A Digital Quality Infrastructure for Europe: The European Metrology Cloud

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1 Introduction

Innovation is essential to European competitiveness in the global economy. Industry accounts for 80 % of Europe's exports and some 65 % of private sector research and development investment comes from manufacturing. Small and medium-sized enterprises (SMEs) are a very important part of the European economy, as they represent around 99 % of all enterprises and employ an increasing number of persons [EUST2017].

Therefore, industrial modernization in Europe must be broad-reaching and must include the successful commercialization of product and service innovations, the industrial exploitation of innovative technologies and innovative business models. New growth opportunities come from providing new products and services from, technological breakthroughs, new processes and business models, non-technological innovation and innovation in the service sector [COM2017].

The European Commission sees an enormous economic benefit could be gained from a digital single market. Hence, the Commission has issued a Digital Single Market Strategy for Europe to push the most essential aspects like cloud computing, big data and platforms [COM2014/442], [COM2015/192], [COM2016/288].

Drivers of the digital transformation in legal metrology are the increasingly globalized market place, the ever-increasing drive for efficiency and the rapidly developing consumer demands. Seizing the chances of digitalization outlined by the European Commission could resolve existing obstacles for innovation in this sector.

The New Approach of the European Commission [COM2016/C272] sets up a quality infrastructure where measuring instruments and related legal processes are embedded. A quality infrastructure is generally understood to be the totality of the institutional framework (public and private) required to establish and implement standardization, metrology (scientific, industrial and legal), accreditation and conformity assessment services (inspection, testing and product and system certification) necessary to provide acceptable evidence that products and services meet defined requirements, be it demanded by authorities or the market place.

It is estimated that there are 850 million measuring instruments on the EU market which are governed by European directives of this New Approach (e.g. 2014/31/EU and 2014/32/EU). In most industrialized countries, legally relevant measurements are responsible for a share of 4 % to 6 % of the European gross domestic product (GDP), equivalent to 660 – 990 billion euros per year.

It is felt by the European manufacturers' associations that the implemented processes within the quality infrastructure hamper the use of technological breakthroughs providing new products, the exploitation of the technological potential to streamline the processes, and the development of new data-based business models [IT2017], [PC2017].

The manufacturers' associations envision marketing concepts based on innovations which are driven by technologies that have matured significantly over the past ten years – namely embedded systems, the Internet of Things (IoT), cyber-physical systems, cloud computing, big data and platform concepts. Hence, in legal metrology, the transition from an instrument with locally concentrated parts towards distributed hardware and cloud-located stored data, data-based services and virtualized processing software is already recognizable (see Figure 1). This approach is pushed by the manufacturers' associations in Europe who are ever more frequently asking for legally acceptable architectures for such technologies, whenever they see a possible economic advantage.

In addition, today, measuring instrument sensors are often fully developed within the

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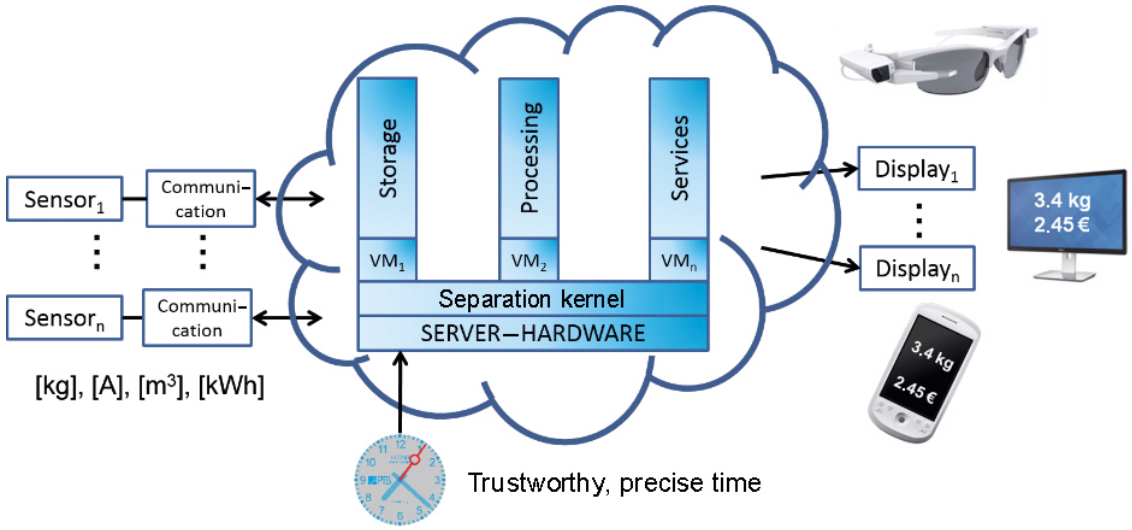

Figure 1:
Instrument with distributed and virtualized components and data-based services.

scope of the required measurement accuracy. New business and service models will therefore address individual customer requirements which are determined based on user data and data collected in the field. Consequently, the need to offer data-based services and business models – for example, based on big data processing schemes – will increase.

The objectives of the European initiative described here aim at addressing these needs by setting up a digital quality infrastructure to improve the coordination in Europe by technology- and data-driven legal metrology services – the "European metrology cloud" – whilst guaranteeing transparency appropriate for conformity assessment and market surveillance in an increasingly globalized economy (see Figure 2).

2 Legal metrology and its economic footprint

Correct and traceable measuring instruments can be used for a variety of measurement tasks. Those responding to reasons of public interest, public health, safety and order, the protection of the environment and the consumer, of levying taxes and duties and of fair trading, which directly and

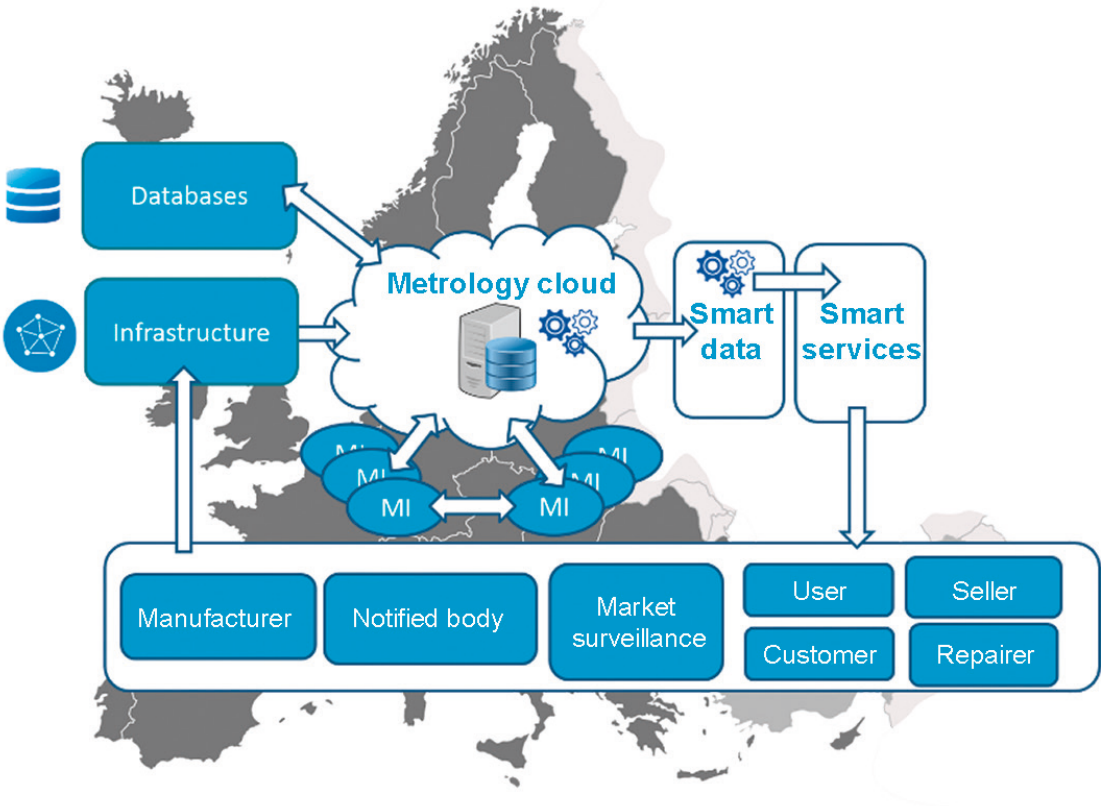

Figure 2:
The "European metrology cloud" – A digital quality infrastructure for Europe.
MI: measuring instrument.

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indirectly affect the daily life of citizens in many ways, may require the use of legally controlled measuring instruments.

To support the intelligibility of the need of the initiative, a brief description of legal metrology and its economic footprint will be provided in the following.

In legal metrology, a restricted community exchanges sensitive information regarding regulated measuring instruments within legally guided processes to guarantee confidence in the correctness and traceability of the measurements and to protect the customer and the user. The stakeholders in legal metrology consist of the users and manufacturers of the measuring instruments, the national notified bodies – often a National Metrology Institute (NMI) – and the national authorities responsible for market surveillance and verification/inspection of the instruments in the market. The responsibilities and rights of these stakeholders are regulated by European directives within the New Approach [COM2016/C272] which sets up a quality infrastructure for products, such as 2014/31/EU and 2014/32/EU, and regulations, such as 765/2008 and Decision 768/2008/EC.

The **14 classes of measuring instruments** which are governed by the directives include water meters, gas meters and volume conversion devices, active electrical energy meters, thermal energy meters, measuring systems for the continuous and dynamic measurement of quantities other than water, weighing instruments, taximeters, material measures, dimensional measuring instruments, exhaust gas analysers and non-automatic weighing instruments. The laws of the Member States add further instrument classes, such as measuring instruments for public traffic, for radiation protection, for "intelligent" or "smart" metering and for temperature, to name but a few.

The European regulations apply to 345 million units of measuring instruments that are sold annually in the European market [COM2010]. In 2010, the annual turnover of the sector was estimated at 7 billion euros [COM2010]. In several Member States, the number of measuring instruments sums up to 150 different types, e.g. in Germany. Based on each Member State's contribution to the GDP [WP2017], an estimate of 850 million measuring instruments in the EU market can be given. The largest share is attributable to the area of meters, such as electricity, gas, water and heat meters, weighing instruments and measuring instruments for measuring the volume of mineral oil. In most industrialized countries, legally relevant measurements are responsible for a share of 4 % to 6 % of the European GDP [DP2015] (660 – 990 billion euros per year).

The notified bodies carry out conformity assessments of a measuring instrument and grant type approval certificates when appropriate. There are 120 such notified bodies listed in an EU database [COM/NANDO]. One of Germany's notified bodies, the Physikalisch-Technische Bundesanstalt (PTB), issued approximately 600 certificates for measuring instruments covered by 2014/31/EU and 2014/32/EU in 2016. Based on the GDP basis, it can be estimated that 2400 certificates were granted in the European Union by the notified bodies in 2016. After putting a measuring instrument into use, the market surveillance and verification authorities are responsible for monitoring their proper use, repair and reverification. There are 205 market surveillance institutions working on this task in Europe [COM/MS]. According to the amount of verifications done in Germany in 2014 [AGME2014] (~1 million), it can be estimated that the market surveillance bodies carry out 5 million verifications per year. More than 80 % of these are verifications taking place after a repair. There are 900 European companies active in the production of measuring instruments [COM2010] together with many being partly active in related fields as well as providing millions of jobs in Europe. They are organized in manufacturers' associations such as CECIP, CECOD, FARECOGAZ, AQUA, ESMIG, VDMA, etc.

3 Demands of a globalized market

To keep this market segment growing, the manufacturers' associations envision marketing concepts based on innovations which are driven by the ever-increasing demands of the globalized market and being facilitated by technologies that have matured significantly [IT2017], [CP2017].

The manufacturers object that the implemented processes set up by regulations and realized by the current analogue quality infrastructure hamper the use of these technologies and the exploitation of their possibilities.

In this context, manufacturers consider the following "inhibitor to innovation" as relevant: Regulated processes – as established today – are considered to increase the time to market. A knowledge gap regarding IT knowledge between manufacturers, the notified bodies and/or the market surveillance and verification authorities can be identified, i.e. the authorities are not acting at "eye level" with the manufacturers (or vice versa). It is therefore felt that the authorities either refuse innovative solutions due to a lack of technological expertise or "bend" them, to squeeze them into known concepts. For the same reason, it is claimed that notified bodies or verification authorities require too much security, rendering the costs of the requested IT security inadequate. Or, on the

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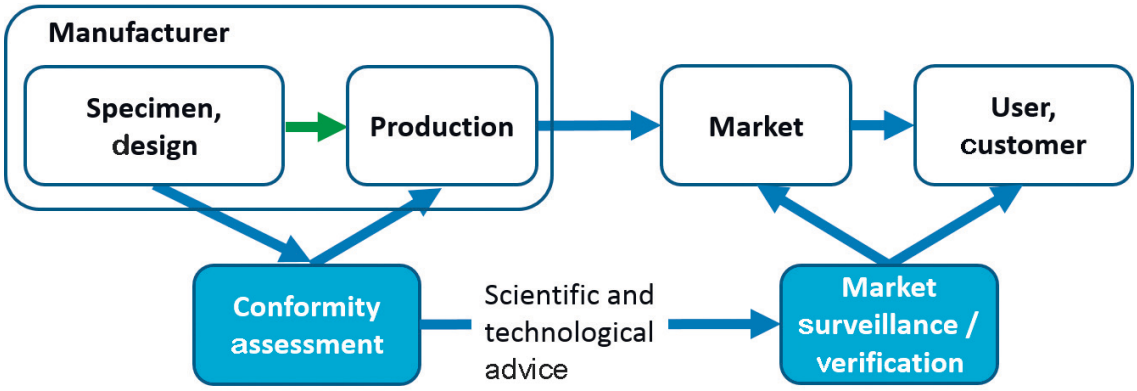

Figure 3:
The part of the quality infrastructure regarding conformity assessment and market surveillance.

contrary, they do not demand a sufficient security level which is to the detriment of the customer.

Additionally, the manufacturers object that the harmonization of processes in Europe needs to be developed to overcome barriers to trade. They feel that there is a lack of coherence in the way Member States carry out conformity assessment and verification of measurement instruments in the field, hence hampering a unified quality standard and the envisioned free flow of goods within the European single market.

The urgent needs of the manufacturers to streamline existing processes by exploiting the technological possibilities provide the guiding objectives that the initiative "European metrology cloud" will address.

4 The current situation

Legal metrology establishes confidence in the correctness of measurements and the protection of users of measuring instruments and their customers. The legal framework defines a quality infrastructure, which supervises the integration of new products in the market and also encompasses the product design and the subsequent production, the placing on the market and finally the use of the product. This supervision is shared by national notified bodies, market surveillance authorities and verification authorities.

Notified bodies assess the conformity of the design and the production to the essential requirements, whereas the market and user surveillance bodies supervise the placing on the market and the correct use of the instruments. The verification and inspection authorities are tasked with the re-verification and inspection of the instrument, respectively. In this way, a chain of trust is established, stretching from the development phase via production to the instrument in use (see Figure 3).

Within this legal framework, a multitude of processes are defined and established in a certain way, applying traditional communication paths. These processes include the exchange of information between partners. Examples are the documentation of the instrument design provided by the manufacturer during the assessment of conformity at the notified body, communication between the market surveillance body and the manufacturer when the instrument is put into use, or correspondence between the manufacturer and the verification authorities during the re-verification phase after the repair of an instrument. The interaction within these processes is currently not based on state-of-the-art communication paths or coordinated via platforms. Furthermore, an obligation for collecting specific data of the instruments for each role in this context has been set up. The notified body may keep a database of the tests during conformity assessments and documentation of all the individual instruments carried out by them. This is highly sensitive information. Another example is the performance data of a measuring instrument. The manufacturers shall carry out sample testing of measuring instruments made available on the market, investigate and keep a register of complaints, of non-conforming measuring instruments and of measuring instrument recalls, and shall keep distributors informed of any such monitoring. Data the market surveillance authorities shall collect include the data necessary for the identification of the non-compliant measuring instrument, the origin of the measuring instrument, the nature of the non-compliance alleged and the risk involved, the nature and duration of the national measures taken and the arguments put forward by the relevant economic operator. Retrieving data from metrology databases is done on request in the traditional ways based on queries carried out by the keeper of the database as an intermediator, and transferred back by this role to the requestor. Direct queries by an authorized partner upon data provided by the partners have not been established so far. There are several processes in place where a large number of different partners are involved and their agreement is needed based on different actions which have to be carried out before a final process could be initiated. A prominent example is the change, repair or update of legally relevant software. There are good prospects for streamlining such a process if it is rendered digital via a platform.

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4.1 Seizing the chances of digitalization

Seizing the chances of digitalization could resolve existing obstacles for innovation within the analogue quality infrastructure set up by legal metrology and foster its digital transformation. The rapid change towards digital approaches is facilitated by the developing information technologies and global political initiatives which foster a data-driven digital market, e.g. by the G20 [OECD2017], the European Commission [COM2014/442] [COM2014/25] and nationally [BR2014]. These initiatives recommend supporting innovative products and joining existing infrastructures and databases via appropriate platforms.

To remove the barriers to innovations within the regulated processes and non-harmonized procedures in legal metrology, it is envisioned to use state-of-the-art digital technology to render those processes digitally for the sake of streamlining and harmonizing.

Conventional concentrated instruments will be replaced or amended towards a distributed hardware system together with virtualized software parts and data-based services. Such virtual measuring instruments allow data storage in a cloud infrastructure, combine those data with other data sources, offer measuring and processing software in the cloud as "software as a service" (SaaS) and provide access to the instrument or its parts via communication networks. On this basis, new technological and data-driven services are possible. For these distributed instruments, the manufacturers' associations in Europe ask for legally acceptable solutions, for they see an economic advantage in this transition which they would like to exploit [IT2017], [PC2017].

Since the required measurement accuracy of measuring instrument sensors is defined by law, its increase is no longer a case for business. Contemporary business and service models therefore address individual customer requirements which are determined based on user and/or non-legal instrument data and will trigger the increased provision of data-based services. For the billions of measuring instruments used on the EU single market, data volumes are generated during their life cycle from the approval and market surveillance processes as well as from the service the manufacturer provides. The size of these data volumes suggests that "big data" solutions could be used to create smart services that can simplify the processes – and therefore the work – of all parties involved. Especially the administrative data of the instrument could serve as one valuable database.

The key issues relevant in our framework are the use of existing infrastructures and databases and their merging via an appropriate platform and providing innovative products to fully benefit from these merged elements via this platform.

Therefore, our proposal for a European virtual quality infrastructure is based on the possibilities state-of-the-art information technologies offer, incorporating the potentialities of the existing distributed infrastructures and databases of the stakeholders, and aiming to improve the coordination in Europe by technology- and data-driven legal metrology services provided via an appropriate platform.

4.2 Objectives of the initiative

The four main objectives of the initiative which form the guiding frame for the work to be done are described in the following.

4.2.1 Objective 1: The trustworthy metrological core platform

The central aim of the initiative is to develop the trustworthy metrology "core" platform (TMC platform) for the European metrology cloud (see Figure 4).

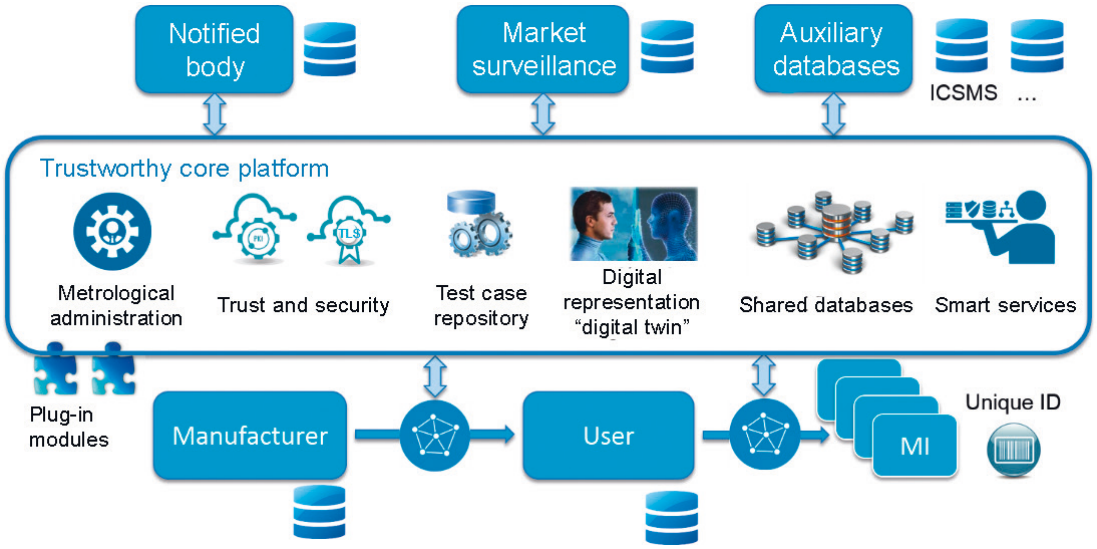

Figure 4:
The concept of the trustworthy metrological core platform. Plug-in modules could be, e.g. e-certificates for calibration, conformity or e-verification markings, etc.

This platform will serve to implement digital concepts for the coordination, concentration, simplification, harmonization and quality assurance of metrological services for the Member States and all parties involved. To this end, the platform consists of elementary modules which allow sharing of the existing databases and infrastructures. It guarantees interoperability, an adaptable level of trust and security, and provides trustworthy metrological administration as a service. In this way, the platform allows further services to be incorporated as "plug-in modules" which use the elementary elements.

This central, trustworthy national element is required for the joining of existing infrastructures and databases already in use by the stakeholders in the Member States. Due to their role and work over the last few decades, the **National Metrology Institutes**, i.e. the notified bodies, have built up confidence and trust in their work and inherent high reputation. The certificates granted and services provided by these institutions are considered a sign of quality – in several cases worldwide. Consequentially, the National Metrology Institutes are the suitable **impartial partner** in the field of legal metrology to host such a trustworthy metrological platform as an "**anchor of confidence**" and provide metrological administration. The trustworthy metrological administration of services, configurations and monitoring of activities running on the platform fills a gap, since the role of an administrator is not known in the legal metrology's regulations.

If different infrastructures are combined and data are exchanged, the question of standardization arises. The current Internet application domain has avoided the dominance of a very limited number of private or public parties. Its "hourglass model" with minimal, rigorous standards and protocols and maximum freedom of implementation has major advantages. It was strongly advised by the Commission High Level Expert Group on the European Open Science Cloud [COM/EOSC2016] to follow a similar approach to implement the European Open Science Cloud (EOSC) [COM/EOSC]. It will allow open and common implementation and so will prevent costly and time-consuming exercises to decide who has the best solutions. Instead, it will allow participation from all stakeholders. All providers, public and private, can start implementing prototype applications for the sharing of data and services on the day minimal standards and the minimal rules of engagement are released. For that purpose, platform independent and open platform communication interoperability standards already broadly applied, like the Open Platform OPC UA [OPCP2017] [BSI/OPC/2017], will be considered for the secure and reliable exchange of data to ensure the seamless flow of information among devices from multiple vendors.

The standards derived from the Mandate M/441 to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability and the Smart Grid Mandate M/490 issued by the European Commission and EFTA to develop a framework in the smart grid field will be considered in this approach [M/441] [M/490]. Additionally, Regulation (EU) No 910/2014 [COM2014/910] of the European Parliament and of the Council on electronic identification and trust services for electronic transactions in the internal market will be considered and the results from our former EMRP projects ENG04 SmartGrids and ENG63 GridSens will be incorporated in this initiative [ENG04], [ENG63]. For trustworthy authentication, existing approaches (public key infrastructure (PKI)) as well as new concepts based on utilizing, e.g. quantum key distribution (QKD), and non-hierarchical approaches taking physical unclonable functions (PUFs) and the blockchain paradigm into consideration will be investigated

Key challenges:

Based on essential use cases – defined in objectives 3 and 4 – the requirements for the interoperability of the platforms need to be defined, concepts to share confidential information between a subset of partners need to be developed and the feasibility of the functioning of each elementary platform module under experimental and real conditions should be proven.

The following elementary platform modules are needed: a module organizing the sharing of databases, and a module for the sharing of infrastructures. A further module should ensure sustainable trust and security and the last elementary module will be responsible for trustworthy metrological administration.

The digital representation of the measurement instrument – the "digital twin" – from objective 3, will be the central communicative element for the different infrastructures, partners and for each type of measuring instrument and will therefore define the basic requirements to be realized.

Since part of the quality infrastructure set up by European legislation is under the sovereignty of the Member States, e.g. verification of the measurement in use, the national realizations will differ. These differences will be identified and a common technological approach will be set up. In that way, the platform developed in this project can serve as a blueprint for the individual national platforms. These platforms can later be combined via a coordinating platform established and maintained by a board of Member States and industrial stakeholders.

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4.2.2 Objective 2: Reference architectures

The next aim is to provide and distribute knowledge via broadly applicable general reference architectures specifically for new and complex technologies fitting the needs of all stakeholders, i.e. the requirements established by the regulations. The IT infrastructure of measuring systems of the future will grow in size as well as complexity and encompass several new basic technologies according to the technology stack of an IoT system (see Figure 5). Legal metrology needs to cope with these separate technologies to provide metrological services for its customers and to support the market entry of innovations.

The process of conformity assessment and market surveillance will be optimized by the research carried out prototyping these architectures, on the risks involved and on how instruments can be verified in the field. The gained knowledge will help to mitigate the risks during these processes for future measuring instruments and will improve the competence of all partners involved.

Key challenges:

The main challenge for the general reference architectures, e.g. for the basic technologies like embedded devices (IoT) and distributed instruments, is to encompass the fulfilment of the essential requirements. These comprise a verification method which provides easy inspection of the meter in the market and exploration of contemporary risks and threats for measuring instruments via an adequate risk analysis. To make general reference architectures applicable for a specific class of instruments, e.g. for weighing instruments, heat meters, fuel dispensers, etc., they must fulfil additional instrument-specific requirements and need tailoring to the individual risk class (see Figure 6). The risk analysis, which considers contemporary threats and guarantees comparability throughout Europe, will be made available, and hence would also increase the competence of all partners involved. An agreed list of attack vectors, i.e. a scheme about how threats could be realized, is needed to guarantee comparability of the analysis between the manufacturers and the notified bodies.

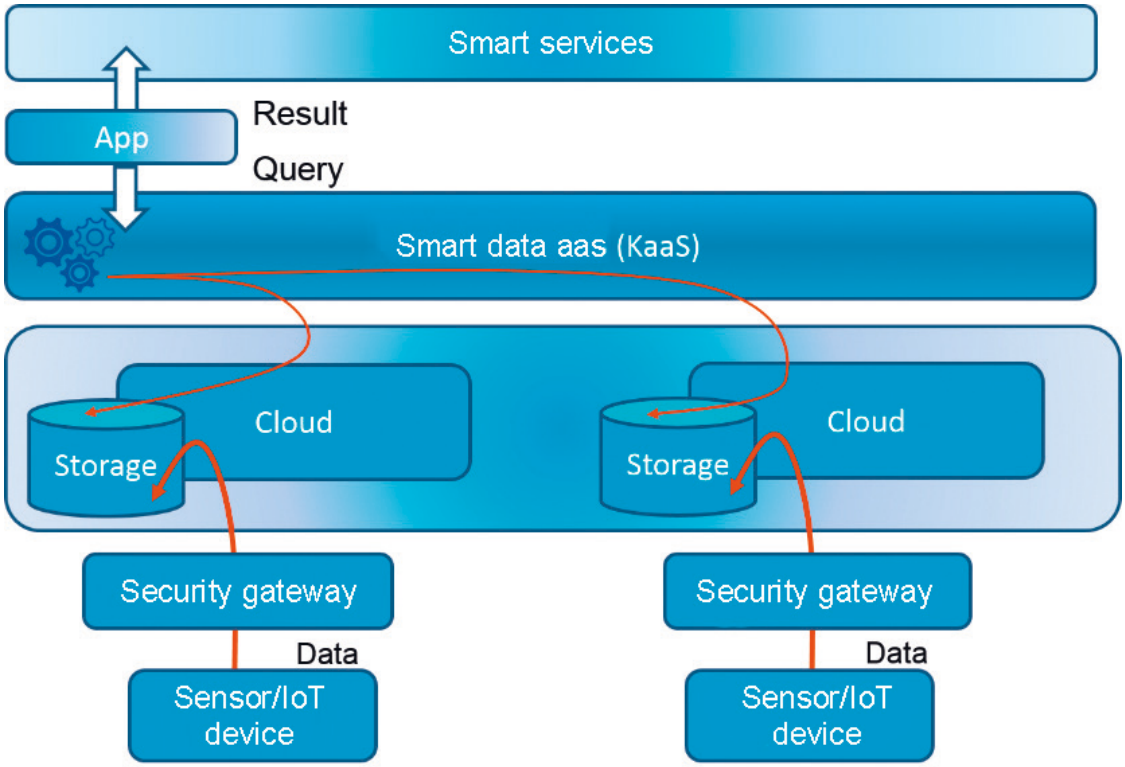

Figure 5:
The basic technology stack of an IoT system. KaaS: knowledge as a service.

For these basic technologies, general reference architectures will be developed and tested, e.g. against the "essential requirements" of the MID and contemporary threats. These architectures make full use of the future European digital quality infrastructure, offering easy verification of complex technologies, like cloud computing and interconnected embedded devices (Internet of Things) for market and user surveillance as well as for verification authorities. These innovative technologies open up new opportunities but also pose risks to the security of measuring instruments and radically change how society interacts with them. Therefore, the reference architectures will undergo an adequate risk assessment [ME2105] as required by Directives (2014/32/EU) and (2014/31/EU).

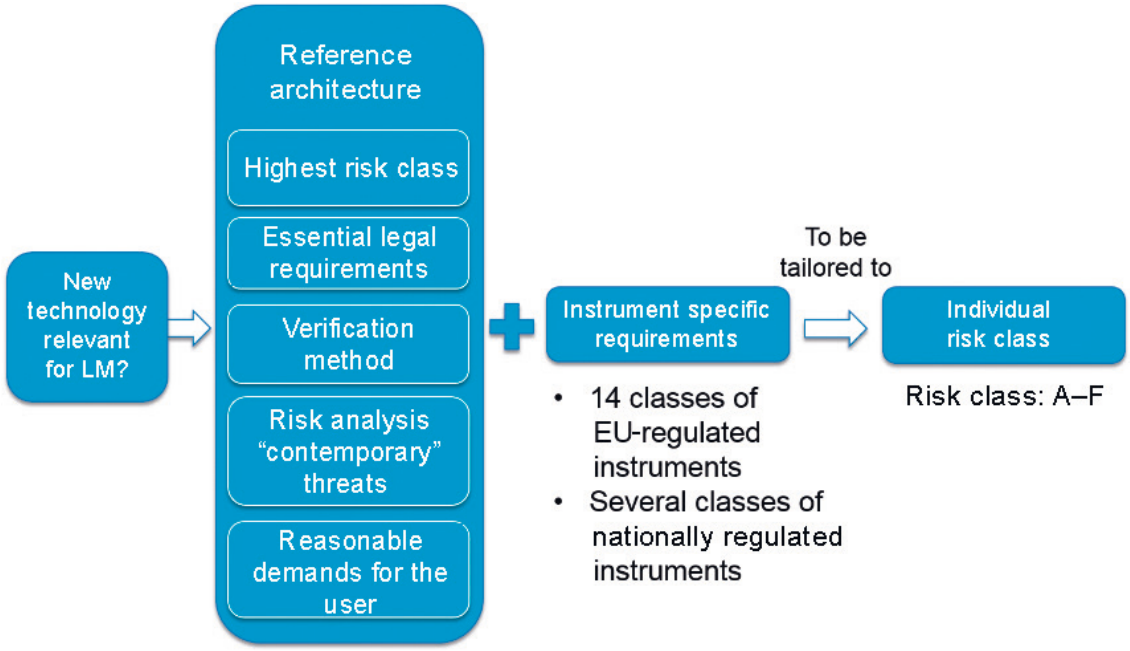

Figure 6: Requirements on a general reference architecture and the required additional steps for a specific class of instruments. LM: legal metrology.

4.2.3 Objective 3: Technology-driven metrological support services

There are several processes defined by European legislation coordinating the interaction of a large variety of partners in legal metrology which could be partly transformed in the digital domain. For instance, results could be made available in a central platform leading to the broader surveillance of meters, better planning of the processes and services and therefore leading to less downtime of the instrument for the user. From these legal processes, we have chosen certain ones for streamlining through digital support. The consortium considers that changing these processes would be most beneficial regarding the organization of market surveillance and verification, the services of notified bodies and manufacturers, as well as the needs of the users of measuring instruments.

The chosen use cases build on each other and consequentially the solution for one will support the subsequent ones. Use cases for the **repair of a measuring instrument and its subsequent verification**, based on digital representations, might allow the future **maintenance of software** in the instruments.

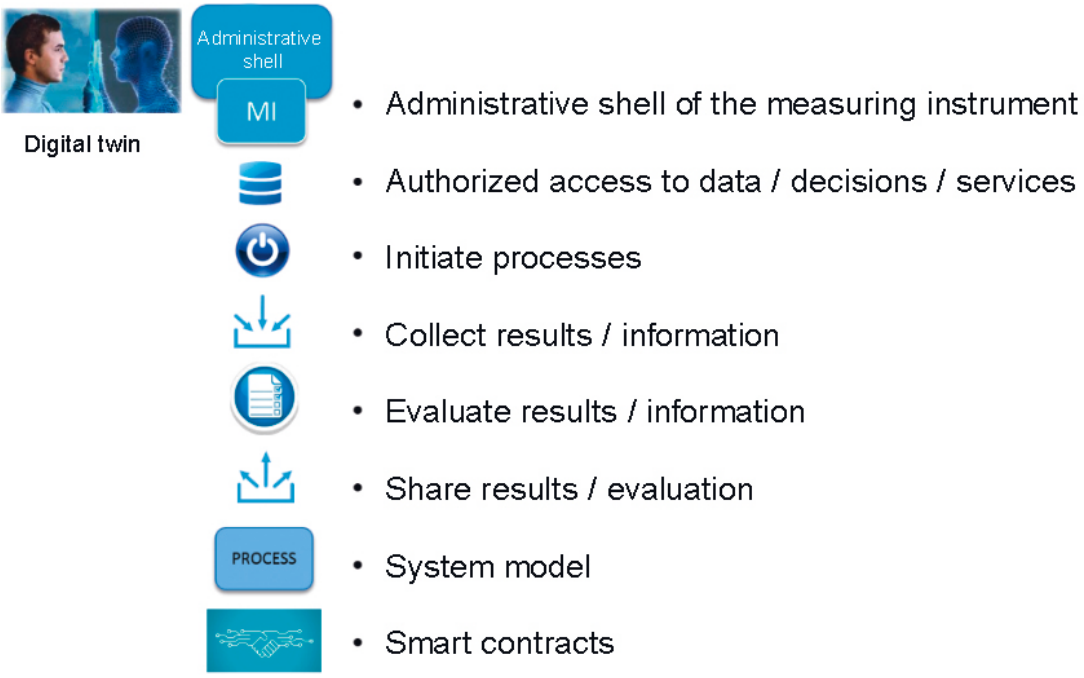

Figure 7: Functions the digital representation of the measurement instrument – the digital twin – might comprise.

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Key challenges:

The development of a digital representation of the measuring instrument is vital for the realization (see Figure 7).

This **digital representation** is a hierarchical database which should contain administrative data and information about processes. It should collect data, evaluate data, disseminate data and initiate actions if certain conditions are fulfilled (for example, smart data services, such as smart contracts, i.e. condition-dependent legally binding decision-making, as proposed in objective 4). To this end, a **digital twin** should contain information on the type of instrument and, in a substructure, information concerning that particular instrument. It will also encompass authorization profiles, a log file and a digital sensor or system model of the instrument. This representation will implement the selective sharing of information between authorized partners already established in the analogue world and needs to be developed and tested within the new core platform with special use cases. The challenges for the digital "**support of repair**" and "**support of verification**" as well as the "streamlining of software maintenance" will be considered. This should include the repair by the service technician, remote diagnosis of the repair, indication and information of the verification authority, as well as initial remote testing and subsequent evaluation by the authority and planning of the local test of the physical sensor within the proposed trustworthy core platform (see Figure 8). Further concepts of streamlining by digital methods will be explored for all stakeholders' benefits, focusing on remote testing modules of the logical part of the digital representation of the instrument.

A selection of types of requests or tests to support verification and inspection might be – in order of complexity – the following: requests of protocols of log files, initiation of runtime integrity tests of the whole system or individual system modules or the whole file system, results of the permanent condition monitoring of the instruments, the application of fixed test cases for the individual logical modules and finally specific test data generated during runtime by the logical system model

4.2.4 Objective 4: Data-driven metrological support services

The aim is to develop data-based services for legal metrology, a theoretical approach taking advantage of the available data sources created by all stakeholders. For the billions of measuring instruments used on the EU single market, data volumes are generated during the complete life cycle of these instruments from their approval and market surveillance processes as well as from the service the manufacturer provides. These data can be distinguished in the main categories: measurement data, administrative data and service data (see Figure 9). Service data represent data which are, e.g., collected by the manufacturers to coordinate their maintenance services in order to guarantee a constant quality level.

It will be investigated how new services and processes could be derived or existing services could be streamlined using merged data from different sources. The focus of the data collecting process will especially be on data provided from the administrative and service data, since these data hold the potential to make the existing processes even more efficient or could be elevated to be accepted within or to add value to legal metrology.

Key challenges:

To investigate the potentials of combined data from different sources, a **metrological data lake** should be established. After identifying the essential questions to be answered by the data lake, appropriate methods should be identified to transfer these questions to the "machine" to interpret answers into smart data concepts. To this end, contemporary methods, such as data mining, information retrieval and machine learning will be applied

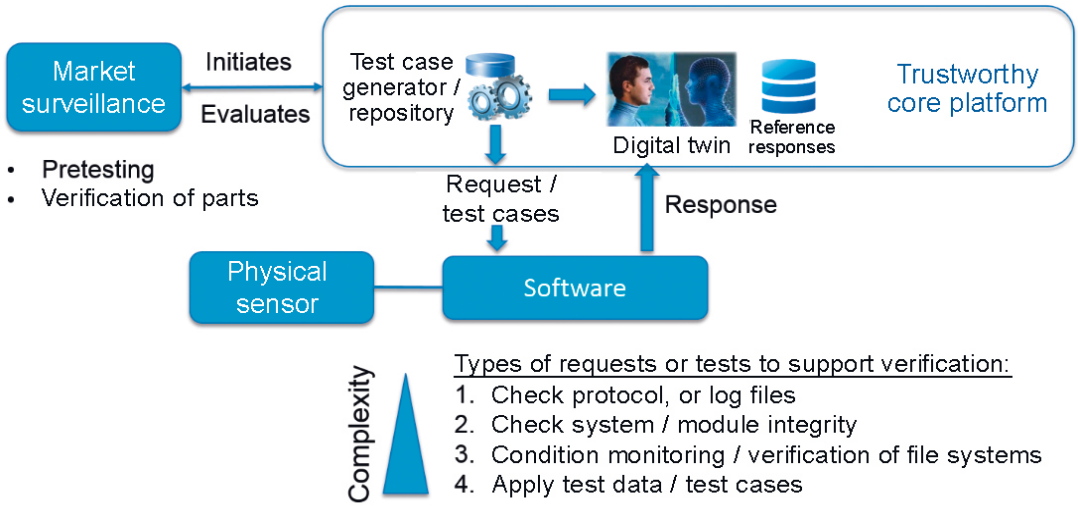

Figure 8:
The use cases for the digital "support of repair" and the "support of verification" as well as the "streamlining of software maintenance" based on pretesting or verification of parts.

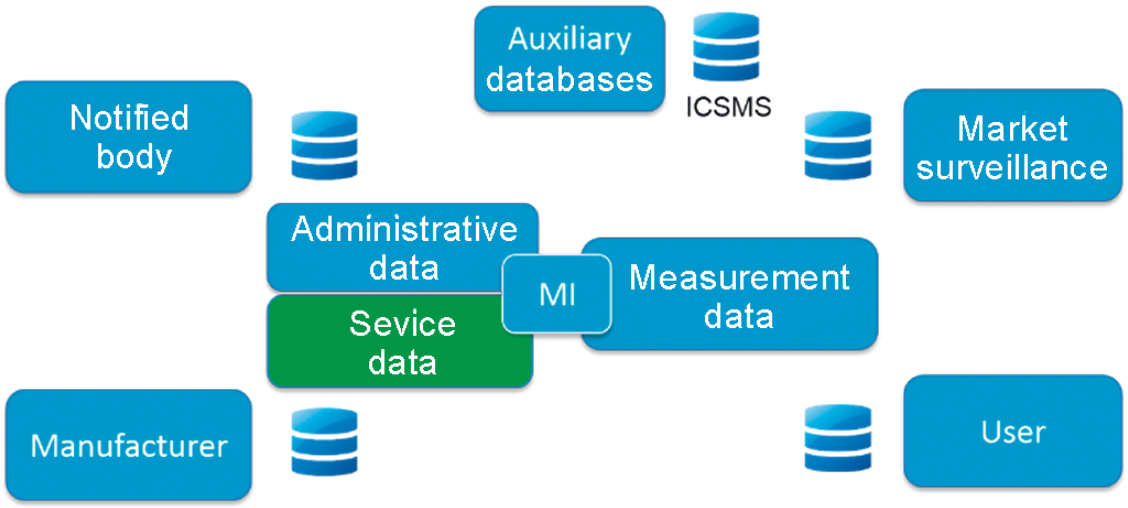

Figure 9:
Major data sources available from the stakeholders and the measuring instrument (MI) which could be part of the metrological data lake. ICSMS: information and communication system for pan-European market surveillance. Auxiliary pan-European and national databases are also shown.

and investigated to extract knowledge to propose the potential creation of smart data services.

Concurrently, we will focus on those services that all stakeholders consider the most beneficial to be supported digitally. These are the usage of **service data as added value** for market surveillance and the introduction of smart data concepts in legal metrology, e.g. **smart contracts**. Such smart contracting, i.e. the initiation of a process based on the fulfilment of conditions or the availability of information, will also help to simplify and speed up several processes where several partners are involved.

How the information originated from the market can be incorporated into the risk assessment method proposed by WELMEC WG7 is an open question. But both the experiences from manufacturers of measuring instruments, obliged to collect such information, and from the market surveillance bodies and their own national databases will aid a European incident database that will be potentially used via the trustworthy metrology core platform, to **close the risk assessment** loop between design, and the market and provide useful new information to all stakeholders.

In order to ensure efficient exchanges of information among authorities in the EU, an online platform (Information and Communication System on Market Surveillance, ICSMS) has been established. This platform helps market surveillance authorities exchange information, but also serves purposes of consumer information. It offers the public information about exceeded limit values and non-conformity with substance prohibitions. In addition, consumers can use the platform's search tool to research the national authorities responsible for market surveillance based on product type and location. Such databases and platforms provided on the national and the European level should be included as well.

5 Expected impact

The role of digital networks as an accelerator of development has been recognized globally, and due to its critical importance to the three pillars of development – economic development, social inclusion and environmental protection – the task of making the Internet universal and affordable was approved as a target of the United Nations' Sustainable Development Goals, echoing the objective already elaborated by the United Nations' Broadband Commission for Sustainable Development [OECD2017]. At this still early stage, legal metrology may have a unique opportunity to help usher in the IoT, an enabling environment that both promotes its many benefits and addresses the challenges.

5.1 Impact on the industrial community

The envisioned early impact of this project on the industrial community is aimed at **driving innovation** in legal metrology and facilitating new or significantly improved regulated measuring instruments through exploiting knowledge in the European measurement institutes. These innovations will improve competitiveness and sustainability, and enable the digitization of European industry active in legal metrology and will lead to increased economic turnover.

The realization of the trustworthy metrological core platform is designed for aggregation of existing data and infrastructures of the participating stakeholders to demonstrate the feasibility of the approach and is the foundation for a realistic concept for a pan-European IT infrastructure for legal metrology. The participating manufacturers and other stakeholders in legal metrology benefit from the **advantage of being the first** to set up, test, use and amend this infrastructure, e.g. to speed up existing processes and therefore reduce downtime of the instruments – which can sum

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up to several hundred thousand euros per day for instruments installed in high throughput industrial production – and improve service quality while saving costs and using their limited personnel resources more effectively.

This will set up an initial quality infrastructure for data to prove the feasibility of the approach and to allow other infrastructures to easily join it. Concurrently, reference architectures will be made available for the highest priority technologies, such as IoT devices, cloud computing or intelligent meters. The developed reference architectures will streamline risk assessment and verification in the field, thus helping SMEs to take part or even enter the digital market faster. Data which provide added value in legal metrology will reduce governmental burdens, and a realistic dynamic risk assessment concept will reduce the cost of the required security implementation down to an adequate level.

Based on these reference architectures, metrological IT services will be made available, such as remote verification and the maintenance of measuring instruments (as the foundation for many other possible services). Data obtained from the administrative data and the service of each individual measuring instrument in service (and of all instruments of the same type) throughout its life cycle will be used to provide smart, data-based metrological services to stakeholders with the aim of optimizing administrative processes. These architectures and services lay the foundation for the advancement of the quality infrastructure created within this project and serve as an attractor for further NMIs, manufacturers and verification authorities throughout Europe.

5.2 Impact on the metrological communities

This initiative enables and promotes collaborative work in the most demanding fields of industrial metrology going beyond the state of the art. It will strengthen the **mutual cooperation of European NMIs,** leading to a **coordinated digital European metrology infrastructure** increasing cohesion within Europe. The reference architectures which will be developed within the course of the initiative will offer the European notified bodies solutions which are in line with the legal framework and provide market surveillance with easy verification methods to support their task without the need of in-depth expertise in the method. It will impact on the development of conformity assessment done by notified bodies and NMIs which carry out type approval, on authorities responsible for market surveillance or verification of instruments in use through the provision of harmonized digital services. This will significantly influence the way manufacturers, market surveillance authorities and notified bodies interact, and establishes a harmonization of procedures on a higher technological level setting up a unified quality standard.

On a broad scope, the initiative will strengthen the collaboration of European NMIs and will increase their competitiveness with NMIs outside Europe. In the area of metrological IT, knowledge transfer between NMIs will support the **building of capacity regarding new technologies**. Secondly, market surveillance and verification authorities will also gain improved services from the platform which will avoid the high costs and associated downtime associated with the verification and in-service control of the instruments abroad. It will also increase the market surveillance's verification capabilities. Furthermore, European industry may use the results of the research as support when new measuring instruments and measuring systems are to be designed.

5.3 Impact on relevant standards

The industrial project partners or collaborators are the most direct and immediate up-takers. They will incorporate the outcome in their current and future work, spreading it to their customers and users. The initiative is designed such that the relevant standardization committees for software in legal metrology (WELMEC WG 7 "*Software*" and OIML TC5/SC2 "*Software*") will be informed about its progress. In that way, these committees will be actively involved to recommend further steps or investigations aiming for more beneficial results for all partners. Furthermore, this project is actively promoting the circulation of the following fundamental European and international guidance documents for software and ICT: WELMEC 7.2:2015 *Software Guide* and OIML D 31:2008 *General requirements for software controlled measuring instruments*. These harmonized standards will be amended with the help of the findings of the project.

These implications may for example be:

- the redefinition of risk classes according to the achieved results and their impact on the instrument-specific annexes of WELMEC Guide 7.2.,
- changes to the device classification,
- the introduction of module-related risk classes,
- an Annex for WELMEC Guide 7.2 and OIML D31 containing the reference architectures.

5.4 The long-term economic impact

The European manufacturers active in legal metrology will benefit directly from this initiative,

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for supporting the digital transformation of legal metrology will ensure that this sector will contribute with its actual share of the GDP of up to 6 % [DP2015] to the 250 billion euros the European Commission expects with cloud-friendly policies [IDC2012]. After its initial three-year phase, the concept for a pan-European IT infrastructure will be expanded by incorporating other existing infrastructures and, where possible, amended to include the opportunities presented by the developed reference architectures and the technology- and data-based metrological services. Industrial and other users are expected to take up the findings in a very short time towards the end of the project or soon after its completion. This is assured by the partners of the consortium and by those who will actively participate in a **stakeholder advisory board**.

The harmonized standards will be amended with the help of the findings of the initiative. By doing so, beneficial concepts and findings will be made available internationally. The OECD [OECD2017] also recommends that governments should consider **updating laws** to address factors that unnecessarily make working through online platforms less attractive: the lack of clarity in certain regulations, tax issues that emerge with the proliferation of small revenues earned via platforms, and consumer and privacy protection of online participants. Therefore, the outcomes of this project will be used to demonstrate that new concepts are in line with the aims of protection of the New Approach and should be used to initiate processes to **future proof legislation** and to **reduce governmental burdens**.

5.5 Social impact

One focus of legal metrology is to protect the consumer and user of a measuring instrument. The possibilities new technologies offer allow novel concepts for measuring instruments which the manufacturers intend to apply. Contemporary measuring instruments are in most cases "concentrated" systems comprising all of their features at the measuring site or close by. The development of measuring instruments, in view of the emerging technologies, is steering towards a "dissociated" instrument, where externalization is applied, i.e. parts are made available by virtualization. The base technologies and concepts for this change have matured in a way which requires more than an intuitive understanding to have **confidence in their correct functionality**. The growth of digital security risks to economic and social activities, including risks to the security of data assets, as well as concerns that privacy and personal data protection is being violated, reinforces the importance of the lack of trust in digital technologies and activities as another barrier to the adoption and use of digital technologies by firms, households and across society. These concerns will only become stronger with the introduction of newer, more advanced technologies and processes (e.g. cloud computing, data analytics, IoT) that will in turn raise additional challenges – most notably related to safety and liability. Therefore, to establish confidence in the correctness of measurements, there must be methods in place which guarantee an adequate level of security the consumer can trust in. At the same time, institutions, i.e. the notified bodies and NMIs, need to be able to guarantee this level. Only by establishing such methods, can confidence and acceptance of new technologies in the market be guaranteed. The initiative addresses this challenge, e.g. with the reference architectures.

At the same time, digital technologies are creating new opportunities for **skill development**. Seizing these opportunities requires a process of institutional learning, where actors in the field of legal metrology are given sufficient scope to experiment with new tools and the systematic assessment of outcomes leads to the selection of the most effective practices. This project will deliver such possibilities. Barriers to accessing these new technologies will be identified and addressed throughout the course of the initiative.

6 The initial consortium

For the quality and efficiency of the implementation, it is vital that the consortium engages all relevant stakeholder groups active in legal metrology on the European level, uses their knowledge, addresses their needs and makes the initiative's results accessible to them. Therefore, the initial consortium – which is coordinated by PTB – has gathered several NMIs deeply involved in conformity assessment and the certification of measuring instruments subject to legal control as notified bodies and/or as verification and inspection authorities (Germany (PTB), France (LNE), UK (NPL), Switzerland (METAS), Sweden (RISE), Czech Republic (CMI), Austria (BEV-PTP), Spain (CEM), and Portugal (IPQ)). Furthermore, these institutions and further collaborators (Ireland (NSAI), The Netherlands (Agentshap Telecom)) are also active as market surveillance authorities and verification bodies bringing in their expertise from measuring instruments in use. Consequentially, the practical experiences from industries developing measuring instruments should be regarded as well. Five European manufacturers' associations representing a relevant amount of measuring instruments in Europe, AQUA, CECIP, CECOD, FARECOGAZ, AQUA and VDMA will provide their expertise from the manufacturers' point of view and will guarantee that the solutions developed in this project are on a general level,

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so that whole classes of instruments will benefit from them. Nonetheless, to incorporate the link to real measuring instruments, the participation of individual manufacturers is inevitable and is guaranteed by the participation of S*artorius, Bizerba, Espera-Werke* and *Diehl Metering* which will develop demonstrators for different instrument classes within the course of the project. It will be the combined effort of the partners with technical and scientific excellence in all aspects of this initiative that will generate powerful synergies and lead to the successful conclusion of this joint research project. The scientific challenges which arise with the objectives of the initiative need competent partners which complement the expertise in the area of security and data science. Therefore, the chair for "Security in Telecommunications" (SECT) and the Berlin Big Data Center (BBDC), both from the Technical University of Berlin (TU Berlin), Germany, are taking part in the initiative. The Berlin Big Data Center pools expertise in scalable data management, data analytics, and big data applications, along with conducting fundamental research to develop novel and automatically scalable technologies capable of performing a "deep analysis" of "big data". The chair for "Security in Telecommunications" is part of the Telekom Innovation Laboratories, an institute of TU Berlin which closely collaborates with Deutsche Telekom AG. Research topics of SECT include virtualization technology, mobile communication standards, invasive and non-invasive circuit analysis and fault injection methods, cloud security, and physically unclonable functions.

Furthermore, TU Berlin, Faculty for Electrical Engineering and Computer Science, Institute of Software Engineering and Theoretical Computer Science and PTB have established the position of a Junior Professorship for the field of "Secure and trustworthy network connected system architectures". The position includes the leading a newly established junior research group at PTB. The position will be filled with a highly-motivated scientist by early 2018. The working field will be the development and implementation of excellent and highly innovative premarket research in the field of secure and trustworthy ICT systems in legal metrology. The commercial as well as social need for a contemporary applicability of novel technological approaches will be taken into account. The Junior Professorship is associated with the SECT group of Prof. Dr. J.-P. Seifert at TU Berlin.

7 Comparison with other European approaches

Due to current developments on the European level, the European Open Science Cloud (EOSC) [COM/EOSC], it seems appropriate to address the question of how our approach could learn from this activity.

There is a rapidly growing, worldwide consensus in the scientific community among science funders and policy makers that the transition to truly data-driven open science can only be achieved when we collectively build a globally interoperable research infrastructure. According to the EOSC report [COM/EOSC2016], this should be a "federated, globally accessible environment where researchers, innovators, companies and citizens can publish, find and re-use each other's data and tools for research, innovation and educational purposes".

Keeping in mind that in legal metrology, a restricted community exchanges sensitive information regarding regulated measuring instruments within legally guided processes to guarantee confidence in the correctness and traceability of the measurements and to protect the customer, it becomes obvious that the aims in the European metrology cloud (EMC) approach and the EOSC approach diverge.

Nonetheless, both concepts are based on a similar foundation: using existing infrastructures and databases and joining them via an appropriate platform. By providing innovative products which fully benefit from these merged elements via this platform, the EMC goes beyond this similarity. Furthermore, the standardization approach according to the "hourglass model" [COM/EOSC2016] with minimal, rigorous standards and protocols and maximum freedom of implementation is inherent in both concepts. It will allow all stakeholders to start implementing prototype applications for the sharing of data and services and for the secure and reliable exchange of data to ensure the seamless flow of information among devices from multiple vendors.

Therefore, we will follow the EOSC initiative and consider, where appropriate, their findings in the European metrology cloud.

8 Summary

To foster the digital transformation in legal metrology, PTB has initiated the development of a coordinated European digital quality infrastructure for innovative products and services; the "*European metrology cloud*". Its foundation lies in a trustworthy metrological core platform in each Member State, designed to support and streamline regulatory processes by joining existing infrastructures and databases and to provide a single point of contact for all stakeholders. Within this quality infrastructure, reference architectures, i.e. innovative measuring instruments, as well as technology- and data-driven digital services for legal metrology will be developed. The first outcomes

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of this initiative will be demonstrators to serve as blueprints for the individual national platforms to attract further stakeholders and services to be integrated and provide results to support or even initiate processes to future proof national and European legislation. These platforms can later be combined via a coordinating platform established and maintained by a board of Member States, authorities and industrial stakeholders. With these objectives, the initiative fosters the digital single market envisioned by the European Commission.

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