CFM | Creative Metrology

Creative Metrology in the world

Le groupe de travail Creative Metrology lancé par le Collège français de métrologie en 2018 continue son travail de veille et d'inventaire des pratiques actuelles et de leurs évolutions afin de dresser un portrait de la métrologie du futur. Dans cette édition de CEM, nous proposons deux interviews d'experts étrangers qui présentent leur vision de la métrologie du futur dans l'industrie 4.0. D'une part, Jan-Theodor Janssen, directeur de recherche au NPL anglais et d'autre part Sascha Eichstädt scientifique et évangéliste digital au PTB allemand. Ils présentent comment les nouvelles technologies impactent le processus de mesure et la métrologie qui le sous-tend. Ils parlent d'impression 3D, de 5G, de l'IoT, des smart sensors, du traitement des datas, de digitalisation, d'intelligence artificielle, des technologies quantiques, du nouveau SI...

Ces thématiques seront largement reprises pendant le Congrès international de métrologie (CIM2019) qui aura lieu à Paris du 24 au 26 Septembre prochain. On les retrouvera notamment lors des tables rondes (capteurs intelligents pour une production optimisée, sécurité et traçabilité de la chaine de mesure, fabrication additive: les défis mesure et contrôle...) et lors des sessions de presentations orales (IoT: défis pour l'étalonnage, traitement des datas métrologie, SI et maintenant ?). JT Janssen et Sascha Eichstädt sont impliqués respectivement dans le comité scientifique et technique et dans le comité d'organisation du congrès CIM2019.

La mesure est au centre de l'industrie 4.0. Nos voisins européens l'ont bien compris. Le think tank Creative Metrology vous présente ici leur vision ●

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Interview of Dr. Jan-Theodoor Janssen, Research Director at NPL (UK)

Dr. Jan-Theodoor (JT) Janssen was born in the Netherlands. He joined NPL in 1998, where he was responsible for the research on quantum electrical standards. At NPL, his research involves a wide range of topics in solid-state physics applied to electrical metrology. He has co-authored more 100 scientific publications on these topics.

In 2015, JT launched and now heads the National Graphene Metrology Centre (NGMC), whose role it is to develop metrology and standardisation for the nascent graphene industry. JT is also a Scientific Co-Director of the Quantum Metrology Institute (QMI), which covers all of NPL's leading-edge quantum science and metrology research and provides the expertise and facilities needed for academia and industry to test, validate and ultimately commercialise new quantum research and technologies. From 2015 to 2017, JT was the Head of Science at NPL for SI Metrology. In this role he was leading in the strategic rebalancing of the NPL science portfolio.

From 2008 to 2016, JT was the contact person for NPL on the Technical Committee for Electricity and Magnetism (TC-EM) of the European Association of National Metrology Institutes (EURAMET), and convenor of the EURAMET DC quantum metrology experts group from 2010-2016, and a member of several international working groups. In 2017, JT was appointed as NPL's Director of Research.

How would you define the mission of NPL?
Jan-Theodoor Janssen: The National Physical Laboratory (NPL) is the UK's National Measurement Institute, and is a world-leading centre of excellence in developing and applying the most accurate measurement standards, and science and technology.

NPL is funded partly (50/50) by public funding and commercial research income. NPL is working hand-in-hand with industry and universities and has more than 200 co-supervised PhD students shared between NPL and around 75 different universities.

NPL has defined its scientific roadmap by identifying four major themes impacting society: Digital, Advanced manufacturing, Health and Life Sciences, Energy and Environment. From these themes, NPL has identified challenges related to metrology and a scientific program to tackle these challenges, with a short time scale (3 years) for very applicative problems and a long-time scale (10-15 years) for more fundamental issues.

For example, in the domain of health sciences: pharmaceutical companies develop new medicines at a very expensive cost (estimated cost of 1.5 billion pounds to develop a new drug). The challenge here is to determine as soon as possible which drugs may be effective from those who are not (i.e. you need to decide as quickly as possible whether a drug is going to work or not so that if it isn't going to work you can save time and money and move to another drug). Within a consortium of research laboratories (some funded by Cancer Research UK and the research councils) and medtech companies like GSK, NPL is developing new instrumental tools based on mass spectrometry imaging to monitor how drugs penetrates inside cells. Such physical based techniques give invaluable information and allow researchers to better understand how cancer and drugs work.

Which role plays metrology in Industry 4.0?
Jan-Theodoor Janssen: Industry 4.0 is strongly related to digital manufacturing. The key words are greater automation, better connectivity, better data processing with AI and less prototyping, using additive manufacturing, and better efficiency.

The role of metrology is key: greater automation needs measurement standards that should be available on the production site. For example, for its production, if a company needs a voltmeter, this voltmeter has to come back to NPL on a regular basis for calibration purposes. This is a loss of time and money, impacting strongly on production efficiency. Also such a calibration chain involves many steps at each of which some accuracy is lost and so the voltmeter at the factory site will have much lower uncertainty than is technically possible.

With the new SI, we are observing a paradigm shift with the possibility of having local primary standards. Of course, several issues have to be solved, above all traceability but the change has started. For mass

measurements, MEMS (Micro Electro Mechanical Systems) devices are allowing the development of miniature balances. This is of great importance for instance for personalized medicine.

What main technological innovations/breakthroughs have had or will have an impact in a near future on metrology?
Jan-Theodoor Janssen: Technological innovations are always a step ahead and we as metrologists must follow their development and adapt the measurement tools accordingly. A good example is 5G. 5G will have a huge impact on industry, allowing high bandwidth connectivity; all sensors being connected all the time. But 5G is operating in the 20-60 GHz frequency range where metrology is not so well defined yet. We are working hard to be prepared, from the metrological point of view, when 5G will be deployed.

Another example is additive manufacturing and 3D printing which is developing for some years now, everywhere in the industry. But many unknowns remain concerning the 3D printed objects: How do they age? How do they break? There are unknowns also in the process and the raw materials: how to measure the properties of the powders like the grain size and purity of the material feedstock.

In the field of data science, with the development of IoT, more and more data is being produced, by various sources, from very accurate sensors to very cheap sensors. One key question is, what is the uncertainty of a measurement performed by such heterogeneous sources? In other words, how do we combine the data from very different sources? Standardization is necessary.

New ways of processing data also implies new metrological challenges. Artificial Intelligence is revolutionizing the way we use data. But how do we ensure that the data is used correctly by AI?
To answer these questions, we cannot work alone. This is why we, at NPL, launched collaborative activities like organizing a workshop on data traceability. We are also starting with NIST, PTB and BIPM an International program to address these kind of topics.

Last but not least, Quantum technology will soon revolutionize many aspects of industry, with quantum computers, quantum communications, quantum clocks, quantum sensors and, of course, this will require quantum metrology. In the UK, we have a Quantum Technology Initiative, which is linked to the European Quantum Flagship, under Euramet. The UK defined four quantum hubs each of them focusing on one specific aspect. Each hub is led by a university but external stakeholders are also present, for instance companies like e2v and MSQuarelasers. The role of NPL will be, amongst other things, to test & validate quantum technologies and quantum systems.

What are the main evolutions in the world of metrology that will have for you the biggest impact in industry?
Jan-Theodoor Janssen: It all depends on the time scale. On a short timescale, the big revolution is data science. On a long scale, the new SI should have a big impact, with this expected shift toward local primary standards. And in between lies quantum technology. The quantum supremacy over traditional computers is expected this year in 2019. Consequences should be visible soon but quantum technologies will reveal their impact on the industry on a longer time scale.

Do you see a specificity of a European metrology? What is for you the place of Europe in the world, from the metrological point of view?
Jan-Theodoor Janssen: First of all, it is important to recall that the UK is an active member of Euramet. The European labs have been working together in the frame of the European Metrology *Programme* for Innovation and Research (*EMPIR*).

Europe is leading the way in many different technological areas. This is the case in particular for smart grids and also in the metrology for the environment where Europe stands at the forefront. On the front of fundamental research, Europe has been leading research on graphene 2D materials, and quantum technologies. Many countries outside of Europe are quite envious of this effective collaboration.

Outside of Europe, we maintain very active relationships with NIST, in particular in the field of data science with a common workshop last year, and in the field of quantum technologies where NIST remains at the top of research with three Nobel Prizes. We also collaborate with other labs, in Canada, China and India. China in particular is developing very fast with lots of investments, a new site with new labs, and primary experiments. India is also growing but at a slower pace.

Are you aware of organizations/groups in your country but outside of your organization that are involved in the Metrology of the future or publications on this topic?
Jan-Theodoor Janssen: NPL is not the only actor in the UK on the metrological field. Other laboratories also play a role such as LGC in chemistry and biology, the British Standard Institute (BSI) mainly working on standardization issues, the National Engineering Lab (NEL) on flow technology for the oil and gas industry. In the UK there are also Catapults, these are institutes inspired by the German Fraunhofer institutes and active on industry 4.0 topics, medicine, and space. NPL also has a commitment on the creation of spinoffs, like for instance FootprintMedical which is developing sensors for temperature measurements to prevent foot ulcers in diabetic patients.

For the coming challenges, the new European metrology networks will be very important. Euramet is playing a key role bringing together NMI (National Metrology Institutes) who wish to integrate more with industrial stakeholders.

*Interview with Sascha Eichstädt, Scientist and Digitalization Evangelist at PTB**

Who are you? What is your mission and the mission of the structure you are working for?
Sascha Eichstädt: PTB's mission is to ensure confidence in any measured data. This mission has been already over 130 years ago and has been further developed over time. In the future, confidence in measured data will be of vital importance in a digitalized world where data is processed automatically.

I am a mathematician with a PhD in theoretical physics. I started my career at PTB in measurement analysis in 2008. My initial scientific expertise is in the field of applied mathematics, in particular time-dependent measurements. For the past 2 years, I have been leading the working group coordinating the digitalization efforts at PTB. I work in an interdisciplinary manner with all the divisions in PTB: on mechanical instruments, measuring forces, torque, pressure, photometry for measuring the performance of photovoltaic cells, in the electrical domain, on flow measurements, etc.

Wherever a research group is working on topics related to digitalization, the job of my group is to ensure that their work is consistent with that of other groups. This relates to the evolution of measurements and measurands as well as the automation of measurements and other areas. In this way, my group coordinates and links up the developments of the many groups within PTB working on metrology for digitalization.

What role does metrology play in Industry 4.0?
Sascha Eichstädt: In industry 4.0, everything starts with data: measuring data with sensors, analysing it with dedicated software and sharing data. Sensors are the connection between the real world and the virtual world; measurement data is thus the backbone of this scheme, and metrology provides confidence in data. PTB is coordinating a European R&D project "Communication and validation of smart data in IoT networks" on that matter.

An example of the work of PTB in industry 4.0 is camera-based dimensional measurement. This requires new approaches to traceability and calibration in order to ensure that measurements are reliable.

Another hot topic in metrology is sensors with a digital-only output that contains preprocessing. This requires, for instance, there is to be an external clock in order to have a traceable time stamping. PTB is coordinating a collaborative research project on this and a related topic, called "Metrology for the factory of the future" (EMPIR project) with NPL, LNE and other partners including industry stakeholders. One important outcome of the project is a calibration facility allowing dynamic calibration of digital-only sensors, with a mathematical model of the data flow that will be demonstrated in industrial testbeds in Germany and Scotland. Overall, this project will provide a metrological framework for industrial sensor networks ranging from the individual sensors to data analysis for the whole network.

What main technological innovations/breakthroughs have had or will have an impact on metrology in the near future?
Sascha Eichstädt: So many things are going on right now in the world of measurement and metrology. But if there is one we should consider, it is the impact of quantum technologies. We are entering a quantum metrology era. Quantum physics lies at the foundation of our understanding of what measurements are. And on the metrology front, we are shifting from the old SI to the new SI, which is a quantum SI.

PTB has been very active in quantum metrology for many years, for example through a national competence centre with the University of Hannover called QUEST, as well as research projects and excellence groups.

Another breakthrough is additive manufacturing, which is having a strong impact on metrology. Dimensional measurements are key for additive manufacturing, and require traditional dimensional metrology to be combined, for instance, with imaging through computer tomography.

What are the main developments in the world of metrology that you see as having the biggest impact on industry?
Sascha Eichstädt: In my view, digital services and innovative

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*Physikalisch-Technische Bundesanstalt, the National Metrology Institute of Germany

digital calibration will impact industry hugely if applied properly. And when I say innovative calibration services, I also mean in the way they will be communicated. I'm talking about digital certificates. An example of such a quality infrastructure is in place for legal metrology in the European Metrology Cloud initiative, coordinated by PTB. These developments started last year and it can be expected that over the next 3 to 5 years, this kind of infrastructure will form the basis for the legal metrology landscape in Europe. Furthermore, I'd expect that we will see digital certificates for conformity assessment, calibration and testing almost everywhere. The question will be how fast customers will adopt them. Metrologists need to work closely with customers to make sure that this happens.

Do you envisage a specific role for a European metrology? How do you see Europe's place in the world, from the metrological point of view?

Sascha Eichstädt: In Europe, we have several top-ranking metrological institutes: NPL, LNE, INRIM, PTB to name but a few. They are well-established and are seen as leading experts worldwide. EURAMET offers a very good and unique framework for the European NMIs and DIs, forming an equal partner to the American NIST, which is the largest NMI in the world. The National Institute of Metrology (NIM) in China plays the same role as NIST economically, although the institute itself is smaller. But they are growing fast, due to strong financial support from the government. PTB is also involved in several collaborations with the Chinese NMI.

Are you aware of organizations/groups in your country but outside your organization that are involved in the Metrology of the future, or publications on this topic?

Sascha Eichstädt: Most of the German sensor manufacturers are doing research, like HBM, Endress+Hauser, etc. Several large universities are performing research in metrology: Nuremberg, Erlangen, Braunschweig, Ilmenau. TU Ilmenau, for instance, is working on the first non-NMI version of a Planck balance, allowing primary measurements of the kg to be done anywhere. However, there is no equivalent to CFM in Germany. A few activities undertaken by CFM in France are conducted by PTB in Germany.

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