EURAMET
European Association of National Metrology Institutes

iMERA-Plus programme

Metrology projects for the collective benefit of Europe

Introduction

Measurement underpins virtually every aspect of our daily lives, helping to ensure quality and safety, to keep us healthy, to help us innovate and to keep our economy competitive. Our understanding of key issues such as climate change, the quality and safety of the food we eat, the air we breathe and the goods we buy, all rely on our ability to make ever better measurements. In industry, measurements are crucial for manufacturing, process control, telecommunications, transport and many other sectors, to ensure fair trade but also to remain competitive.

The iMERA-Plus programme brought together the metrology know-how of 33 organisations in 19 countries to work on 21 prioritised metrology projects for the collective benefit of all of Europe.

The programme focused European metrology resources towards targeted solutions to meet the needs of European stakeholders, increasing the scope of the activities and challenges addressed, reducing fragmentation of activities and resources, and increasing the impact of the research for stakeholders and end users, be it for industrial applications, in support of regulation and healthcare, or to underpin the international system of measurement units.

*The iMERA-Plus project **Power & Energy** developed new measurement instruments and methods to support an EU regulatory framework for electrical goods and power generation. The EMRP project **SmartGrid** then focused these developments on helping to maintain electricity quality as the grid evolves into a decentralised system capable of both giving and receiving energy from renewable sources.*

iMERA-Plus provided an ideal opportunity to trial many of the approaches and processes that were to later feature in the much larger European Metrology Research Programme (EMRP) – helping to shape the programme and bring good practice.

The EMRP went on to deliver a 400 M€ research programme from 2009 to 2013 delivering significant benefits that will be outlined in future publications. The success of iMERA-Plus meant that the EMRP had increased financial commitment from participating countries and additional organisations and countries joining the programme.

The European metrology dilemma

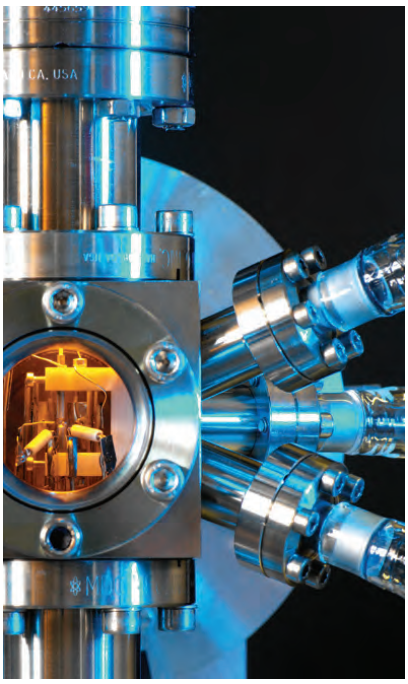
Practically all governments in advanced technological countries and many less developed countries support a measurement infrastructure because of the benefits it brings. In many countries national research programmes and activities respond to the demand for measurement standards of ever increasing accuracy, range and diversity, striving to improve that measurement capability. Although there are subtle national differences, broadly all have the same three core objectives to:

Drive innovation

Support sound policy and regulation (and thus to protect both the citizen and the environment)

Provide ever better tools for other scientific disciplines

The measurement infrastructure and the associated research are managed and delivered via the National Metrology Institutes (NMIs). The NMIs are additionally charged with ensuring the international system of measurement (SI) functions appropriately, including the primary realisations of the base units and the dissemination to stakeholders.



It is not practical to have just one clock from which the world derives its time, so the world time system is made up of over 250 atomic clocks that are constantly compared to create a stable timescale. All of these clocks, based in different countries, need to be able to work together to keep the accurate time that modern life depends upon.

Government priorities, financial pressures and metrology challenges

The current economic climate has meant that all European NMIs are facing financial pressures while trying to respond to increased demands. Our stakeholders are innovating and we have to provide cutting edge metrology R&D to keep up with and support them.

Regulation, quality of life, innovation and fair trade all require an effective and advancing metrology infrastructure. There are demands for wider scope and greater precision from traditional stakeholders (typically industry), a need to support emerging areas such as biotechnology and nanotechnology, and the greater demand from established areas such as food safety, clinical medicine, the environment and, more recently, security.

Many of the new or highest priority challenges affect most countries and require resources beyond those of an individual NMI or national metrology system. It was clear that realistic expectations on budget increases in the European NMIs would not be sufficient to resource the growing demands, stretching the available resources, and some areas faced the significant risk of becoming sub-critical, damaging the excellence of the research carried out.

Action was therefore required to address the so-called 'European metrology dilemma'. The metrology community needed to collaborate and join forces on projects that crossed national boundaries to meet the challenges we are all facing. 'Metrology in the European Research Area' (MERA) was proposed and launched to facilitate this collaboration.

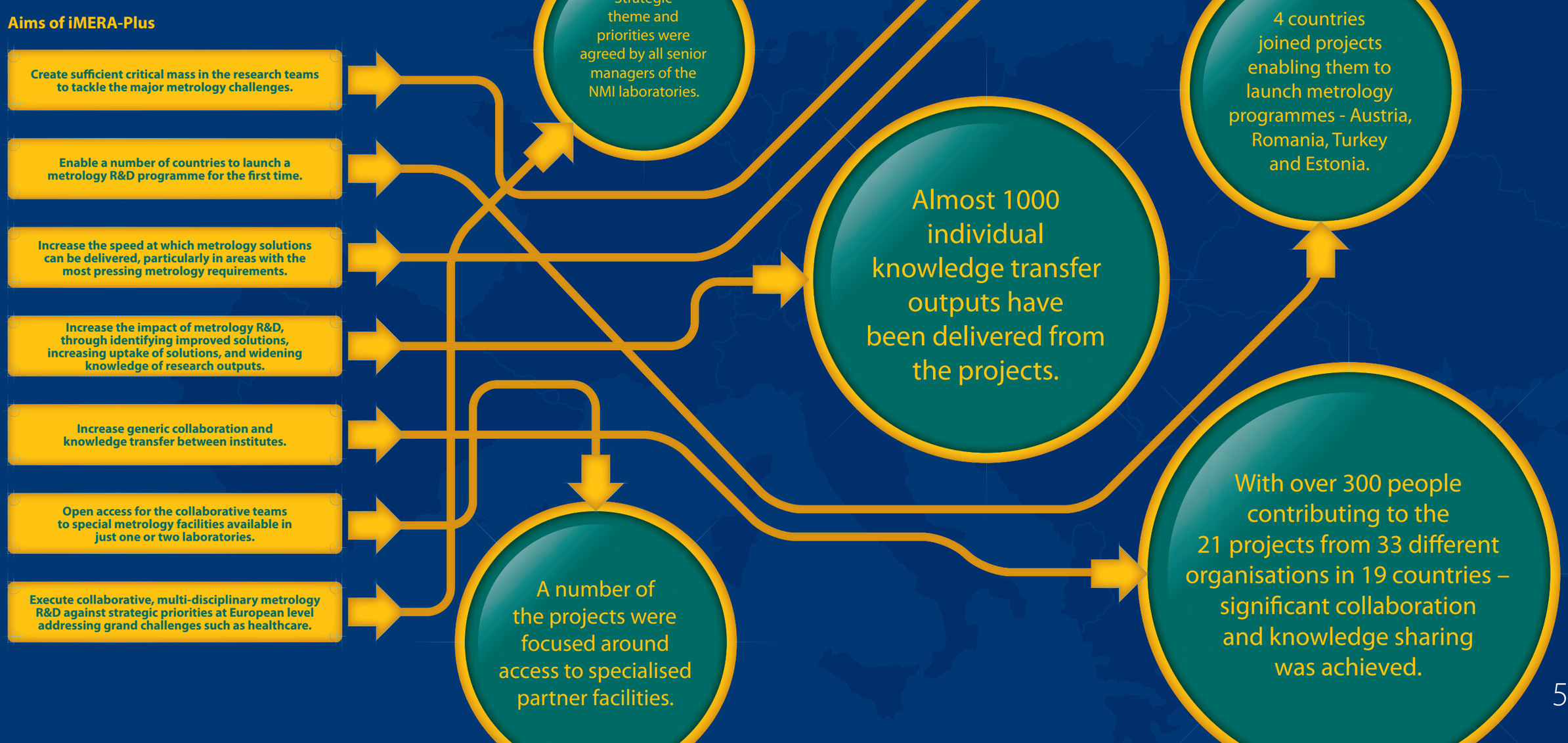
In essence iMERA-Plus was the first step towards switching metrology R&D from a broadly national-only activity, addressing essentially national issues, to a European activity bringing critical mass to bear and able to address major European socioeconomic issues.

Aims of iMERA-Plus

The direct objectives of iMERA-Plus were to deliver a series of joint research projects within four of the Targeted Themes that tackled the areas of most pressing metrological needs. These priority areas are sufficiently diverse to make best use of the wide expertise and capabilities within the metrology community and addressed projects prioritised by socioeconomic challenges rather than the traditional metrology SI Unit discipline. Each Theme selected covered an area identified as:

- Having urgent metrological needs identified in the iMERA roadmapping activity.
- Being prepared and able to collaborate within the iMERA-Plus project timetable.
- Having potential to demonstrate significant impact, both to the metrology community and to the EU as a whole.

The aim of the iMERA-Plus programme was to increase coordination between existing national metrology research and development resources.



*The **Power & Energy** project results could only have been achieved through intense collaboration. Every project partner contributed unique expertise. For the first time in the field of power and energy research, laboratories and researchers realised a common goal that they could not have reached individually - Two partners were involved in constructing current shunts, two others performed DC tests, a further two characterised the AC properties and one partner carried out computer modelling calculations. The project was monitored by an active stakeholder committee of more than 20 members throughout its full duration. This committee included standardisation bodies (including the IEC - International Electrotechnical Commission), manufacturers of electrical equipment and utilities. The stakeholders will ensure that power and energy measurement guides and guidelines will be implemented for use within the European Smart Grid system.*

The benefits of working in collaboration

The metrology community has always needed to collaborate internationally. Improved measurement ability can only support trade or regulation if all necessary parties can access that measurement locally – agreeing on how to measure and on the results of measurement across the world are the prime goals.

Previous projects that worked in partnership across the national metrology community made slow progress because the priorities were not agreed at a high enough level between the laboratories. iMERA-Plus changed this radically.

- For the first time, senior managers from the laboratories, the European Association of National Metrology Institutes (EURAMET) and other participating organisations took a strategic coordinated view of the most pressing challenges, discussed priorities and agreed the areas where they wanted to drive collaboration to realise the full benefits; this became a top-down imperative rather than a bottom-up activity.

- The financial commitment to the Programme was made up front by Member States and the decision making process for the choice of projects and the award of project funds was left to iMERA-Plus. The scale and scope of the funded projects (ranging in size from around 1.6 M€ - 4.6 M€) applied 'critical mass' to the prioritised areas - large teams tackled the priorities and made significant progress in a shorter timeframe than before.

- The senior managers reserved the resources necessary to ensure selected priorities could be delivered efficiently. They agreed a number of technical objectives, encouraged consortia to build proposals to deliver those objectives, and allowed a set of independent experts to select the best proposals. The funded projects were required to demonstrate excellent science, good management practice and good engagement with those that would take up the outputs of the project.

- The projects delivered one European solution rather than many national ones. When taken to regulators or standards bodies they came as agreed approaches – not as separate competing solutions that require further lengthy debate – speeding up the process significantly.

- The programme facilitated the sharing of knowledge and access to major facilities available at collaborators such as beamlines and power distribution networks.

- The programme included participants from a diverse range of countries in Europe, from the largest economies to smaller countries that have only recently joined the European Union. The funded projects included 5 organisations from 4 countries (Austria, Estonia, Romania and Turkey) that were launching a metrology R&D programme for the first time. In addition a further 7 participating organisations were from another 4 countries with relatively small or focused metrology capabilities or budgets. The programme, which covered multiple areas, enabled these organisations to participate in large collaborative projects in a few selected strategic research areas of national importance, making valued contributions to the projects in their specialist fields.

Impact of iMERA-Plus

The projects addressed a wide range of topics of importance to a diverse range of stakeholders, including regulators, industry, the healthcare sector, the metrology community, academic research, SMEs and the standardisation community. The impact of the programme was realised by three key mechanisms:

- Sharing knowledge though the publication of papers, conference presentations, workshops and websites.

  The joint projects delivered over 300 presentations and 90 posters at conferences, workshops and events in many countries, including across Europe, South Korea, the USA, China, Brazil, Australia, Argentina, Japan, Singapore and Russia; over 300 peer-reviewed papers were published in journals ranging from *Physical Review Letters to Metrologia*, with at least a further 50 submitted for publication; more than 150 articles and papers appeared in non-peer reviewed journals, conference proceedings and the popular press; 8 research theses were based upon projects; and the projects organised more than 45 workshops and 25 conferences between them.

- Improving measurement practice through the production of reference artefacts, the commercialisation of equipment or devices, the production of industry or sector specific guides or input to standardisation.

  The programme delivered 1 patent and 2 patent applications; 2 new calibrations services; 4 new standards; 2 new instruments, 2 good practice guides, contributed to 14 documentary standards; contributed to 3 external studies, provided techniques to respond to 5 regulations; and identified a number of other techniques that are in consideration for commercialisation.

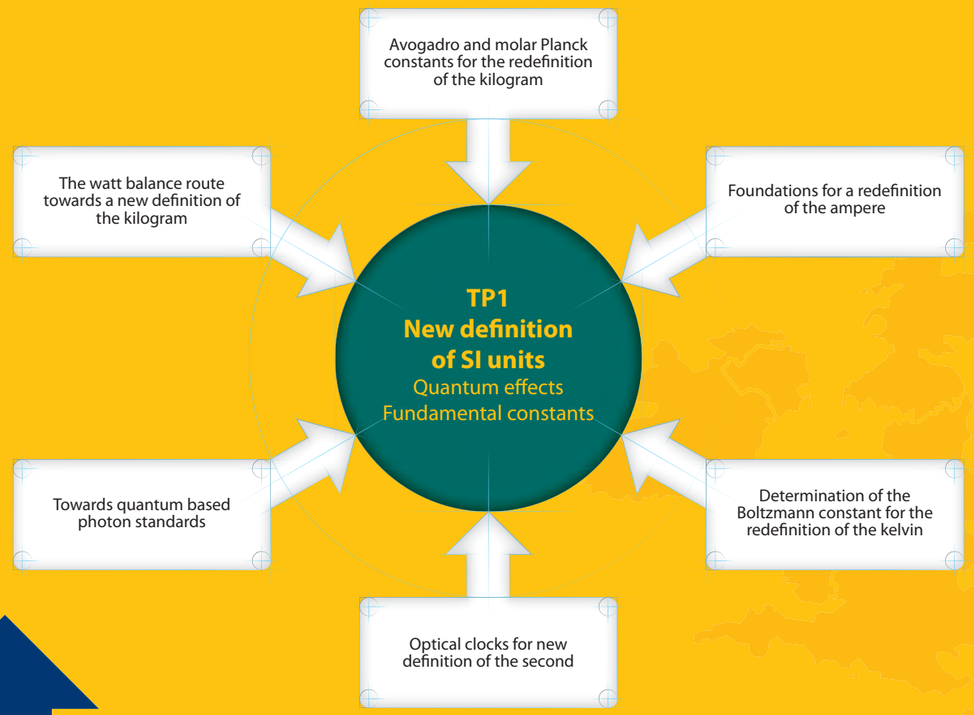
- Making a significant step change in scientific progress.

  While all the projects contributed to the metrology science base, a number of them also made a significant impact on the wider scientific community: the uncertainty associated with the measurement of the Boltzmann constant k was reduced by a factor of 1.5 and the results submitted to CODATA for evaluation. It is anticipated that as a result the final uncertainty for k will be reduced to a temperature equivalent of $u(k=1) \approx 0.25$ millikelvin, by the time of the redefinition of the kelvin; three strontium ion optical clocks were developed with significant improved frequency stability. The clocks will be at the heart of two future space missions: ACES/PHARAO and STE-QUEST; a new generation of quantum voltage systems for synthesising and measuring waveforms was established – thus enabling numerous previously unavailable calibration methods based on an intrinsically stable quantum effect (i.e. the Josephson Effect).

*The **NIMTech** project developed a large involute gear standard and a new multi-lateration measuring system to help industry assess the performance of large-scale measurement machines and make accurate measurements of complex parts. It also developed a new performance verification method for laser trackers that improves the available diagnostic information and reduces the verification time from 6-8 hours to 1 hour. This will greatly reduce downtime, leading to cost savings for businesses.*

*The **TRACEBIOACTIVITY** project developed new methods that were used in a European clinical trial on the possible use of selenium to lower the risk of prostate cancer, or slow its development. The project's new measurement procedures for ion activity were also submitted to the Joint Committee for Traceability in Laboratory Medicine (JCTLM), which will improve the traceability and comparability of measurements in clinical chemistry, a mandatory requirement of the In Vitro Diagnostic Medical Devices Directive.*

*The **Brachytherapy** project used new absorbed-dose-to-water standards to establish traceable measurements of radiation sources used in brachytherapy - a radiotherapy approach where small, sealed radioactive sources are placed inside or near to the area requiring treatment. These new standards will simplify existing measurements and should reduce the uncertainty in the dose for cancer treatment to below 5 %. This reduction in uncertainty will help improve the placement of the radioactive sources, leading to an increase in radiotherapy dose to tumours and improved cancer treatments.*



Theme 1 – SI and Fundamental Metrology

The SI and fundamental projects addressed some of the deepest challenges in metrology; providing answers for new standards that push forwards the boundaries in metrology for mass, current and temperature, light to the single photon level, and time to unimaginably small periods. The projects helped increase the precision and reliability of measurement at the very highest level, increasing our understanding of the fundamental physical constants, and support the redefinition of some of the units within the International System of measurements.

NAH – Avogadro and molar Planck constants for the redefinition of the kilogram

The mass of the platinum-iridium cylinder used to define the kilogram is changing as it ages, due to environmental factors, and a redefinition on the basis of a fundamental physical constant is needed. This project linked the kilogram to the atomic mass unit via the Avogadro constant, which specifies the number of atoms in one mole of substance. By calculating the volume taken up by each atom in a silicon sphere, it was possible to work out how many atoms were in the sphere and consequently in one mole. The project results will be exploited by the Committee on Data for Science and Technology and the International Committee for Weights and Measures to help redefine the kilogram.

Qu-Candela – Candela: Towards quantum-based photon standards

The candela is the SI base unit of luminous intensity. However, its definition is not linked to the concepts of modern physics that underpin the development of quantum optical technologies. This project developed new primary standards for photometry and a traceability chain based on the most widely used detectors – silicon photodiodes. These new standards are portable, cheaper and easier to use than current standards, making them more accessible to end-users such as National Metrology Institutes and LED manufacturers. The project also developed Predictable Quantum Efficient Detectors, which have been made commercially available by Fitecom Ltd, a Finnish service provider of measuring equipment.

Theme 2 - Health

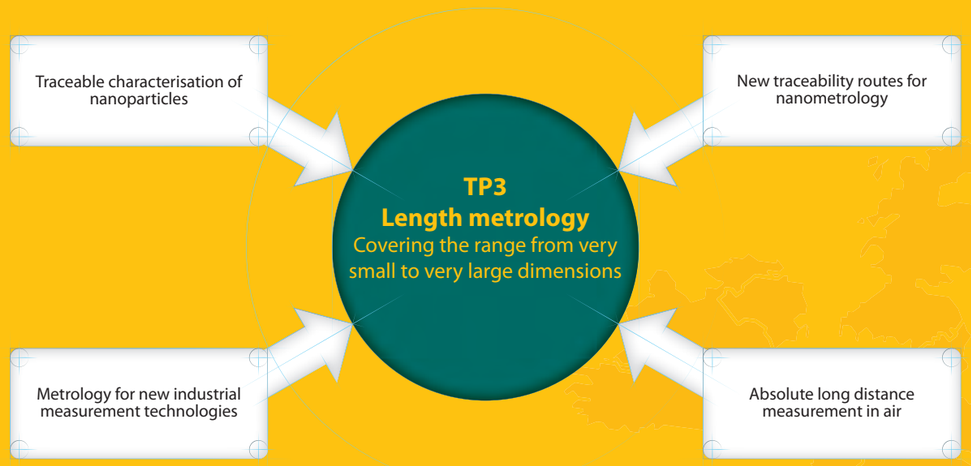
Metrology projects within the health area aimed to underpin new diagnostic tools for early disease detection, increasing our understanding of biomolecules and biomarkers, biospecies and ion activity underpinning clinical chemistry and clinical medicine. They accelerated the exploitation of new regenerative treatments and offered major improvements in the accuracy of external beam and implanted source cancer therapies. Research led to better measurement of field strength and specific absorbed dose for non-ionising radiation in support of the *Physical Agents Directive*, protecting workers from harmful electrical fields.

Breath Analysis – Breath analysis as a diagnostic tool for early disease detection

Early disease detection can literally mean the difference between life and death for patients with diseases such as cancer. New laser absorption spectroscopy techniques have led to the development of small, calibration-free devices for performing breath analysis tests to monitor volatile organic compounds in breath, as a diagnostic tool. This project successfully demonstrated the potential application of spectroscopic techniques in the medical field and the techniques and methods developed have resulted in improved measurement quality for medical trials. The project also supported the improvement of databases used to convert spectroscopic measurement data into gas compositions, expanding the benefits to those outside of medical breath analysis, for example, gas manufactures.

EBCT – External Beam Cancer Therapy

The International Commission on Radiation Units states that applied dose in radiotherapy should have an uncertainty of less than 2.5 %. New therapies such as high intensity therapeutic ultrasound pose a challenge for dose measurements because of the small size of the radiation field, which is limited in order to focus the dose on the tumour and spare healthy tissue. This project improved dosimetry for modern radiotherapy treatments, for example by developing better sensors for measuring spatial pressure distributions and total acoustic power of transducers. The project results have also supported dose verification studies in Belgium and the UK, undertaken in collaboration with healthcare organisations.



Theme 3 - Length

The length and dimensional metrology projects addressed precise and reliable measurement for the characterisation of nanoparticles, and the development of state-of-the-art traceable displacement measurements to drive the development of next generation ICT hardware. The enhanced capability developed in 3D metrology will improve the manufacture of large precision objects such as aircraft components. New, innovative methods will overcome limitations related to variations in the refractive index of air in precise optical measurement techniques for measuring distance over hundreds of metres.

NANOTRACE – New Traceability Routes for Nanometrology

There is increasing demand to measure smaller structures and components as nanotechnologies and ICT play increasingly prominent roles in modern life. Laser interferometry is a measurement tool widely used in the semiconductor industry but new production processes require reproducibility at a level of around 0.3 nanometres, which is currently not possible. This project aimed to reduce uncertainty values by an order of magnitude and produced six high-resolution interferometers, one of which can be used for the modelling and correction of interferometer non-linearity with 0.01 nanometre accuracy. The project also produced a phasemeter which can help improve the accuracy of other instruments such as atomic force microscopes and scanning electron microscopes, used widely throughout science and industry.

Long distance – Absolute long distance measurement in air

There is also increasing demand for measurements over larger distances, between 10 and 1000 metres, in particular within the aerospace, global monitoring and waste management industries. This project aimed to improve long range distance measurements in air to produce a relative accuracy of 10^{-7}, which is five times higher than before. Devices were produced for both indoor and outdoor distance measurements and there are ongoing discussions with measuring instrument manufacturers to commercialise these. Understanding the properties of air is vital for these types of measurements and the project also produced a prototype spectroscopic thermometer that has been used by Gasmet Technologies Inc in the development of a commercial oxygen analyser.

Theme 4 – Electricity and Magnetism

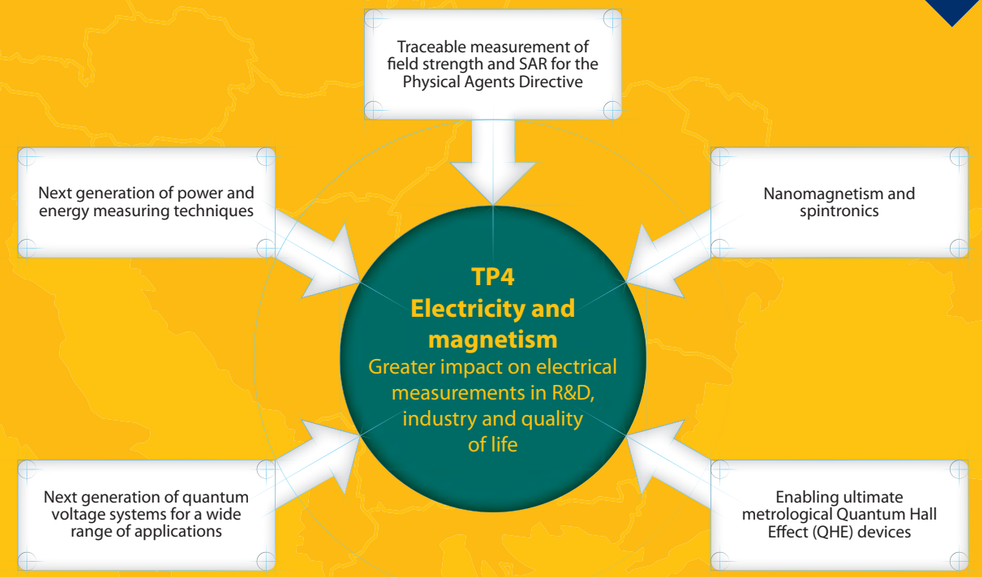
Metrology projects in the electrical and magnetic area helped to underpin the reliability of power distribution, as renewable generation increases its contribution to the grid, and also delved deeply into the esoteric world of nanomagnetism and spintronics. Electrical measurements are everywhere and, although most people would never be aware of it, new or improved quantum standards for AC current and improved quantum Hall resistance measurements offer rewards far and wide.

JOSY – Next generation of quantum voltage systems for wide range applications

The wider use of microelectronic circuits in control systems in commercial devices is improving the performance of mass produced items. However, these control systems can only perform as well as the electronic components inside them and the measurement equipment used to test them. This project established a new generation of quantum voltage systems to measure waveforms and enable new calibration methods based on the stable Josephson Effect. It also established methods for calibrating equipment such as thermal convertors, amplifiers and analogue-to-digital convertors. The quality of these new quantum-based voltage standards was demonstrated in an on-site test at an industrial location in Germany and their wider use will help improve the performance of the electronic devices that are so ubiquitous in modern life.

EMF and SAR – Traceable measurement of field strength and SAR for the Physical Agents Directive

The European Physical Agents (Electromagnetic Fields) Directive 2004/40/EC lays down the minimum requirements for the protection of workers from risks arising from exposure to electromagnetic fields and waves. However, the existing standards did not comprehensively cover the specific absorption rate at the necessary ranges. This project provided traceable standards, where there were previously none, for the calibration of sensors and established facilities for calibrating commercial probes at an extended frequency range. It also validated the use of a computer model called 'Virtual Family' which is used by communications companies to model electromagnetic fields and specific absorption rate with human subjects, when designing devices such as body-worn antennas.



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European Association of National Metrology Institutes

EURAMET coordinates the cooperation of the National Metrology Institutes of Europe in metrology research, traceability of measurements to the SI units, international recognition of national measurement standards and of the calibration and measurement capabilities of its members.

iMERA-Plus Management

iMERA-Plus was operated by the European Association of National Metrology Institutes (EURAMET), the Regional Metrology Organisation for Europe.

Resources from the National Metrology Institutes and the Designated Institutes from 19 European countries, plus the European Commission's measurement institute (IRMM), were pooled within a single joint call for metrology research projects. In total some 64.6 M€ of resources were brought together, with the European Commission providing 21 M€ of funding, with just over two thirds of the funding provided by the participating Member States.

In developing the iMERA-Plus programme it was important to understand and incorporate the wider stakeholder needs and to source input from outside the metrology community. As part of the process, consultation was undertaken through a series of stakeholder workshops and focus groups covering health, energy, environment and security. The workshops included representatives from the medical profession, the Medical Research Council, the pharmaceutical industry, the Joint Committee on Traceability in Laboratory Medicine, the power generation industry, the oil and gas industry, an organisation involved in nuclear fusion research, environment agencies, universities and policy Directorate Generals of the European Commission. An extensive road mapping exercise was also undertaken by technical committees and focus groups.

EURAMET ran a two-step call between May and December 2007 for proposals of work from the participating countries, based on the four chosen research themes. The initial call sought project ideas and the second call provided full proposals of those that were chosen. Independent peer review ensured the selection of the very best metrology research proposals that would deliver wide reaching scientific benefits and impact in their chosen fields.

21 Joint Research Projects (JRPs) were funded, coordinating 33 organisations from 19 countries.

Programme management successes

The two-stage call enabled the many initial outline proposals to be brought together with similar work across organisations and countries to develop the final proposals in collaboration. All the members felt this was a good approach.

The independent peer review process took the form of a Review Conference enabling face-to-face discussions and questioning between the proposers and the referees. Both parties found this rewarding and greater understanding about projects was gained before decisions were made.

The concept of participating countries providing an additional 'reserve' commitment proved a very successful approach, as it helped avoid the need for countries to obtain an additional funding commitment from their national funding body if, once the projects were selected, they discovered they had been more successful than originally anticipated. However, it should be noted that four countries did have to seek and obtain additional funding.

Lessons learnt

For the subsequent European Metrology Research Programme (EMRP) a number of changes were proposed and implemented:

- Researcher Grants were set up to engage the wider scientific community in projects, and increase and diversify metrology capabilities across Europe.
- The call seeking project ideas and issues from stakeholders was expanded to make this open to anyone ensuring a much wider and diverse needs analysis.
- Additional information was provided on the project marking criteria and some 'rules' were instigated for the independent review panel.
- Commitment for a national reserve was raised to 50 % to avoid delays if a Member State found they were more successful in winning projects than anticipated.

The iMERA-Plus programme was the first time that the European metrology community had coordinated large scale collaborative metrology research, across a broad range of stakeholder groupings and technical areas. Overall, it proved to be particularly successful. This is in part reflected by the fact that during the course of the programme no organisation withdrew from any of the funded joint research projects.

The experience gained from operating iMERA-Plus enabled the management team to demonstrate its competence in handling a programme of significant scale.

MERA

Metrology in the European Research Area

September 2002 – November 2003

In 2002 and 2003 a number of European NMIs carried out a study examining the structure of and approach to top-level metrology in Europe. The study was prompted by the challenges of supporting emerging technologies such as nanotechnology and biotechnology, while still providing ever better capability to more traditional industrial stakeholders. One of the key outcomes of this study was to propose significantly increased collaboration in metrology research amongst the NMIs and other Designated Institutes in Europe.

iMERA

Implementing Metrology in the European Research Area

April 2005 – December 2008

This programme built on the original 'Metrology in the European Research Area' study, through the concept of pooling resources across Europe and developing a joint European Metrology Research Programme. The iMERA project brought the NMIs, their ministries and the European Commission together, and enabled EURAMET to collectively understand the challenge and resources available across Europe. It 'set the scene' for closer coordination and collaboration and addressed the core issues of restructuring the organisation of European metrology.

iMERA-Plus

Implementing Metrology in the European Research Area – Plus

June 2007 – May 2012

This was the first phase of the European Metrology Research Programme (EMRP) and one of the first of a new type of medium-sized actions launched under the EU Seventh Framework Programme. Resources from the publicly funded metrology laboratories from around 19 European countries, plus the European Commission's measurement institute, were committed within a single joint call for metrology research projects. The successful projects were launched between February and July 2008 and ran for three years.

Europe's National Measurement Institutes working together

The iMERA-Plus programme brought together the metrology know-how of 33 organisations in 19 countries to work on 21 prioritised metrology projects for the collective benefit of all of Europe.

EURAMET has since implemented the European Metrology Research Programme (EMRP), organised by 22 National Metrology Institutes (NMIs) and supported by the European Union, with a value of over 400 M€. The EMRP facilitates the formation of joint research projects between different NMIs and other organisations, including businesses, industry and universities. This accelerates innovation in areas where shared resources and decision-making processes are desirable because of economic factors and the distribution of expertise across countries or industrial sectors.

EURAMET wants to involve European industry and universities at all stages of the programme, from proposing Potential Research Topics to hosting researchers funded by grants to accelerate the adoption of the outputs of the projects.

Full details can be found at: **www.euramet.org**

For more information, please contact:

Dr Duncan Jarvis - EMRP Programme Manager
EURAMET e.V.
Bundesallee 100
38116 Braunschweig
Germany

E-mail: **emrp-pm@euramet.org**
Phone: **+44 20 8943 6707**

EMRP

European Metrology Research Programme

Programme of EURAMET

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