancing big data science. Participants sketched out a vision for applying big data to benefit society and cultivating a workforce capable of fulfilling this vision. The **workshop uncovered potential synergies between the two regions, offered insights relevant to prioritizing future research investments in research, innovation and training, and yielded promising leads for potential jointly-funded projects to propel research and innovation**. Several common challenges also became clear. Issues around data sharing, interoperability, and standardization, for example, were apparent in nearly every domain and application discussed. Public-private partnerships in any domain also must find ways to align the diverse interests, strengths, and motivations of stakeholders. These stakeholders may include businesses, academic researchers, governments, public bodies, nonprofit organizations, and the wider public, each of which present their own set of challenges regardless of the specific problem the partnership is intended to address. The need to increase data literacy and to better integrate data science into relevant fields was another common theme. Finally, participants grappled with ethical and legal questions around privacy, the responsible use of data, public trust, and the potential for unanticipated consequences of well-intended efforts. Participants discussed these underlying challenges, debated domain-specific needs and priorities, and exchanged reflections on previous and ongoing efforts. Efforts to establish a vision for the strategic use of big data and to foster a workforce capable of keeping pace with the field's opportunities will greatly benefit from international collaboration among academic researchers, governments, and businesses.

2.3.   General Outcomes & Conclusions

Big Data, used strategically and appropriately, holds great potential to improve the way people live. Both the opportunity report and the Transatlantic Workshop outcomes, underlie the need of coordinated efforts to bring big data to bear on addressing societal needs by growing the big data ecosystem. Common challenges, arising from both activities, can be summed up in the following topics:

2.3.1. Big Data for Smart Cities

Transatlantic collaborations will be essential to identifying smart city initiatives and examining their successes and failures. Improved data sharing, standardization, and interoperability, especially for publicly-generated or crowdsourced data, could be undertaken by specialized working groups jointly funded by the EU and US. These collaborations would also uncover and potentially improve synergies for areas where public perceptions and priorities differ between the US and the EU, especially in regard to data collection and use. Different attitudes toward crime, for example, would impact what data is collected, how it is shared, and where it is applied.

2.3.2. Big Data and the Environment-Food-Energy-Water Nexus

EU Lighthouse projects partners and US BD Hubs and spokes-affiliated researchers should examine their projects for matchmaking possibilities that can lead to improved data sharing, interoperability, and international standards. For example, JTC-1 is an ISO in use across several projects and could serve as a model for others. Transatlantic webinars or conferences should be convened to answer questions about sensors, including the strengths and weaknesses of various products, how they can be used, and how their data can be interpreted and applied. Studying US and EU citizen science projects could also yield valuable lessons. Additional data processing and improved metadata would also lead to a better understanding of how data is collected, accessed, used, and shared, and inspire improvements.

2.3.3. Big Data for Better Health

Big Data are already considered as critical for the Health sector. With a growing need for efficient and accessible healthcare, companies and healthcare organizations are starting to invest in applications and analytical tools that help healthcare stakeholders identify value and opportunities, in fields such as[7]:

- **Build sustainable healthcare systems:** The healthcare industry is constantly faced with competitive and legislative pressure and must determine ways to reduce the cost of care, while efficiently managing resources. Healthcare organizations should focus on understanding the patient and improving patient care by promoting effective resource utilization.

- **Collaborate to improve care and outcomes:** Healthcare organizations should improve patient engagement and personalize healthcare initiatives that improve the quality and efficiency of care. Understanding a patient individually is important when designing tailored yet effective healthcare programs.

- **Increase access to healthcare:** A major issue with healthcare is access. In order for the population to thrive, healthcare must be available and accessible. Educating consumers on preventive care can improve health and reduce the demand and waste of healthcare resources.

EU and US should synchronise their efforts mainly on reinventing electronic health records by incorporating machine learning advancements to automate clinical documentation and on performing meta-analyses on EHR data quality, which would inform data model standardization. These activities could achieve much-needed interoperability and standardization, thus enabling more sharing of data sets with strong privacy protections. As Health data are directly related to nearly all aspects of one's life, including the physical environment, living conditions, education, lifestyle, economic stability, and social support systems, by integrating these fields with traditional medical data into mHealth initiatives could generate more advanced models and insights.

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[7] https://www.business2community.com/big-data/why-is-big-data-important-in-healthcare-0576823

Moreover, adoption of the Blue Button Standard[8] which allows patients to view and download their personal health records, is also a critical joint theme both for EU and for the US.

2.3.4. Leveraging Partnerships to Build Our Workforce

There is a great potential for EU and US universities to collaborate in order to fulfil the huge demand of Big Data graduates, and cooperate in order to learn from each other, mutually sharing experiences. Moreover, the cooperation of educational institutions and businesses, coming from both regions will benefit both sides in order to better understand the needs and, possibly, define new ways and curriculums for tackling them. Adding to the above, at a skills level it was noted that it is difficult to recruit for smart jobs. Some joint initiatives between EU-US could be a) creating a roster of rotating faculty to cross-pollinate expertise, accrediting programs to create curriculum consistency, b) comparing transatlantic definitions of competencies, c) creating an inventory of job titles and associated skills, and d) training on existing data sets. Several data science programs already exist, and these can be mined for best practices and cross-disciplinary potential.

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[8] https://en.wikipedia.org/wiki/Blue_Button

3. Fostering EU-US Collaboration on IoT-enabled Cyber-physical Systems

The main objective of the PICASSO Expert Group on IoT/CPS was to identify, validate, concretize, and disseminate opportunities and promising mechanisms for EU-US collaboration that will help to solve key societal challenges for *IoT-enabled cyber-physical systems*, i.e. modern large-scale technical systems in which streams of real-time data from a large number of IoT-connected devices with sensing capabilities enable new approaches for monitoring, optimization, management, and intelligent service provision that promise large improvements in performance, cost-efficiency, and safety. To this end, the Expert Group first created a comprehensive analysis, comparison, and assessment of EU and US needs, R&I priorities, funding and collaboration landscapes, and barriers that was used to define preliminary propositions of technology themes, collaboration opportunities, and mechanisms that are a suitable basis for EU-US collaboration. The elements of this list were then elaborated, prioritized, and refined to define two concrete proposals for strategic initiatives that should be realized over the next years to foster EU-US collaboration.

3.1. Identification and Validation of Needs, Priorities, Barriers, and Opportunities

The first step towards the development of concrete proposals for strategic collaboration initiatives was the development of the *IoT/CPS Opportunity Report* that provides comprehensive surveys and comparisons of EU and US cross-domain and application-specific drivers and needs, enabling technologies, research and innovation priorities, current funding and collaboration landscapes, and potential barriers for collaboration in the IoT and CPS sectors that was developed using extensive analytical work as well as in-depth discussions and validations with a large network of EG members and external stakeholders, including US funding agencies, the relevant EC units, industry-led associations, international technology companies, EU-US collaboration initiatives, international expert networks, R&I projects, and a variety of roadmapping initiatives. Based on these background investigations, a list of technology themes was defined that are most promising for EU-US collaboration, and an initial list of collaboration opportunities and mechanisms was proposed.

The report has been discussed face-to-face with a variety of stakeholders (in personal interviews and at events of PICASSO and of other initiatives) and was circulated widely, with positive feedback by a variety of relevant stakeholders from the EU and the US. Feedback from important stakeholders indicated that the analyses and comparisons of the EU and US R&I priorities and applications domains, as well as the analyses of the collaboration environment and potential barriers are seen as very useful to promote the understanding of the "other side", and to clarify the concrete options that exist for future collaborations and their success probabilities, where the practical relevance of the report is strengthened by the comprehensive feedback that was provided by many stakeholders.

In the Opportunity Report, six technology themes were identified that are relevant in both the IoT and CPS domains and that are of high importance in the EU and the US:

- **Closing the Loop in IoT-enabled Cyber-physical Systems** which includes subtopics such as system-wide management and coordination, data-based operation, cloud-supported control, and novel control architectures,

- **Model-based Systems Engineering** which includes subtopics such as integrated full-life-cycle engineering, high-confidence IoT and CPS systems, and modeling,

- **Trust, (Cyber-)security, Robustness, Resilience, and Safety** which includes subtopics such as trustworthiness, behavior-based methodologies to establish trust, and secure real-time and mixed-criticality systems,

- **Integration, Interoperability, Flexibility, and Reconfiguration** which includes subtopics such as semantic interoperability and models, joint testbeds and large-scale pilots, open standards, and plug-and-play integration,

- **Autonomy and Humans in the Loop** which includes subtopics such as autonomy in systems that are not domain/knowledge-"contained", human interactions and analysis of user behavior, and collaborative decision making, and

- **Situational Awareness, Diagnostics, and Prognostics** which includes subtopics such as real-time data analytics and data management, machine learning, predictive condition monitoring, and self-diagnosis.

In addition, we compiled a comprehensive list of potential barriers to EU-US collaboration:

- **Structural differences in funding environments** are an important barrier since the US funding landscape is very different to the EU landscape along several dimensions, such as the level of centralization, the targeted technology readiness levels, and the funding time spans and cycles.

- **Administrative overhead** is a major barrier, in particular for high-level, top-down, heavyweight mechanisms that provide comprehensive frameworks for international collaboration, such as high-level multilateral agreements, thematic, targeted funding programmes and project calls with joint funding.

- **Legal requirements** are seen as major barriers since many potential (in particular commercially oriented) project partners are not interested or able to sign complex, restrictive legal documents. Within H2020, this requirement has recently been removed under a new "Implementing Arrangement" if the participating foreign partners do not receive EU funding. US organizations are allowed to partake in research efforts and other relevant activities in the scope of EU projects without having to sign grant and consortium agreements, thus providing a new basis for EU-US R&I collaboration.

- A **lack of clarity of the benefits of EU-US collaboration** has been identified as a major barrier; it is imperative to be able to make the benefits of collaboration clear by answering questions such as "Is there a skill gap which can be complemented by collaboration?", "Is there mutual economic benefit?", "What will be missed if there is no collaboration?", or "What are the common interests?" Generally, collaborations within the research community are easier to justify than academic-commercial or purely commercial collaborations since the research community is inherently global and universal, and often significant advances in key areas are only possible in international collaboration efforts (prominent examples are CERN and ITER). In addition, the education of the scientific work force should be as international as possible.

- **Restrictions due to intellectual property protection** can inhibit collaboration, and collaboration may be difficult on topics of high near-term commercial importance, i.e. innovation efforts that focus on products and services that may lead to large profitable businesses in the near term. An exception is the joint work on international standards and interoperability. While this is of commercial importance, it usually does not require companies to disclose information and technology that affects stand-out features of their products. Despite this, it is arguably easier to collaborate on basic research than on applied research.

- A **lack of awareness and knowledge** can be a major challenge for EU-US collaboration.

- Other barriers that were identified are a **lack of joint EU-US funding mechanisms and policies**, a **lack of awareness and knowledge** of EU and US actors of the other side, **export control and privacy restrictions**, and a **lack of interoperability and standards**.

Based on the analyses and discussions done for the opportunity report, conclusions can be drawn on the features and constraints that collaboration actions should possess to maximize their success probability. The most important conclusions are:

- Especially in light of the current political climate, **lightweight collaboration actions** are seen as being promising, in particular those with low complexity that are relatively easy to set up (e.g. joint workshops and staff exchange), while heavyweight collaboration measures are not considered to have a high probability of success, in particular in the CPS domain (on which the Expert Group focuses) where interest in collaboration is currently very limited.

- Collaboration actions should either focus on **pre-competitive R&I with a low *TRL* (*Technology Readiness Level*)** or on other efforts that do not require access to sensitive company-internal IP, such as increasing **interoperability**, developing **international standards**, **joint demonstration**, **testbeds**, or **business model development**.

- A key requirement for the successful initiation of EU-US collaboration actions is **benefit assessment and promotion**. Collaboration actions will only be set up if the expected benefits are larger than the administrative overhead, and if these benefits are made very clear to all participants, such as funding agencies and private companies. The set-up of benefit assessment and promotion activities and of EU-US collaboration actions will require **significant coordination, support, and facilitation effort**.

- Despite the increased difficulties in the set-up of higher-TRL collaboration actions compared to fundamental R&I collaboration, **private companies and industry-led associations** may be promising partners for EU-US collaboration actions, because they are more interested in R&I results than funding (they often can provide their own funding or may even offer funding means to academic participants), are less affected by governmental policy than federal agencies, and are inherently internationally oriented, i.e. not focused on national boundaries.

All of these results and lessons were synthesized in the IoT/CPS Opportunity Report into distinct preliminary recommendations for EU-US collaboration actions:

- An important prerequisite for the establishment of future EU-US collaboration measures in the areas of the IoT and cyber-physical systems is to reinforce **roadmapping and the identification, assessment, and promotion of benefits**, in particular in the form of **joint, thematic EU-US workshops** that are co-funded by the EC and suitable US partners (such as NSF, NIST, or industry associations like IIC and SMLC). The objectives of such workshops should be to discuss specific joint collaboration opportunities, to identify specific R&I topics and concrete technology and application scenarios for collaboration, to synthesize a list of benefits that can be used to justify the effort of collaboration actions to all involved parties, and to generate proposals for facilitation mechanisms that can be used to identify suitable participation and funding structures within the diverse EU and US funding landscapes. The Trans-Atlantic symposia that have been organized by the PICASSO project were very successful in this regard.

- An **organization is needed that serves as a central contact point, coordinator, and facilitator** for the set-up and execution of **EU-US collaboration actions with many potential partners**, and for the integration **of non-governmental US entities into EU projects**.

- Any joint research and innovation programmes should be kept lightweight. An option to achieve this is a **joint, targeted EU-US collaboration work programme** that is set up based on the results of dedicated roadmapping and benefit analysis efforts (see above) and that focuses on **coordinated calls**

between the EU and the US (i.e. with separate funding). Calls should require project proposals to integrate **mandatory (lightweight) collaboration items**, such as **short-term student, researcher, and staff exchanges** between EU and US partners and r**egular joint workshops for knowledge and experience transfer**. The involvement of non-governmental partners, such as enterprises, SMEs, and industry-led associations should be encouraged and supported by a facilitation mechanism or organization.

- Since a fruitful EU-US exchange of IoT, CPS, and application experts is seen as an important mechanism to advance the state of the art in these domains and to exploit synergies for the training of scientists and engineers, a separate lightweight program should be set up that provides **fellowship and exchange funding** for students and researchers to work and study abroad, and that promotes knowledge transfer between the EU and the US by funding **joint workshops**, **conferences**, and **seminar series** on IoT and CPS topics. This program should provide a **twinning option** that allows to link these collaboration actions to running R&I projects.

- Private companies and industry-led associations are promising partners for EU-US collaboration actions, but they often have very specific R&I needs that they require a short-term return and a quick start of funding. It is recommended to set up a **targeted, US industry-focused program** that allows US companies and associations to quickly set up R&I projects of limited scope with European research institutions and/or companies.

- **Infrastructure sharing** and the development and joint usage of **large-scale test beds and demonstrators** should become a focus area of EU-US collaborative research and innovation funding. The EU and US should launch **synchronized initiatives** that (a) provide financial support and administrative assistance for researchers and industry representatives to do **joint experiments on existing infrastructure** in the IoT, CPS, and relevant application domains, and that (b) provide support for the set-up of **new testbeds and demonstrators** on high-priority technology topics. Successful international testbed and infrastructure initiatives should be used as an inspiration (such as the joint testbed initiative of the *Industrial Internet Consortium*), and **companies and industry-led associations should be encouraged to contribute to infrastructure sharing initiatives**.

3.2. Derivation of Strategic Initiative Proposals

After the IoT/CPS Opportunity Report with its promising technology themes and preliminary recommendations was published, the Expert Group focused its efforts on the refinement and prioritization of the recommendations and on the identification of the most promising areas for technological collaboration from the six technology themes. Two avenues were followed to identify the most promising opportunities for **technological R&I collaboration** and for **collaboration focusing on standardization**.

Internal discussions within the EG (both face-to-face at the 2nd Trans-Atlantic PICASSO Symposium and remotely, e.g. at the PICASSO IoT/CPS webinar in May 2018) and with external stakeholders yielded that for **technological R&I collaboration**, the technology theme of **autonomy** currently is of highest importance in both the US and the EU. Our analyses have shown that there is an increasing trend towards autonomy in many areas and all analyzed application domains, as well as the need to predict how autonomous systems will behave when interacting with humans. The significant overlap of the needs and interests in the EU and the US in this area is a good basis for R&I collaboration. In addition, autonomy has more recently gained importance within the EU R&I landscape, with "autonomous cyber-physical systems" likely becoming a major focus theme in FP9. Other themes that are currently seen as important are **model-based systems engineering** and **trust / (cyber-) security**.

Since **industry-driven standardization** was identified as a suitable topic for EU-US collaboration, and since the topic of interoperability is of high importance in IoT-enabled CPS, which often are inherently multi-national, the

current landscape for **standardization for interoperability of IoT-enabled CPS** was analyzed in detail. To this end, the EU and US approaches to interoperability standardization and the multitude of existing interoperability standards and reference architectures were analyzed and compared. While we found that in particular design and engineering tools for IoT-enabled CPS were not considered much yet in interoperability standardization, we decided to drop the topic of standardization due to the multitude of international activities that are already ongoing in this area.

With respect to collaboration opportunities, our discussions and activities since the publication of the Opportunity Report have resulted in the insight that it has become even more challenging to establish concrete EU-US collaborations in the current political climate. While there are currently some initiatives in the IoT space in this direction (and there are future calls that are specifically focused on EU-US collaboration on the next-generation internet in the H2020 work programme 2018-2020), we have found that collaboration in the CPS space (which is the focus of the EG) is currently only feasible for scientific collaboration but not for the type of projects that the EU sponsors in the LEIT domain. In addition, it is unlikely that collaboration actions that involve commercial aspects are feasible.

Thus, we propose to establish two different strategic initiatives to foster EU-US collaboration at this time, a **joint EU-US knowledge exchange initiative** on IoT-enabled cyber-physical systems in the short term, and a **joint NSF-EC collaboration programme** at a later stage (i.e. in FP9) that focuses on low-TRL research and innovation on **autonomous cyber-physical systems**. The strategic initiative proposals are described in section 1.2.

The remaining recommendations that we present in our opportunity report, although not feasible at this time, provide concrete guidelines for promising initiatives in EU-US collaboration that may become feasible again in the future.

4. Steering 5G EU-US Collaboration towards Creating Long-term Societal Impact

4.1. Obstacles for EU-US Collaboration in the 5G Domain

In general, there is a very strong interest in the 5G domain for EU-US collaboration especially among academia, non-profit organisations, and some international companies. However, big obstacles exist and make it very challenging to achieve meaningful and sustainable collaboration in the 5G domain:

Asymmetric Public Funding Scopes in the EU and the US

In the EU, major public funding on wireless research, e.g. from the European Commission, is eligible for industry participants. This is not the case on the US side. Most US federal funding agencies are not allowed to fund commercial and industry research. A few exceptions are DARPA and Department of Energy. In these two agencies, DARPA is more related to wireless research yet it imposes rules and terms that differ greatly from normal EU projects. Such asymmetric public funding scopes suggest that EU-US research collaboration in the 5G network will be most likely an academia one.

5G is a Highly Competitive Area for EU and US Peers

On both the EU and US sides, there are a large number of prominent companies that are developing and/or providing wireless products and services. They compete on research, standardisations, products and national/regional/international markets. At the government level, US and EU policy makers also practice different spectrum licensing approaches and may stand for different campaigns, e.g., for global spectrum harmonisation in the world radiocommunication conference (WRC) 2019. The inherent strong global competition in the 5G domain will limit the scope of EU and US collaboration.

The High Relevance of 5G with Economics and Politics

Based on statistics from GSMA, in year 2016, mobile technologies and services generated 3.9% of GDP and 2.5 million jobs in North America[9] and 3.4% of GDP and 2.6 million jobs in Europe[10]. These figures are expected to grow to 4.7% of GDP in North America and 3.9% of GDP in Europe by 2020. In the current global environment, economics and employment are the most important aspects that need to be addressed by governments in all the major countries/regions. This imposes a great challenge for EU and US peers to build strong collaboration and a partnership due to the fact that the 5G network is considered as a key enabler for digitalization and digital economy in both EU and US. In particular, the 5G network is not just a wireless network any more but will empower and upgrade many vertical industries, e.g., energy, automotive and manufacturing. In this context, the development of 5G networks will be eventually mapped to an indicator of national or regional competence, which makes it very challenging to build sustainable 5G collaboration between EU-US wireless industries.

4.2. Opportunities and Strategies for Steering Collaboration

In this context, it is very critical and highly important to strategically steer the proposed initiatives towards a direction that is mutually beneficial and interesting to the both EU and US sides. Based on the feedbacks from

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[9] https://www.gsmaintelligence.com/research/?file=b0cf4f71cb2d035f429d9de8ca4fc72e&download

[10] https://www.gsmaintelligence.com/research/?file=89a59299ac2f37508b252124726a1139&download

PICASSO expert groups, here are some **recommendations** for constructing the proposed strategic initiatives in section 1.3:

- **Using the right or mutually agreed terminologies:** Despite of the terminology "5G" has been used globally, it shouldn't be taken for granted that everyone defines its scope in the same way. In fact, based on feedbacks collected by the PICASSO expert groups, it is highly likely that the definitions of 5G differ greatly at the EU and US sides. Also, at the US side, the term "5G" is considered to be too close for commercialization. US Federal agencies, e.g., NSF, doesn't fund such research. Therefore, for naming any EU-US collaboration initiative, the PICASSO 5G expert group recommends to use terminologies that are less specific to any commercialisation application and focus on the **fundamental side of research**, e.g., "beyond 5G", "advanced wireless" or "future wireless".

- **Directing collaboration targets towards addressing EU-US common societal challenges:** In general, it will be difficult to direct the proposed EU-US collaboration initiatives towards industry applications due to the strong competitions as mentioned above. On the other hand, both EU and US are facing some common societal challenges that can be addressed by close collaboration. One example is to provide broadband access to rural and less developed areas, which is one of the most important technical subjects for the policy makers at the both EU and US sides at the moment. Close collaboration on enabling technologies as well as policies will help both sides to address this issue with reasonable cost and also benefit the rest of world[11]. This has been recommended in the final PICCASO opportunity report together with other 6 technology themes for collaboration:

    o   Connecting the last billion – ultra large cell

    o   mmWave technology at carrier frequencies beyond 100 GHz

    o   Narrowband IoT devices for goods tracking in global supply chain management

    o   Ultra-wide band RF IC at mmWave frequency

    o   V2X for regional niche markets

    o   Satellite communications for broadband access in oceans

    o   Spectrum farming

The details of the above topics are described in [11]. The general recommendation from the PICASSO 5G expert group is to focus on technologies that have niche market shares yet have strong society impact.

- **Targeting for mid-long term goals**: Focusing on fundamental research and experiments and then directing them towards addressing societal challenges, the proposed strategic initiatives are advised to set for mid or long term goals instead of immediate returns. The expectations would be to establish a long-term and sustainable research partnership and deliver research outputs that will shape the future and eventually benefit industry at the both side of Atlantic in a long run.

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[11] PICASSO Consolidated Opportunity Report, deliverable report D2.7, 2018.