Nordic Metrology: Now and in the Future

Innovation, Growth and Competitiveness by Increased Co-ordination of National Metrology

Conclusions of the N-MERA project

SP Report 2004:33

http://www.sp.se/metrology/NMERA
Executive summary

Nordic Metrology: Now and in the Future

Innovation, Growth and Competitiveness by Increased Co-ordination of National Metrology

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The quality and interoperability of products and processes in all sectors of industry and society, which are essential as an infrastructure for innovation and growth, can be assured by calibration against nationally and internationally traceable measurement standards. Any innovative product or service will need the support of traceable measurement to function correctly.

Increased needs of society for traceable measurement, in traditional sectors (manufacturing, communication, food, environment etc) as well as new areas (such as nanotechnology and biotechnology) become increasingly resource intensive. This is a challenge both at the European and Nordic levels and can be met through a more co-ordinated use of resources by increased co-operation among the Nordic countries and in the wider European context.

All Nordic National Measurement Systems (NMS) operate at relatively low budget levels seen in an international perspective, but considering what they achieve, the Nordic NMS can be considered to be amongst the most efficient in Europe in providing measurement traceability. However, future needs of traceable measurement require an infrastructure for innovation, supporting high-technological companies in the Nordic region and making Nordic centres of excellence in metrology attractive even to researchers from outside the Nordic region. To achieve this, a injection of Nordic funds as a complement to national resources would provide for the necessary increased co-ordination and efficiency in Nordic metrology.

The present Nordic project, N-MERA – Nordic Metrology Research Area, has formulated a strategy for the future of Nordic metrology. This is a satellite project to corresponding European projects (such as MERA [2002]). N-MERA includes, as participants, representatives of the NMS of the Nordic and Baltic countries (Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway and Sweden) and important stakeholders (industry, universities, funding agencies, politicians) in Nordic metrology. The project has been partially financed by NORDTEST [N-MERA 2003].

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The main results are:

- A strategy for the development of a Nordic infrastructure for traceable measurement that meets future needs for calibration, KT and innovation in the coming 10 years
- A description of scenarios for greater co-operation in Nordic metrology at research infrastructure level, including models reflecting new structuring of metrology research capability for areas of importance
- A presentation of a view of the Baltic NMS, as New Member States - positions and issues in a Nordic perspective, using established or proposed new contact channels between the Baltic and Nordic countries
- An overview of metrology research topics that are deemed to be a priority, over the next decade, in the Nordic region

harmonised with a corresponding strategy developed in the European co-operation through EUROMET and the wider European Metrology Research Area. Increased co-operation among the Nordic metrology organisations in particular may be helped by geographical closeness and cultural similarities amongst the Nordic countries. Closer contacts in the Nordic region can increase Nordic influence in European and global metrology initiatives and research. These are some of the main reasons for the Nordic initiative N-MERA.

**Key words:** Nordic, Metrology, Research, Infrastructure, Traceable, Measurement, Innovation, Competitiveness
1 Background ........................................................................................................................................5
Innovation and Metrology: Objectives of N-MERA .......................................................................5
2 Innovation and Metrology: State-of-the-art in traceable measurement ......................................6
2.1 National metrology systems (NMS) provide equivalence and reliability of results and excellence in metrological competence ................................................................. 6
2.2 Metrology and innovation ........................................................................................................... 7
2.3 EUROMET and WELMEC provide fruitful European co-operation in metrology ..................7
3 International Developments in Metrology technology and Market demands .......................... 9
3.1 Measurement foresight ................................................................................................................. 9
3.2 Examples of Nordic excellence in metrology .............................................................................10
4 Nordic Co-operation in Metrology – state of the art ..................................................................15
4.1 Systematic information exchange .............................................................................................15
4.2 Strategic activities in Nordic and European Metrology .............................................................16
4.3 Implementation of joint activities in Nordic metrology ............................................................16
4.4 Trans-national research activities in Nordic metrology .............................................................17
5 Proposals for the future of Nordic metrology .............................................................................18
5.1 Strategy for development of Nordic infrastructure for traceable measurement ...................19
5.2 Description of scenarios for greater co-operation in Nordic metrology at research infrastructure level .........................................................................................................................20
5.3 Baltic view of co-operation in Nordic metrology .....................................................................20
5.4 Overview of metrology research topics .....................................................................................21
6 Conclusions .......................................................................................................................................24
Deliverables produced by N-MERA project, overview ................................................................25
Seminars and workshops ..................................................................................................................25
Publications ........................................................................................................................................25
Annex A Planning a Metrology European Research Area ..........................................................26
Annex B N-MERA project and its sub-projects ..............................................................................27
N-MERA 1 – Nordic metrology research area ..............................................................................27
N-MERA 2 – Collaboration amongst the national laboratories of the Nordic region ..................28
N-MERA 3 – Collaboration in legal metrology .............................................................................28
Annex C N-MERA 1 Seminars ”Nordic metrology research area” .................................................30
C.1 Stakeholder views of priorities and the role of NMIs ...............................................................30
C.2 Planning a Nordic Metrology Research Area for Innovation, Growth & Competitiveness .................................................................................................................................32
Annex D N-MERA 2 Workshops “Collaboration between national laboratories in Norden” ....33
Scenarios ...........................................................................................................................................35
Annex E N-MERA 3 Workshop “Legal metrology” .......................................................................37
Legal metrology co-operation in the Nordic region ......................................................................37
Annex F N-MERA Examples of suggested Nordic pilot projects ..................................................38
1 Background
Innovation and Metrology: Objectives of N-MERA

International metrology is facing a dilemma of increasing consequence.

On the one hand, the demands are growing due to three driving mechanisms:

- Emerging areas of science and technology such as nanotechnology, communications and biotechnology which demand new measurement capabilities as a support to innovation
- The need to support traditional areas in which the demands for accuracy are not only increasing but also becoming more complex
- Increased recognition of the importance of Metrology in existing areas (clinical medicine, the environment, food safety etc)

On the other hand, resources to meet the demands are limited. The provision of metrological traceability by National Measurement Systems (NMS), underpinned by research and development work, calibration facilities and the necessary international co-operation to secure confidence, is funded mainly through Government. The resources available are however not increasing in line with increasing and wider demand.

There are several conceivable ways of meeting the higher demands for metrological traceability on a substantially fixed budget and the Project “Metrology European Research Area” (MERA) and the corresponding Nordic satellite project N-MERA were established to explore these ways, for instance, through a closer co-operation.

Having successfully created the scientific base for the realisation and dissemination of the SI International System of Measurement Units (the ‘Metric System’) through national standards, EUROMET has turned to the dilemma of growth in demand for top level metrology support, particularly in areas such as nanotechnology, biotechnology and analytical chemistry, exceeding any realistic increase in public funding. A summary of the EU accompanying measure “Planning the European research Area in Metrology - MERA”\(^8\), which proposes ways of meeting this “metrology dilemma”, is given in Annex A.

The N-MERA project “Planning a Nordic Metrology Research Area” has shared the same aims as the European MERA project, with the support of NORDTEST and now part of the Nordic Innovation Centre (NICe). The N-MERA project has consisted of three sub-projects under a common management with the aims as described in more detail in Annex B. Before giving the results and recommendations of the N-MERA project for the future of metrology from a Nordic perspective in section 5, a review of the current state and trends of Nordic metrology in its international context is given in section 4.

\(^8\) MERA 2004 ”Planning the European Research Area in metrology”, Final Report, G6MA-CT-2002-04012
2 Innovation and Metrology: State-of-the-art in traceable measurement

2.1 National metrology systems (NMS) provide equivalence and reliability of results and excellence in metrological competence

The mission of the NMS is to ensure fit-for-purpose measurements made in industrial, scientific and regulatory fields as an essential infrastructure for innovation and growth. This is achieved by providing measurement traceability which ensures comparability of measurement results made on different occasions and in different fields, that is, are equivalent within uncertainties. The NMS act also as centres of excellence in measurement technology, performing in selected areas world-class research as well as extensive knowledge transfer in connection with their maintenance and development of primary measurement standards.

National Measurement Systems (NMS) in each country cover both a national metrology institute (NMI) and organisations responsible for legal metrology and accreditation and form the metrological basis for the commercial calibration laboratories that provide the majority of calibrations to end-users. A few, high accuracy calibrations of a particular quantity at the primary level provide the basis for perhaps fifty times (typical values) as many calibrations at a secondary (accredited) calibration laboratory which in turn supplies metrological traceability to maybe a further five times as many calibrations in industry on the workshop floor or elsewhere in society at large, as illustrated in figure 1.

Figure 1. Example of a calibration hierarchy (acoustic metrology in Denmark)\(^9\)

Metrology and its associated national measurement institutes continue to play a vital intermediary role, linking advances in science and technology to areas of growth in industrial, scientific and regulatory fields\(^10\). Stakeholders view the provision of traceable measurement

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\(^9\) DPLA Danish primary laboratory of acoustics, [http://www.daniamet.dk/dpla/dpla.htm](http://www.daniamet.dk/dpla/dpla.htm)

and National Metrology as predominantly a continuing public service. They are willing to lobby for increased support to the European NMS but at the same are unprepared to pay much more for the services provided. This is nicely summarised in the PREST [2002] project conclusions:

“Public service laboratories provide services which are important in socio-economic terms but which are difficult to capture in the price mechanism. A responsible government can not expect the market to provide adequate service without a corresponding commitment from its side.”

Metrology, in providing a generic infrastructural support, has such a wide diversity of customers, from all branches of industry and society, that it would be difficult to find one dominant industry prepared to pay more than its fair share. Impartiality is also a hallmark of national metrology much valued by industry.

2.2 Metrology and innovation

If innovation is “the successful exploitation of new ideas”\(^\text{12}\), then metrology provides support to innovation at every step in the value chain from idea to finished product. This can be exemplified with a number of active metrology projects at Nordic NMIs given in section 3.2.

The value added to society by the NMS in enabling reliable and quality-assured measurements is in providing for the interoperability and exchangeability of parts and systems in complex industrial products and global trade; is essential in the synchronisation of signals in communication systems; and provides a fair and quality assured basis for measurement in the environmental, pharmaceutical and other chemical sectors. Any innovative product or service will need the support of traceable measurement to function correctly.

Metrology also plays a key role in providing a basis for decision-making in conformity assessment and other regulatory fields such as metrology with legal implications.

2.3 EUROMET and WELMEC provide fruitful European co-operation in metrology

The various national metrology systems have in the last decade or so formed regional organisations allowing for increased co-ordination of metrological activities, reflecting increased globalisation of trade and industry as well as more extensive demands for traceable measurement. A European collaboration between the NMIs in the EU and EFTA states called EUROMET\(^\text{13}\) was established in 1987 and covers co-operation in the development of national measurement standards and measuring methods; optimisation of the use of resources and services; improvement of measurement facilities and making them accessible to all members; and the performance of comparisons to ensure a better coherence of measurements. In the field of legal metrology, the corresponding European collaboration is WELMEC\(^\text{14}\).

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\(^{13}\) http://www.euromet.org

\(^{14}\) http://www.welmec.org
NMI collaborative efforts within EUROMET have been dominated in recent years with extensive work, particularly in performing key comparison, in the successful launching of a Mutual Recognition Arrangement under the auspices of the intergovernmental Metre Convention. The MERA project has now identified a need for EUROMET to shift the focus of collaborative effort again towards R&D.

In order to meet challenges of a deeper and broader need for traceable measurement in both traditional as well as new areas of innovation and growth, it is increasingly being realised that (even the largest) NMS need to create new networks, not only amongst the NMIs but also between other research organisations and the NMIs\textsuperscript{15}. The N-MERA project has considered corresponding scenarios for greater co-operation in Nordic metrology at the research infrastructure level which would provide a platform for promoting Nordic measurement interests as part of an on-going, informal and non-bureaucratic sub-regionalisation of European Metrology collaboration.

\textsuperscript{15} Richter W and Güttler B 2003 „A national traceability system for chemical measurements” \textit{ACQUAL 8}, 448 - 53
3 International Developments in Metrology technology and Market demands

The continual increase in demand for accurate and efficient measurement in science, technology and international trade lead to the need to develop improved measurement standards and techniques. These developments need to be carried out well in advance of their application in science and industry, and can only take place on the basis of a solid foundation of long-term metrological research closely linked to advances in science.\(^\text{16}\)

3.1 Measurement foresight

Metrology foresight exercises have been performed recently by the CIPM\(^\text{17}\) and in the European MERA [2004] project and the reader is referred to these reports for details.

Particular challenges in the development of metrological traceability which can be met by intensified research are\(^\text{18}\):

\begin{itemize}
  \item \textbf{A. Implementation of measurement systems}
    \begin{itemize}
      \item Extended measurement areas and measurement quality
      \item Extended scales (pico to tera)
      \item On-line, dynamic measurements
      \item Several simultaneous parameters
    \end{itemize}
  \item \textbf{B. Development of measurement systems}
    \begin{itemize}
      \item Sensor development
      \item Fundamental science (nanophysics, microwave photonics, surface chemistry, etc)
      \item Networking of measurement sensors
    \end{itemize}
  \item \textbf{C. Measurement knowledge transfer}
    \begin{itemize}
      \item Industrial metrology training
      \item Industrial measurement needs and applications
      \item University measurement education
      \item Mobility of national metrologists
    \end{itemize}
\end{itemize}

Within this broad area, a task in the framework of the present project is to identify research topics of highest relevance for the Nordic region.

\(^{16}\) CGPM 1995 “The need for long-term metrological research”, Resolution 3 of 20\textsuperscript{th} General Conference of Weights and Measures, *Comptes rendus de la 20\textsuperscript{e} CGPM* (1995), 1996, 221


3.2 Examples of Nordic excellence in metrology

3.2.1 Communications and metrology
As a typical example of the challenges facing NMS by technological growth through innovation, the development of information and communication systems presents formidable metrological challenges. A general overview of the needs for advanced research and development for the Internet and Internet applications in the Nordic region has been recently published. Many of our modern electronic IT systems need to be mutually synchronised in order to function properly in terms of providing a secure and predictable communication in important applications such as e-government and tele-medicine. In an increasing number of IT applications, synchronisation to a point in time (‘epoque’) is needed, in which case use is made of frequency standards where phase is related to a regionally agreed time scale and where delays in communication have to be compensated for. The primary method of providing the necessary infrastructure for precise synchronisation, both nationally and globally (in terms of UTC), is to use data direct from a satellite navigation system such as the GPS. For added robustness and security, an alternative synchronisation infrastructure which is less reliant on a specific satellite system is being developed by the national time & frequency laboratory at the Swedish national metrology institute at SP in Borås, in the form of a time-keeping system based on groups of clocks and multicast techniques using existing IT infrastructures with optical fibre networks and SDH protocols. This development is a continuation of internationally leading activities which have to date included the establishment and maintenance of an infrastructure which provides the Swedish part of the Internet with secure and correct access to time. This is achieved through a number of national Internet nodes in Stockholm, Göteborg and Malmö which have been provided with group clock systems and associated NTP time servers. Such time-keeping presents challenging measurement tasks which will have to function even in the communication systems of tomorrow with substantially increased information rates.

![System for common time](image)

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19 Nordunet3 "Recommendations for a future programme on Advanced Internet and Internet Application Research and Development", Nordic Council of Ministers and Nordic Industrial Fund.
3.2.2 Nanotechnology and metrology

A second example is Nanometrology which deals with traceable measurements of nanosystems. A Nordic nanotechnology research & development programme “NanoNord” has recently been proposed\(^{20}\). Nanotechnology presents in particular formidable metrological challenges by demanding the ability to measure in three dimensions with atomic resolution over large areas. Measurements are required and/or enabled for all important physical, chemical and biological quantities at various stages in the development of nanosystems, from design, prototype evaluation, to implementation. Several areas where several of the Nordic NMIs are active in developing nanometrology are: aerosols and particles (especially environmental and health aspects); functional surfaces in biotechnology and medical devices; microelectronics and optoelectronics. Nanofabrication involves designing materials and structures with a high degree of control on the atomic/molecular level. Surfaces and interfaces often play a key role. The Department of Materials and Chemical Analysis at SP in Sweden has extensive instrumentation for and wide experience of microscopic materials characterization and chemical analysis. With partial financing of the Swedish nanometrology programme, techniques such as ToF-SIMS, partly directed towards micro- and nanofabricated materials and biological systems (cells and tissues), and a related technique, MALDI, which is primarily used for polymer and biomolecular analyses, are being developed at SP to provide structural and/or chemical information, often at a submicron spatial resolution or from nanoliter sample volumes, in the development of new nanofabricated devices and analytical techniques. Likewise, DFM in Denmark is developing new measurement methods and facilities that can support industrial needs in research, development, production and quality control of advanced micro optical components such as phase masks and other kinds of optical gratings. Figure 3 illustrates a development at DFM, in collaboration with a number of Danish SMEs, of nanometrology for the exact determination of the profile of these key component in micro optics. Deep structures, that is structures which are much deeper than they are wide, are a particular challenge. Results obtained with an AFM are compared with optical measurements of functionality and complementary optical diffraction microscopy (ODM) measurements of grating profiles.

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\(^{20}\) NanoNord, report of ad hoc group Nanotechnology, M Lehtinen NICe, project 02116, March 2004
3.2.3 Micromechanics and electrical metrology

The relation between innovation and metrology is twofold. On the one hand, metrology serves a necessary support for innovation, but on the other hand, metrology is often an important application area of new scientific innovations. Use of the Josephson effect and the quantum Hall effect in establishing quantum standards in electrical metrology are examples of the latter relation. An example of a recent Nordic innovation with special applications in metrology is the possibility of utilising microelectromechanical systems (MEMS) in electrical precision measurements, for example as a voltage standard. Such applications are being developed in an EU-funded project ‘EMMA’, which was initiated by VTT (Technical Research Centre of Finland) and MIKES in 2000. The project is co-ordinated by VTT, and other participants are MIKES, PTB, NMi, VTI Technologies, Fluke, and Twente University (see Fig. 4a). The idea is to convert the extreme stability of the mechanical properties of single crystal silicon into stability of voltage by using the interplay of electrical and mechanical forces in a capacitative MEMS sensor. The main goals of the project are to develop a DC voltage reference with properties comparable to those of Zener voltage standards; an AC voltage RMS converter with properties comparable to those of thermal voltage converters; and a new type of high frequency power sensor which measures a transmitted signal without power dissipation. Sensors are fabricated by VTT using SOI (silicon on insulator) technology; by Twente University using surface micromachining; and by VTI Technologies using bulk micromachining. The main role of the metrology institutes (MIKES, PTB, and NMi) is to perform the metrological characterisation of the final components. However, especially the Finnish NMI MIKES has also been actively involved in the development work, for example by using its special facilities and know-how to investigate the long-term stability of different test structures and also by developing read-out methods. The main problem has been drift caused by slow electrostatic charging effects in the silicon structures, but the problem can be solved using AC-readout. At present, stability of the output voltage of the AC reference (see Fig. 4b) is better than 2 ppm in 24 hours.

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Figure 4. (a) Participants of the EMMA project. (b) Micromechanical AC reference fabricated by VTT
3.2.4  Measurement knowledge transfer

Knowledge transfer (KT) activities in measurement are an important complement to technical R&D and maintenance work at a national metrology institute\(^{22}\). An aim is to disseminate efficiently the knowledge and experience built up at the NMI to the national infrastructure, especially to industry. A programme of metrology education with courses, workshops and consultancy service can be based on a fundament of knowledge established through the experience of an NMI ranging from its activities in national and international networks (such as EUROMET and the Consultative Committees of the CIPM), to daily experience from calibration, measurements and related development activities. The measurement KT programme at the Swedish NMI at SP includes annually about 60 planned training activities as well as a number of tailor-made, company-specific training events. Courses, which during 2003 attracted as many as 750 participants, treat the metrology of physical and chemical quantities and associated subjects in a number of ways. In most cases the focus is on the requirements and perspectives of measurement stakeholders and include laboratory exercises in several cases. Most KT deals with a specific measurement, e.g. laboratory weighing, but some courses cover a wider scope of related questions such as requirements on measurements in quality standards (ISO/IEC 17025, ISO 9000) and general aspects like uncertainty evaluations or the conformity assessment of measuring instruments. Some of the training courses have a wide scope including even measurement issues such as laboratory medicine. Some are in the form of seminars where metrology specialists, producers and end users present papers. Measurement KT such as provided by SP is an important element in innovation, improving knowledge and skills and meeting the increasing interest in measurement knowledge transfer from stakeholders in metrology, including especially highly qualified participants from a range of both Swedish and multi-national industries.

\(^{22}\) Optimat 2003 "NMS KT International Best Practice Study", DTI (UK)
4 Nordic Co-operation in Metrology – state of the art

The different Nordic NMS are of course at different levels of development but in general compare well with their Continental counterparts. Summaries of each Nordic NMS are available in the so-called ‘Panorama’ report\(^{23}\), which have been up-dated by the Nordic members during the current project and are available on the N-MERA website.

4.1 Systematic information exchange

The EUROMET members, and thereby even the Nordic NMIs, already collaborate, including the systematic exchange of information as a means of improving mutual knowledge and trust-building:

- Use of common portal [www.euromet.org]
- Project portfolios and databases,
- Major facilities database

During the N-MERA project, a common Nordic metrology website\(^{24}\) has additionally been established in order to encourage the more ready exchange of information about Nordic metrology in particular.

4.1.1 Nordic Metrology Projects

The NORDTEST N-MERA project has performed an initial mapping of current collaboration amongst the Nordic NMS. Co-operation in EUROMET has been a cornerstone for the development of even the Nordic NMI ever since EUROMET came into being. There is currently an active organisation NORJUST for legal metrology. While national funding is the predominant form of support, some support for Nordic metrology collaboration is provided by NORDTEST, NIF (since 2004 combined to NICe), and the EU Commission.

![Figure 4 Participation by country in EUROMET projects](http://www.sp.se/metrology/NMERA)

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\(^{23}\) Erard L et al. 2001 ”A Panorama over the European Union Metrology Infrastructure”, Grant Agreement Nr. SI2.300554, BNM (FR)

\(^{24}\) [http://www.sp.se/metrology/NMERA](http://www.sp.se/metrology/NMERA)
The Nordic NMS are amongst the more active in European collaboration, especially when allowing for the relative smallness of these countries. Figure 4 shows participation by country in EUROMET projects. A list of current Nordic collaboration is available on the N-MERA website.

Plans for future activities amongst the Nordic NMS in the further systematic exchange of information and good practice are given in §5 of this report.

4.2 Strategic activities in Nordic and European Metrology

To date, Nordic as well as other European NMS have performed strategic activities of collaboration related to the CIPM Mutual Recognition Arrangement\textsuperscript{25}, with EUROMET formally identified as the European regional Metrology Organisation under the auspices of the intergovernmental Metre Convention. These MRA activities, including the performance of key comparisons and the establishment of quality management systems, can be considered as practical networking activities and might encourage mutual opening mechanisms for increased collaboration between the NMS. However the MRA does not include strategic planning or execution of research and associated activities.

Collaboration so far amongst the Nordic and European NMS has taken place amongst national standards holders supported by national research with occasional \textit{ad hoc} identification of common research activities.

In planning for increased co-operation in Nordic metrology, an important strategic activity is the collection of the views of stakeholders, be they from industry, the universities or from politicians and decision-makers. Two N-MERA seminars were arranged and are summarised in Annex C of this report and in a NORDTEST Position Paper no. 010 [2003].

Many of the recommendations of these N-MERA Seminars and the NORDTEST Position Paper are given together with other plans for future strategic activities for increased collaboration in Nordic metrology in §5 and Annexes of this report.

4.3 Implementation of joint activities in Nordic metrology

The Nordic NMS through EUROMET already provide fora for the implementation of joint activities:

- Technical committees for each of the measurement fields of the SI
- Regular meetings of European NMI representatives.
- General Assembly of NMI delegates.
- Executive Committee that steers EUROMET policy.

Most co-operative NMS research to date consists of \textit{a posteriori} clustering of national research projects in an \textit{ad hoc} manner.

During the N-MERA project, implementation of joint activities amongst the Nordic NMS has been encouraged by the arrangement of a series of workshops during Autumn 2003 and Spring 2004 attended by representatives of the Nordic NMS grouped according the main measurement fields. Summaries of these workshops are given in Annexes D and E.

\textsuperscript{25} MRA 1999 "Mutual Recognition Arrangement", CGPM \url{http://www1.bipm.org/en/convention/mra/}
Plans for future implementation of joint activities amongst the Nordic NMS include pilot collaborative research projects as detailed in Annex F of this report.

4.4 Trans-national research activities in Nordic metrology
EUROMET including the Nordic NMS have already formulated:

• a common strategy for collaboration
• a common plan for the dissemination of results

In almost all European metrology projects, each country pays for own participation, although there has been a certain amount of funding from the European Commission.
5 Proposals for the future of Nordic metrology

In order to meet the burgeoning needs of industrial innovation systems for quality-assured measurement, the development of a Nordic metrology research area is planned. While much is established (section 4), strategic planning of European and Nordic Metrology Networks is needed to achieve more effective trans-national management of Nordic metrology cooperation.

Adapting the Nordic Metrology structures for increased coordination

Co-operation among the Nordic metrology organisations in particular may be helped by geographical closeness and cultural similarities amongst the Nordic countries. Closer contacts in the Nordic region can increase Nordic influence in European and global metrology initiatives and research. These are some of the main reasons for the Nordic initiative N-MERA.

All Nordic National Measurement Systems (NMS) are operating at relatively low budget levels seen in an international perspective, but considering what they achieve, the Nordic NMS can be considered to be amongst the most efficient in Europe. However, future needs of traceable measurement require an infrastructure for innovation, supporting high-technological companies in the Nordic region and making Nordic centres of excellence in metrology attractive even to researchers from outside the Nordic region. To achieve this, an injection of Nordic funds as a complement to national resources would provide for the necessary increased co-ordination and efficiency in Nordic metrology.

The Nordic region is perhaps unique in Europe in having already what might be regarded as a prototype regional Metrology Research Council in the form of NORDTEST, NIF and the new Nordic Innovation Centre (NICe) to which the Nordic NMS have the opportunity of applying for complementary joint research financing. It is proposed that a dialogue should take place between representatives of the Nordic NMS and the Nordic Innovation Centre (particularly the latter’s Metrology & Quality Expert Group) about ways to strengthen strategic planning of research co-operation in Nordic metrology.

The main results are explained in the next sections and are:

- A strategy for the development of a Nordic infrastructure for traceable measurement that meets future needs for calibration, KT and innovation in the coming 10 years
- A description of scenarios for greater co-operation in Nordic metrology at research infrastructure level, including models reflecting new structuring of metrology research capability for areas of importance
- A presentation of a view of the Baltic NMS, as New Member States - positions and issues in a Nordic perspective, using established or proposed new contact channels between the Baltic and Nordic countries
- An overview of metrology research topics that are deemed to be a priority, over the next decade, in the Nordic region
5.1 Strategy for development of Nordic infrastructure for traceable measurement

A clear management strategy of this increased Nordic metrology collaboration is proposed and includes:

5.1.1 External activities

- Improved identification of R&D needs from innovation – taking particular notice of non-traditional and emerging areas
  - Future foresight studies, including identification of measurement needs for emerging technologies.
  - Collaboration with other measurement foresight, e.g. MET\textsuperscript{26} in UK in areas such as biotechnology, ICT and nano-technology.
- Improved identification of R&D needs from stakeholders such as regulators, customers from industry and other policy makers\textsuperscript{27}
  - Interaction (incl. secondment) with industry, funders, Government, NICe, universities, other research organisations (Annex C)
- Continued international co-ordination of Nordic metrology with networks EUROMET, ERA-NET\textsuperscript{28}, CIPM

5.1.2 Internal activities

- The opportunity for strategic planning of longer-term major metrological R&D investments and projects in a co-ordination of NMS organisations (policy, administration)
  - continued systematic exchange of information and good practice about NMS metrology (e.g. recurrence of Nordic NMI workshops at regular intervals as an important and perhaps more focussed complement to larger corresponding EUROMET meetings)
  - opening up/establishing common Nordic measurement resources
  - establishment of centres of excellence (decision plan)
  - establishment of so-called ‘virtual institutes’ for different measurement fields
  - mobility, exchange of strategic personnel, competence development
- Plans for networking between NMIs and other research institutes/organisations in developing metrological traceability for the non-traditional and emerging areas such as nanotechnology and biotechnology

For these proposed research management activities, an allocation of EUR 0.1M/year from NICe would complement the existing NORDTEST metrology project support and national metrology grants (in total about EUR10 M).

\textsuperscript{26}NMS Measurement for Emerging Technologies (MET) Programme, \url{http://www.npl.co.uk/met/}


\textsuperscript{28}ERA-NET 2003 “Strengthening the foundations of the European Research Area – 11. Support for the co-ordination of national, regional and European activities in the field of research and innovation”, Work programme
5.2 Description of scenarios for greater co-operation in Nordic metrology at research infrastructure level

For each proposed project, the N-MERA working groups were asked not only to identify what new collaborative projects were at hand, but also to answer why the project would be worth doing and how, that is, what kind of collaboration was envisaged. Suggested kinds of collaboration include the scenarios:

I  Centralised facilities - a few, larger projects
II  "Federated excellence" – majority
III  Collaboration with stakeholders
     – e.g. universities, instrument makers, ”4E” …

![Scenarios for Nordic metrology research collaboration](image)

Figure 5 Distribution of proposed Nordic metrology research projects according to scenario

The Nordic NMIs have earlier contributed to discussions of the so-called “four scenarios” of the corresponding MERA [2004] project, which deal mainly with different ways for NMIs to collaborate (ranging from A: Network of autonomous NMIs to D: Fully integrated European metrology system). In the present N-MERA project, it was already foreseen that only a few fully centralised metrological facilities could be expected in the Nordic region for particular measurement quantities. On the other hand, it was felt more interesting to investigate Nordic views about an additional form of collaboration in metrology, namely between NMIs and stakeholders (scenario III above), thereby reflecting an emphasis in the Nordic NMIs on a perhaps closer relationship with the needs and resources of stakeholders. In fact, as is evident from figure 5, the large majority of proposed Nordic metrology research projects involve active participation of stakeholders.

5.3 Baltic view of co-operation in Nordic metrology

In Baltic States, Lithuania, Latvia and Estonia, the national measurement systems have been intensively developed in recent years. The re-arrangements in measurement systems have
been mostly caused by the need of providing ensured traceability to local economies. For that purpose NMIs have been established and the development of national measurement standards started.

The strategies behind the development of measurement standards reflect national priorities:

- In Lithuania the measurement standards in the fields of temperature, DC voltage and time and frequency have been developed at the primary level;
- In Latvia and Estonia measurement standards have been or are developed at secondary level.

In the cases of secondary level measurement standards the traceability has to been achieved from another NMI. By now, traceability routes in measurements in Baltic States have been established to European NMIs (Germany, France, Denmark, Finland, Sweden) in most cases. In order to share knowledge and experience in setting-up metrology infrastructure the annual meetings between Baltic NMIs are hold since year 2000. Co-operation in metrology is presented mostly in exchanging of calibration and measurement services.

Academia is actively involved in metrology in Lithuania and in Estonia where researchers or students from universities carry out some part of development work.

To further facilitate the developments in economy and society the common areas for Baltic States in metrology co-operation are:

- Training of personnel working in metrology, particularly in Metrology in Chemistry,
- Knowledge transfer to measurement service customers and industry stakeholders,
- Joint use of facilities which are presently used for providing cross-boarder calibration services (ionising radiation, flow, liquid density).

5.4 Overview of metrology research topics

Meeting the challenges of future metrology requires a well-co-ordinated research effort. As the result of earlier metrology foresight studies [section 3], a number of clear research challenges have been identified in providing traceability when developing and implementing measuring systems, especially associated with extended measurement areas, quality and scales as well as a trend towards more on-line, dynamic measurements and the measurement of several parameters simultaneously. Metrological research challenges arise across the board of traditional and emerging technologies and industrial sectors.

5.4.1 Existing Nordic metrology research topics

Examples of existing areas already receiving the attention of Nordic NMS are quoted in section 3, such as information and communication systems, nanometrology and microelectromechanical systems.

5.4.2 New areas of Nordic metrology research. Examples of environmental metrology and the metrology of ionising radiations

Many environmental measurements are carried out in the various EU countries, mainly to meet requirements set by EU and national legislation. The data collected represent a great
source of potentially valuable information in support of decision-making. Quoting from a position paper submitted Spring 2004 to the EU Commission by the EU thematic network METROPOLIS\textsuperscript{29} – which has included a number of Nordic measurement and related organisations, such as, IVL\textsuperscript{30}, NILU\textsuperscript{31}, NORDTEST, Risø Danish National Laboratory, SP, VTI\textsuperscript{32}, etc – “Unfortunately, the quality of the data available is still highly variable: some of the collected data have to be critically examined to establish whether they provide a suitable basis for decision-making.

Why is this so?

- lack of \textit{traceability}: it is impossible to base decisions on data that are not sufficiently documented (not traceable to well established references and therefore not reliable).
- lack of \textit{harmonisation} of the procedures applied by laboratories (starting with the sampling procedure, but also including the approach adopted for the calculation of the uncertainty). This lack of harmonisation makes the data obtained from different sources difficult to compare
- lack of \textit{representativeness}: data that do not reflect the reality that we want to represent are simply not fit for purpose.
- a-too high a level of \textit{uncertainty} associated with the data collected makes the process of decision-making critical (on the other hand, in some cases the uncertainty is not expressed at all!)
- lack of metadata: \textit{information about the data} (what, how and when measurements were made, who owns the data, and so on...) and the way they are reported / used is an essential requirement to allow the use of the data for other purposes (e.g. compilation of databases).

All this emphasises the role of metrology (as a basic infrastructure for measurement sciences) as a means of ensuring the quality (traceability and therefore comparability) of the data obtained from the various EU monitoring programmes, throughout the whole “measurement cycle” (i.e. from the collection of the \textbf{data} to the delivery of the \textbf{information} to decision-makers).”

Proposed Nordic metrology projects in the area of \textbf{ionising radiations} include

| Comparison of calibrations of air kerma-area product meters (DAP meters) | Research/Intercomparison. Exchange of information | Most of the medical X-ray units are equipped with DAP meters to define the patient doses. Traceability for DAP as a quantity doesn’t exist at the moment. Prepare guidance for users (hospital physicists, manufactures) to calibrate the DAPs at hospitals. DAPs of X-ray units are part of the X-ray equipment installation. Calibrations must be performed on site. | SSI, NRPA, SIS, STUK, GR. |

\textsuperscript{29} METROPOLIS \url{http://www.metropolis-network.net/}, Position paper ”Evaluation of current gaps and recommendations for further actions in the field of environmental analysis and monitoring”, March 2004

\textsuperscript{30} Swedish Environmental Research Institute

\textsuperscript{31} Norwegian Institute for Air Research

\textsuperscript{32} Swedish National Road and Transport Research Institute
| Development of traceability for fundamental quantities used in metrology of ionizing radiation (picoamps, kV of X-ray generators, temp, pressure, time). | Quantities of ionising radiation are derived and influences by other quantities. Relations to NMIs of other areas | SSI, NRPA, SIS, STUK, GR. NMIs of other areas. |

These, as well as many other project proposals in other areas can be found in the extensive portfolio of Nordic collaborative metrology research projects proposals identified during the N-MERA workshops [Annexes D and E]. A number of ‘pilot’ projects – listed in Annex F - are selected as good examples of ways and means of collaborating in Nordic metrology. Each pilot project has a clear aim, is well-motivated and are examples of different scenarios for research collaboration.
6 Conclusions

The competitiveness of Nordic and European industry and society can be enhanced through better metrology. To meet (extensive) needs for traceable measurement in new technologies (e.g. nanotechnology, bio-technology, environment, food, medicine etc), current metrology research co-operation in the Nordic region has to be intensified. The development of Nordic metrology for the coming years can lead to a transition from a collaboration amongst national standards holders supported by national research with occasional ad hoc collaboration to a better and more structured collaboration of R&D performers providing other science areas, industry and society with cutting edge measurement and metrology capabilities, disseminated through national standards and associated expert advice.

There is a clear willingness and enthusiasm to achieve a significant increase in the amount of R&D collaboration within the Nordic metrology community, as is evident from the results of this N-MERA project.

A proposal is being made by the N-MERA project to the Nordic Council of Ministers which, through the Nordic Innovation Centre, has asked in what ways Nordic metrology can be further developed to promote an innovative and knowledge-intensive Nordic business sector [N-MERA 2004d].
Deliverables produced by N-MERA project, overview

Seminars and workshops

- “Seminar: Stakeholder views of priorities and the role of NMIs”, 14th – 15th May 2003, SP Borås (SE)
- “Seminar: Planning a Nordic Metrology Research Area for Innovation, Growth & Competitiveness”, 31st March 2004, MIKES Helsinki (FI)
- “Nordic metrology collaboration workshop - Electricity, Time and Frequency and Temperature and Humidity”, 4th March, JV, Oslo (NO)
- “Nordic metrology collaboration workshop - Mass, Force, Pressure, Torque, Length and Photometry and Radiometry”, 10th March, Borås (SE)
- “Nordic metrology collaboration workshop - Chemistry, Ionising, Radiation and Interdisciplinary Metrology”, 30th March, MIKES, Helsinki (FI)
- “Legal metrology co-operation in the Nordic region”, November 2003, FORCE Institute (DK)

Publications

N-MERA 2003a “Nordic Metrology Research Area 2003 – 2004”, NORDTEST project 02x794b, 2003-03-17, and 786cx02, 2003-05-13 Project proposal


N-MERA 2003c “N-MERA Nordic metrology research area”, presentation at MERA Workshop, Berlin, May 2003

N-MERA 2004a, “Planning a Metrology Research Area in Norden”, presentation at EUROMET INTMET meeting, Berlin, May 2004

N-MERA 2004b, “Nordic Metrology Research Area – N-MERA”, Agreed EUROMET INTMET project


N-MERA 2004d “Promoting an innovative and knowledge-intensive Nordic business sector through better Nordic metrology”, Proposal to the Nordic Council of Ministers through the Nordic Innovation Centre, September 2004.


N-MERA website http://www.sp.se/metrology/NMERA
Annex A  Planning a Metrology European Research Area

EXECUTIVE PUBLISHABLE SUMMARY

Regulation, trade, and economic activity depend on effective, consistent measurements and on the interoperability of systems and manufactured components. The underpinning state-of-the-art measurement standards are maintained by National Metrology Institutes (NMIs), which provide traceability to the standards through a wide range of calibration services. In Europe, the 30 or so NMIs are finding it increasingly difficult to meet ever-growing demands for new standards, particularly in emerging areas of technology, whilst still meeting the expectations of existing sectors – the so-called metrology dilemma.

EUROMET, the European collaboration in measurement standards, is addressing this issue by developing closer collaboration between its member NMIs. This strategy is based on closer collaboration in research as well as increased sharing of major facilities and rationalisation of calibration services. EUROMET quickly recognised that increasing cooperation beyond the current level - a move that could be characterised by a transition from ad hoc cooperation to strategically planned collaboration - represented a major challenge. The MERA project is investigating all the issues associated with an infrastructure that would embrace a common metrological European Research Area. The project was divided into 10 work packages, including preparatory data collection and analysis, two workshops and consultation with stakeholders at European and national level, with a specific workpackage looking at the particular challenges faced by NMIs in the Newly Associated States (Accession countries). Lessons have been learnt from each of the work packages. The various surveys of the NMI user communities identified the importance of maintaining the technical competence in individual NMIs, but were concerned that any rationalisation in Europe would reduce the local availability of calibration services. Users understood the need for each NMI to focus on the capabilities that are most relevant nationally, so that it might be necessary to rely on other foreign NMIs for more marginal needs. Many of the EUROMET countries already adopt this approach, although the larger NMIs have traditionally offered a fully comprehensive calibration capability.

The project confirmed that significantly increased collaboration in R&D should be the cornerstone of any solution to the dilemma and identified the key issues coming to the conclusion that a new paradigm for NMI collaboration is warranted. The project presented to EUROMET - and EUROMET has accepted - the challenge, which can be summarised, in the words of the EUROMET Chairman, as follows:

“Currently EUROMET could be described as a collaboration amongst the holders of the national measurement standards, NMIs which also perform R&D to keep the standards up to date. The current ad hoc collaborations have added value to the R&D, although a variety of factors limit the potential impact. These factors include differences in planning cycles, variations in the ways of formulating and prioritising research and restrictions on funding. The project recommends that facilitating R&D collaboration be moved to the heart of EUROMET activity. It is suggested that EUROMET aspire to recognition as a collaboration of institutes engaged in measurement science R&D that provides enabling capability to all other fields of R&D, enabling European industry to remain world class and enhancing efforts to improve the quality of life. That R&D must be embodied in the development and validation of measurement techniques and tools, and made available in emerging areas of technology such as food, medicine, chemistry and pharmaceutical, whilst still maintaining cutting edge capabilities in traditional areas”.

33 MERA 2003 “Planning the Metrology European Research Area” (http://www.euromet.ie/projects/mera/), NPL (GB) project co-ordinator, MERA-G6MA-CT-2002-04012
Annex B  N-MERA project and its sub-projects

This Nordic project has had the overall aim of presenting and debating Nordic (including Baltic) ideas and opinions about what needs to be done and which is the most effective and efficient system for the future of Nordic metrology. The aims of the project have been to collect and analyse the present national needs for metrology development in Nordic and Baltic states, and to map future scenarios of increased co-operation amongst Nordic NMS in line with European metrology strategy and as part of a future co-ordinated Metrology Research Area. The results and conclusions of this NORDTEST project have and will continue to provide Nordic input to the EU project MERA and other future projects.

N-MERA 1 – Nordic metrology research area

Project group:
Leader project N-MERA1: Leslie Pendrill, SP (SE)
Others: Kim Carneiro, DFM (DK), Toomas Kubarsepp, Metrosert (EE), Heikki Isotalo MIKES (FI), Gisli Fridgeirsson LS (IS), Helge Kildal JV (NO)

Specific aims:
- Overview of the current level of collaborative activity at NMI level in Norden
- Overview of metrology research topics that are deemed to be a priority, over approximately the next decade, for Norden
- Scenario(s) for greater co-operation/integration of activity (reflecting the full scale of possible options) between the NMIs in Norden at research infrastructure level,
Annex B  N-MERA project and its sub-projects

i.e models reflecting new structuring of metrology research capability and measurement knowledge transfer in Norden.

- National and Nordic NMI position on the various proposed structural scenarios leading to a European Research Area in Metrology,
  - which is the preferable scenario, and why;
  - how the scenario might be implemented, difficulties etc
- National and Nordic industrial and other stakeholders’ views of the scenarios
- A current view of the Baltic NMIs positions and issues (as EU Candidate Countries) in a Nordic perspective using for instance existing and future contact channels between the Baltic and Nordic countries

N-MERA 2 – Collaboration amongst the national laboratories of the Nordic region

Project group:
Leader project N-MERA2: Gunnar Østergaard, FORCE (DK)
Others: Toomas Kubarsepp, Metrosert (EE), Heikki Isotalo MIKES (FI), Gisli Fridgeirsson LS (IS), Helge Kildal JV (NO), Leslie Pendrill, SP (SE)

Specific aims:

- Ensure greatest possible Nordic influence in planning the future role of the national metrology systems in Europe and the Nordic and Baltic countries
- Identify areas of metrology which are most important for the different Nordic countries, including the needs of industry for traceable measurement
- Identify areas of metrology which are most appropriate for a Nordic co-ordination in such a way that the results of use to as many as possible and are an optimal use of available resources
- Encourage the development of a mutually acceptable form of metrological collaboration and a network of personnel amongst the Nordic (and Baltic) countries
- Arrange and collate results from Nordic workshop(s) as input to main N-MERA project

N-MERA 3 – Collaboration in legal metrology

Project group:
Leader project N-MERA3: Gunnar Østergaard, FORCE (DK)
Others: P. Claudi Johansen DANAK (DK ), Tuomo Valkenpää TUKES (FI), Jouko Roine Inspecta (FI ), Tor Jens Gunnarsson LS (IS), Knut Lindlöv JV (NO), Agneta Ebbesson SWEDAC ( SE ) and Håkan Källgren, SP (SE)

Specific aims:

- Make certain greatest possible Nordic influence in the development of legal metrology
- Identify areas of legal metrology which are most important for the different Nordic countries, including the needs of industry and society
Annex B  N-MERA project and its sub-projects

- Identify areas of legal metrology – particularly the development of measurement and testing procedures and pre-normative research, such as measurement uncertainty in conformity assessment - which are most appropriate for a Nordic co-ordination with the national metrology institutes and others in such a way that the results of use to as many as possible and are an optimal use of available resources
- Encourage the development of a mutually acceptable form of metrological collaboration and a network of personnel amongst the Nordic countries as a support to legal metrology
C.1 Stakeholder views of priorities and the role of NMIs

In planning for increased co-operation in Nordic metrology, an important strategic activity is the collection of the views of stakeholders, be they from industry, the universities or from politicians and decision-makers. During the N-MERA project, the views of major stakeholders in national and Nordic metrology were heard at a seminar held 14 – 15 May 2003 at SP Borås (SE) under the title “Nordic Metrology Research Area – Stakeholder Views”. The participants were from Denmark, Estonia, Finland, Iceland, Norway and Sweden, and stakeholders of NMS, both so-called ‘end-users’ – such as industry - as well as ‘providers’, which give either intellectual or other resources to the NMS. A major result of the first N-MERA seminar was the production of a NORDTEST Position Paper [No. 010].

Interaction with stakeholders to the NMIs and metrology in the Nordic region has shown the following needs, challenges and opportunities for future direction.

C.1.1 Wider service to industry, more involvement, local competence

Industry is traditionally viewed mainly as an “end-user” of NMI calibration services. Increasingly, however, industry is asking for:
- additional/supporting services (such as measurement knowledge transfer)
more collaboration with NMIs and being able to suggest metrological research plans.

**Calibration services** at the primary (or national reference) level needs to receive state support, but such services at lower levels of the traceability hierarchy should be provided through free competition and on the terms of the Market.

In the provision of **measurement knowledge transfer**, there is a need to:
- provide mechanisms for local availability of knowledge transfer,
- take stock of the (apparently rapidly) increasing need for such transfer
- encourage increased co-operation between the Nordic NMSs in the development and provision of measurement knowledge transfer.

**Research in metrology** should take-off from areas where industry is strong and/or has special needs or great potential for growth and development.

**C.1.2 Stronger ties between NMI and academic research**

High-level research at the NMIs is necessary to maintain confidence in the international metrology community and to be able to reap the benefits of research being conducted elsewhere.

- Several good examples exist of Nordic academic research groups contributing with fundamental research promising future development of the SI as well as new measurement technology.
- Many NMIs rely additionally on university students at the graduate and post-graduate level to perform significant portions of the metrological research.
- The NMIs contribute in higher education by presenting research topics, making research facilities available and offering guidance to students

Ties between NMIs and academic researchers should therefore be strengthened as a means of sustaining and further developing metrology.

**C.1.3 NMS and the Government: Metrology important for innovation, sustainable growth and national strategies**

Traceable measurement is long recognised as an essential part of the technological infrastructure of industrialised nations. Therefore governments have a high stake in securing growth/health and supporting further development:

- Metrology provides support to innovation through sustainable growth at every step in the value chain.
- Metrology and confidence in traceability are essential in facilitating free trade and removing technical barriers and form a cornerstone of European free market and international trade agreements. Metrology also plays a key role in providing a basis for decision taking in conformity assessment and other regulatory fields such as metrology with legal implications.
- Some specific national strategic problems may motivate the maintenance and development of particular metrology, (for example the measurement of trace elements
in fish and the marine environment, which is a key competence for Iceland and Norway).

- Decision-making at the top level on the future of Nordic metrology should reflect a balance between national and regional needs and resources, opportunities for increased co-operation in some areas and in the context of international developments.

C.2 Planning a Nordic Metrology Research Area for Innovation, Growth & Competitiveness

A second N-MERA seminar, held at Helsinki (FI), 31 March 2004, and attended by close to 30 Nordic and European participants, considered strategic ways of coordinating Nordic metrology.

These discussions formed an important input to the conclusions of the N-MERA project.
Annex D  N-MERA 2 Workshops “Collaboration between national laboratories in Norden”

During the N-MERA project, implementation of joint activities amongst the Nordic NMS has been encouraged by the arrangement of a series of workshops during Autumn 2003 and Spring 2004 attended by representatives of the Nordic NMS grouped according the main measurement fields.

- N-MERA workshop 4 Feb 2004 Denmark, Acoustics, Volume, Density, Flow
- N-MERA workshop 4 March 2004 Norway, DC/AC Electricity, T&F, Temperature, Humidity
- N-MERA workshop 30 March 2004 Finland: Chemistry, Microbiology, Ionising Radiation, Interdisciplinary etc

There have been 4 meetings in the Nordic countries – 1 in Denmark on February the 2nd concerning Acoustics, Volume, Density and Flow – 1 in Norway on March the 4th concerning Electricity, Time and Frequency and Temperature and Humidity – 1 in Sweden on March the 10th concerning Mass, Force, Pressure, Torque, Length and Photometry and Radiometry and 1 in Finland on March the 30th concerning Chemistry, Ionising, Radiation and Interdisciplinary Metrology.

Prior to the meetings information regarding the present situation (Measurement capabilities) in the specific fields in each country were collected and the information were handed over to the participants at the meeting.

All the national laboratories were invited to attend and so were other calibration laboratories and other interested parties.

The programme for the meetings was a short introduction with the aim of the project and a description of the developments in International Metrology. Afterwards there were workshops
for the technical fields where a list of future possible projects were discussed and in the end projects were elaborated. The lists have been circulated for further comments and at present we have a list of 137 proposed projects.

The workshops were well attended both regarding participants from the countries and from the technical fields – see statistics below.

Participants divided by subject

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Project proposals represent all the technical fields:

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The participation in the workshops and the enthusiasm shown by the participants clearly indicate a wish for and a willingness to participate in an enlarged future co-operation. Many of the technical fields in each country are small with only one or few technical experts and limited financial resources and time to initiate the necessary developments. A continuation of the workshops, where one can meet fellow experts and can discuss technical matters and agree on common projects, is wanted by many.

**Scenarios**

At each N-MERA workshop, the main activity consisted of measurement subject-wise working group discussions of ways in which to extend Nordic NMI research collaboration, particularly the questions:

1) Identify joint metrology R&D projects and fields
2) Classify projects in R&D scenarios and discuss prioritisation criteria

The projects listed were classified in 3 categories:

I: Centralised facilities one centralised unit or a virtual institute (Centre of Competence)

II: Collaboration between national laboratories

III: Collaboration in research with stakeholders

**No. of projects**

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Annex E  N-MERA 3 Workshop “Legal metrology”

Legal metrology co-operation in the Nordic region

Measurements are used not only in industry and science but also in our daily life. The confidence needed in order to avoid repeated measurements, disputes or legal actions can be provided by placing measurement requirements defined by authorities, most commonly within trade but increasingly also within the health and environmental sectors. Ongoing harmonisation in Europe will help authorities in the establishment of measurement requirements as these are stated partly in directives. With the recent introduction of the new measuring instruments directive (MID), there remains however a need for harmonisation of routines in its implementation. There are clear international trends that metrology and testing are becoming closer, and legal metrology is that part of conformity assessment closest to metrology.

Areas of legal metrology – particularly the development of measurement and testing procedures and pre-normative research, such as measurement uncertainty in conformity assessment - which are most appropriate for a Nordic co-ordination with the national metrology institutes and others have been identified in the N-MERA 3 sub-project, amongst others through the arrangement of a Nordic workshop (November 2003, FORCE Institute (DK) attended by authorities and experts from Denmark, Finland, Iceland, Norway and Sweden.

The agenda of the workshop was to discuss possible closer co-operation and sharing of information. The items were OIML/WELMEC participation, MID, Measurement uncertainty, Market surveillance/verification and type approvals.

After the meeting work has continued and we have agreed that for each of the 72 OIML TC’s or CS’s there are a Nordic country coordinating the Nordic activities. Also the members of the WELMEC working groups (WG2, WG4, WG6, WG7, WG8 and WG10) from the Nordic countries were named.

Measurement uncertainties were discussed and work will continue in the new Nordtest project (and also connected to the work in WELMEC WG4).

A table showing present requirements regarding type testing and verification in the Nordic countries has been prepared.

Each country gave a short presentation of the present activities in market surveillance...

The co-operation will continue and especially areas like implementation of the MID and Market Surveillance are of interest.
## Annex F  N-MERA Examples of suggested Nordic pilot projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Collaboration type</th>
<th>Motivation for Projects</th>
<th>Responsible // Possible partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interdisciplinary Metrology</td>
<td></td>
<td>Need to continue N-MERA work in co-ordinating Nordic metrology. Includes <strong>external activities</strong> such as:</td>
<td>N-MERA Management group</td>
</tr>
<tr>
<td>Strategy for future Nordic metrology</td>
<td>I</td>
<td>• foresight, MET                                                                                           • stakeholder interaction   • EUROMET, ERA-NET, CIPM</td>
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<tr>
<td></td>
<td></td>
<td>and <strong>internal activities</strong> such as:</td>
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<td></td>
<td></td>
<td>• opening up/establishing common Nordic measurement resources</td>
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<td></td>
<td></td>
<td>• establishment of centres of excellence (decision plan)</td>
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<td></td>
<td></td>
<td>• mobility, competence development</td>
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<td></td>
<td></td>
<td>• co-ordination of NMS organisations (policy, administration)</td>
<td></td>
</tr>
<tr>
<td>Foresight, MET</td>
<td>III</td>
<td>Future foresight studies, including identification of measurement needs for emerging technologies (MET).</td>
<td>N-MERA Management group</td>
</tr>
<tr>
<td>Stakeholder interaction</td>
<td>III</td>
<td>Interaction with industry, funders, Government, NICe, universities, other research organisations</td>
<td>N-MERA Management group</td>
</tr>
<tr>
<td>Joint measurement knowledge transfer (KT) activities</td>
<td>III</td>
<td>Number of joint measurement KT activities, ranging from short industrial training courses to university degree courses:</td>
<td>N-MERA Management group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Review of current status, national schemes</td>
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<tr>
<td></td>
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<td>2. Development of common elements</td>
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<td>3. Development of training materials</td>
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<td></td>
<td></td>
<td>4. N-MERA as conference sponsor (e.g. Scientific Partner of Metrologie 2005 conference (June))</td>
<td></td>
</tr>
<tr>
<td>IT and Metrology</td>
<td>III</td>
<td>• IT discussion for a</td>
<td></td>
</tr>
<tr>
<td>Measurement &amp; Conformity Assessment</td>
<td>III</td>
<td>• Internet calibration</td>
<td>SP//</td>
</tr>
<tr>
<td>Multivariate Data Analysis &amp; Uncertainty</td>
<td>III</td>
<td>Measurements in many fields are increasingly made multi-variately. For instance, control of industrial production processes often made with one (or a few) control parameters. Treatment of uncertainties not well developed to date.</td>
<td></td>
</tr>
</tbody>
</table>
### Annex F  
**N-MERA Examples of suggested Nordic pilot projects**

<table>
<thead>
<tr>
<th>Flow – Volume – Density</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Looking into possibilities of establishing/sharing joint Nordic Reference Facilities</strong> (e.g. high pressure gas flow, hydrogen and large flows of water)</td>
</tr>
<tr>
<td>I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research for improved surface temperature measurements (contact and radiometric, including emissivity). Methods and training for industry.</strong></td>
</tr>
<tr>
<td>II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency comb</strong></td>
</tr>
<tr>
<td>I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Development of AFM-metrology</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CMM calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Photometry and Radiometry (Photonics)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Refractive index, glas, gloss, thin films, fluorescence</strong></td>
</tr>
<tr>
<td>II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Nordic virtual institute in fibre optical metrology</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acoustics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Methods for free field comparison calibrations under non-ideal free field environments</strong></td>
</tr>
<tr>
<td>II/III</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Improved accelerometers</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>II/III</td>
</tr>
</tbody>
</table>
## Time and Frequency

<table>
<thead>
<tr>
<th>Project</th>
<th>Stage</th>
<th>Description</th>
<th>Responsible Entities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Characterization</td>
<td>II/III</td>
<td>Needed especially by telecom equipment users and oscilloscope manufacturers and suppliers, and in time and frequency metrology due to the rise time of the 1-s pulses.</td>
<td>TI-No, FLO-No, SP, MIKES, DFM</td>
</tr>
<tr>
<td>Phase measurement 50 Hz, 60 Hz, 400 Hz – 10 kHz</td>
<td>III</td>
<td>Needed especially by energy companies</td>
<td>JV, MIKES, SP, DFM</td>
</tr>
<tr>
<td>Nordic Atomic Time Scale</td>
<td>II</td>
<td>The average time of almost 30 atomic clocks of the Nordic countries would have a considerable weight for UTC.</td>
<td>JV, MIKES, SP, DFM</td>
</tr>
<tr>
<td>Knowledge Network</td>
<td>III</td>
<td>Collaboration and exchange of information and ideas in regular meetings is important for efficient development of measurement capabilities in NMI’s of all Nordic countries.</td>
<td>TI-No, FLO-No, JV, MIKES, SP, DFM</td>
</tr>
</tbody>
</table>

## Electricity

<table>
<thead>
<tr>
<th>Project</th>
<th>Stage</th>
<th>Description</th>
<th>Responsible Entities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantum electrical measurements</td>
<td>II/III</td>
<td>Most electrical quantities are already realised or derived from quantum standards and frequency. Important further applications are under development. Collaboration is essential to keep Nordic countries in front of the competition in this important field of the future.</td>
<td>SP, MIKES, HUT, VTT, DFM, JV, CTH</td>
</tr>
<tr>
<td>DipVolt</td>
<td>III</td>
<td>To provide Scandinavian industry with traceable calibration of electric power calibration measurements.</td>
<td>SP, MIKES, HUT, JV, Arepa, CTH</td>
</tr>
<tr>
<td>AC resistance</td>
<td>II/III</td>
<td>Establish traceability and methods for AC resistance measurements in Nordic countries. Many transducers in process industry have a resistance output which is often measured using AC techniques. Until now the traceability has been based upon the DC resistance and certain assumptions about capacitance and inductance.</td>
<td>SP, DFM, JV, MIKES, Arepa</td>
</tr>
<tr>
<td>LossFactor</td>
<td>III</td>
<td>To provide less uncertainty in calibration of systems used to measure losses in power systems. Economically very important.</td>
<td>SP, ABB, Celsius Metech, MIKES-HUT</td>
</tr>
</tbody>
</table>
### Chemistry

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Grade</th>
<th>Description</th>
<th>Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Nordic Education program and material for education in Metrology in Chemistry</td>
<td>II</td>
<td>Need for trained personnel within metrology - To draw up a common nordic view of the training program in the area of chemical metrology in education.</td>
<td>SP, DFM, JV, MIKES, LS and Baltic states</td>
</tr>
<tr>
<td>Microbiology: Measurement uncertainty</td>
<td>II</td>
<td>Need to have a common Nordic guidance based on the Finnish publication: J4/2003, Uncertainty of quantitative determinations derived by cultivation of micro-organisms, Advisory Commission for Metrology, Seppo I. Niemelä</td>
<td></td>
</tr>
</tbody>
</table>

### Ionising Radiation

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Grade</th>
<th>Description</th>
<th>Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison of calibrations of air kerma-area product meters (DAP meters) Research/Intercomparison. Exchange of information</td>
<td></td>
<td>Most of the medical X-ray units are equipped with DAP meters to define the patient doses. Traceability for DAP as a quantity doesn’t exist at the moment. Prepare guidance for users (hospital physicists, manufactures) to calibrate the DAPs at hospitals. DAPs of X-ray units are part of the X-ray equipment installation. Calibrations must be performed on site.</td>
<td>SSI, NRPA, SIS, STUK, GR.</td>
</tr>
<tr>
<td>Development of traceability for fundamental quantities used in metrology of ionizing radiation (picoamps, kV of X-ray generators, temp, pressure, time).</td>
<td></td>
<td>Quantities of ionising radiation are derived and influences by other quantities. Relations to NMIs of other areas</td>
<td>SSI, NRPA, SIS, STUK, GR. NMIs of other areas.</td>
</tr>
<tr>
<td>Identify the resources required for EUROMET comparisons. To be the reference laboratory in a EUROMET project personnel, organizational and scientific resources are required. (e.g. Calibration of DAP meters) Exchange of personnel and excellence</td>
<td></td>
<td>Lot of comparisons are required to support the CMCs of MRA. Financing: stakeholders are not only industry representatives but also society safety.</td>
<td>SSI, NRPA, SIS, STUK, GR.</td>
</tr>
<tr>
<td>External audits of QS (ISO 17025) Development/co-op</td>
<td></td>
<td>Increase the reliability of calibration. According to requirements of MRA, external “peer reviews” shall be performed.</td>
<td>SSI, NRPA, SIS, STUK, GR.</td>
</tr>
</tbody>
</table>
## Mass/Force/Pressure/Torque

| Small high precision weights | 1) Calibration of weights and balances below 1 g with accuracy better than E1 (E0).  
2) Investigate production possibilities of weights below 1 mg with accuracy corresponding to extrapolated E1 class.  
3) Handling equipment for small weights  
Output: Improved capacity in balance calibrations | SP, MIKES, JV?, DFM? |
<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>A nordic facility for primary vacuum measurements</td>
<td>The need for traceability in vacuum is continuously increasing and uncertainties offered by the NMIs has to be improved. Need to provide primary standards in (a static expansion system) in range 100 Pa down to 0.1mPa as complement to existing facilities above and below this region at both MIKES and SP.</td>
<td>SP/MIKES</td>
</tr>
<tr>
<td>Calibration/verification of roll brake testers for trucks. Methods of calibration and confirmation of the correct capability.</td>
<td>Finland has most developed test trail to check the testers and also the best knowledge of the measurements in this area. Symposium arranged in beginning of 2005 (week 4 or 5) and as well a Nordic comparison project (project application to Nordic Innovation Centre)</td>
<td>MIKES-Raute, SP (Bilprov-ningen, Väverke t), JV (?,), Force (?)</td>
</tr>
<tr>
<td>The traceability on torque.</td>
<td>State of the art: Finland has the best capability of the torque calibration and as well the knowledge. The other countries have very few calibration facilities for torque. MIKES-Raute could work as a centre for torque in Nordic countries, giving traceability to torque as well the education on torque measurement and practical support by building new equipment.</td>
<td>MIKES-Raute, SP, Force, JV</td>
</tr>
</tbody>
</table>
Figure 4  N-MERA is scientific partner of the Metrology 2005 congress
http://www.cfmetrologie.com/index_congres.htm