

REACTIVE METROLOGY OR PROACTIVE METROLOGY - WHICH APPROACH WILL BEST MEET THE GRAND CHALLENGE OF SUSTAINABLE DEVELOPMENT?

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Abstract: The traditional *modus operandi* of the National Metrology Institutes has been the development, realisation and dissemination of the SI Units. However sustainable development poses challenges for our economies and societies that do not neatly align themselves with the SI Unit divisions of mass, length, time etc. Whilst the need for the NMIs to support the core mission is not questioned, this paper examines the case for top-level metrology to play a far more proactive role in rising to the grand challenges of the future.

Keywords: National Metrology Institutes, grand challenges, international cooperation.

1. HISTORICAL BASIS

The origins of metrology lie far back in history, the Egyptian civilization, the Greek and Roman Empires all implemented effective metrological processes. It was their ability to measure that enabled these ancient civilizations to construct structures that stand thousands of years later and still inspire awe today. Furthermore the ability to weigh and measure reliably was the enabling technology that underpinned the intricate networks of commerce and trade that formed the backbone of these early empires.

The tools of the metrologist improved with each scientific advance, and they in turn provided new measuring instruments and techniques to enable the experimental scientist to separate sound theory from fallacy. Along the way metrologists touched history, for example the development of accurate time measurement at sea enabled the British navy to accurately place its forces across the world's oceans, underpinning yet another imperial power.

It was not until the late 19th and early 20th century that metrology fully came of age. The 1875 Metre Convention [1] laid the foundations of a truly global system of measurement and the foundations of international collaboration in metrology. Following on from both the Convention and the wider recognition of the need for

metrology from the burgeoning scientific and technical communities, the leading economies of the time created laboratories specializing in measurement science, materials and testing. Before the first decade of the 20th Century had passed, significant dedicated centres of metrological excellence – now referred to as National Metrology Institutes or NMIs – had been established in, for example, Germany, the USA, France and the UK. Other nations followed suit – and as new nations come into being they continue to do so. The establishment of national institutions with coherent missions facilitated the development of the *Système International d'Unités* (“the SI”), a coherent science based system of measurement launched in 1960. Indeed the SI, realized at the leading NMIs, forms the backbone of measurement interoperability, a crucial part of the technical infrastructure that underpins scientific, economic and societal expectations of a modern nation state and the global economy.

In the early days the NMIs were focused around precision mechanical engineering and the fledgling materials sciences. The advent of quantum theory led to a revolution in metrology that has not yet fully run its course. It was the metrologists that first put this strange and exotic theory into practice and we now all take for granted levels of accuracy that, without real applications of quantum physics daily in our laboratories, would be unthinkable. This revolution was epitomised by the development of the atomic clock, which came of age when the National Physical Laboratory in England built the first caesium-beam clock used as a calibration source in 1955. Precise timekeeping had enormous consequences; many of them were most certainly unexpected at the time. Indeed, unrecognised by the public at large, the atomic clock heralded a revolution in our technological capability ranging from deep space exploration; global positioning; modern telecommunications through to the electronic financial transactions that we take for granted, but which would not be possible without the new levels of precision.

2. THE STRUCTURE AND OPERATION OF AN NMI AT THE END OF THE 20TH CENTURY

Not surprisingly the internal structures of the NMIs tend to reflect the fundamental and derived units of the SI. Departments, or subdivisions thereof, classically are organized along the unit specialities of mass, time and frequency, length, electricity and magnetism and so on. The key stakeholder for the NMIs has been – and continues to be – industry, with each department servicing appropriate industry sectors. The scientists within those departments therefore invest significant effort identifying industry’s “problems” within their field, prioritizing those problems, and bringing their research excellence to bear to solve them. Thus we see a specialist in measuring voltage scanning the various market sectors – or at least those with which he or she is familiar – typically asking stakeholders what problems they need solving, or perhaps looking for justification to continue an existing line of research. Their colleague from the “Pressure” department will similarly scan, and so on across the disciplines and their sub divisions.

3. THE GRAND CHALLENGE PHILOSOPHY

The model described above has served the metrology community, and its industrial stakeholders, well for a century. However with the increasing importance of multidisciplinary solutions, the emergence of new technologies and sectors such as biotechnology and nanotechnology, and the recognition of the value of good metrology in non-traditional sectors such as chemistry, medicine and software, questions have been raised for some time regarding the suitability of the traditional model. It is common to hear metrologists complain that those in Government do not understand their work, nor support it with appropriate funding. If we look more deeply some of the reasons for this become more apparent. To those outside the world of metrology a “traceable measurement”, unfortunately but not surprisingly, does not have any magical property nor intrinsic value. Consequently unless focused on the impact, pleas for increased support for metrological R&D or infrastructure investment are likely to go unheeded.

Yet policy makers are grappling with many grand challenges that can only realistically addressed if metrology plays its essential part. We now repeatedly hear our politicians openly state that sustainable development is perhaps the biggest challenge facing the human race. Sustainable development is multifaceted, made up of myriad individual “grand challenges”. Many would include climate change, overcoming poverty in the developing world, addressing diseases such as HIV/AIDS and perhaps Asian Bird flu, on their list, but there are surely others too. At a technological level we are already seeing the responses, for example the development of effective fuel cells, renewable energy sources, the decision to go ahead with the International Thermonuclear Experimental Reactor, the desire for security and sound governance of the environment

and the many initiatives aimed at achieving them. This list is not, of course exclusive. These then are some of the grand challenges and the responses that the citizens, and therefore the politicians, recognize. It is therefore not surprising that the majority of public funding for R&D flows towards these challenges.

An example of a metrology grand challenge approach is exemplified in the proposed, as yet unfunded, “Traceable Radiometry Underpinning Terrestrial and Helio Studies - TRUTHS” mission [2]. Whilst it is becoming increasingly difficult to deny global warming the arguments continue to rage over the contribution of mankind. The issue is not just a philosophical one, nor one of the practical implications of a warmer climate. The stance taken by Governments on this issue will have an immense impact on our economies and thus on employment and general well being. One major natural contributor to climate change is variation in solar irradiance. A drop of around 0.3% in solar irradiance in the 16th century caused a mini ice age in the northern Atlantic region, with an average temperature drop of around 2^o C, evidenced by the many paintings of Londoners ice skating on a frozen river Thames. Yet current satellites are able to monitor the irradiance of the sun to an accuracy of around 0.5%, and scientists are faced with a spread of data from a range of satellites, requiring correction factors that may mask vital changes, see Fig 1.

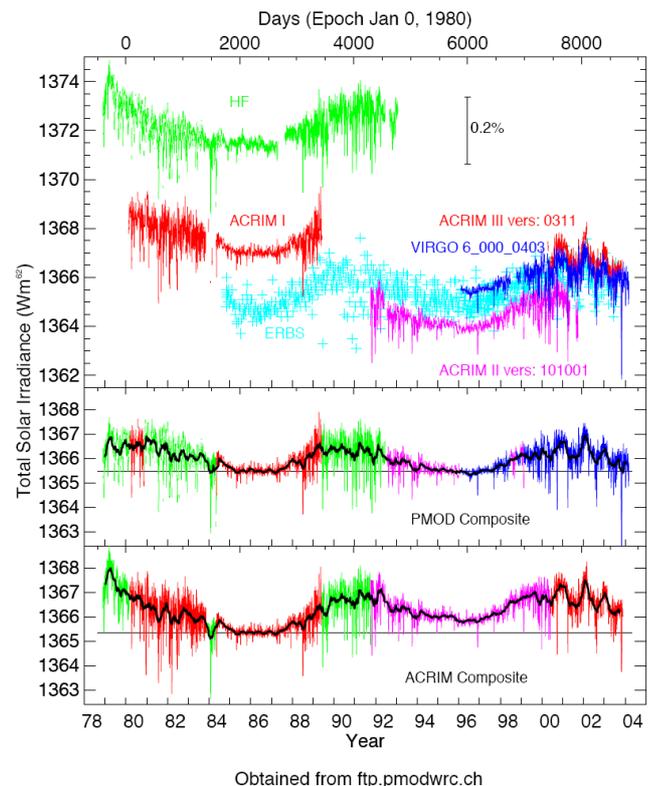


Fig 1. Raw and processed satellite data [3]

The proposed mission is ambitious, to place a primary measurement capability – a cryogenic radiometer – in space, in effect an NMI in the sky. The TRUTHS mission may or may not come to fruition, at around €90M for the mission it

requires substantial funding measured by NMI funding levels. Yet balanced against the prize, correct policy responses to global warming based on sound data, it begins to look like a very good investment and certainly qualifies as a grand challenge response by the metrology community.

In other areas of endeavour new technologies bring ethical and social acceptability challenges too, with strongly held and divergent views on issues such as genetically modified organisms, animal testing, stem cell research and human cloning. Almost unnoticed, and often unrecognised, metrology has – or at least should – become a cornerstone for policy making, with the mantra of “evidence based policy making” increasingly adopted by Governments. Yet too often in practice the “evidence” is expert opinion based on the interpretation of partial or extrapolated data, or even occasionally no data at all. The science behind policy decisions is becoming ever more complex. The role of the NMI is evolving beyond sound measurements and encompassing a wider custodian role with respect to the sound data that provides policy makers with the evidence they seek.

The NMIs are not blind to this challenge, and we already are seeing some response. In NPL for example the internal structure of the laboratory, that had followed the classical model, has recently been completely reorganized to encourage a multidisciplinary approach and to be outward, rather than inward, looking. We work more closely with regulators and policy makers, not only generating reliable measurement results, but also educating and advising.

Grand challenges are, as the name suggests, grand. Often that implies that the issue is by its nature not just national, but one of international magnitude or relevance. Consequently we are also recognizing that in many cases single national approaches are unlikely to provide sufficient critical mass to achieve the necessary impact and effective solutions. Within Europe the iMERA [4] initiative is a demonstration of what is possible, given the will. We are however still lacking authoritative reviews of the major challenges that identify across the full spectrum the contribution and impact of focused metrological effort, irrespective of the “Unit” discipline. Industry has in many cases adopted the concept of “technology platforms” which brings together all the different technologies and disciplines necessary to reach specific goals. Too often this approach does not fully integrate the metrological needs, with the assumption, if indeed there is any assumption about metrology, presumably being that it will be available when needed. Why not a metrology platform for challenges such as fuel cells, the ITER initiative, climate change? These platforms, understandable to the wider stakeholder community, could then in turn be integrated into the planning processes that drive and fund the various initiatives. Indeed, in Europe many of the challenges that need to be addressed collaboratively by the R&D community are routinely distilled and form the basis of the European Commission’s Framework Programmes. We are starting to think about the ‘Grand Challenge’ approach within the European metrology community [5], for example

we are discussing the concept of a horizontal metrological response to the proposals in the next Framework Programme [6] (the 7th) due to begin in 2007.

4. CONCLUSIONS

If the metrology community wishes to play a full role over the coming decades – and it is vital that it does so – then we need to raise our game. It is no longer enough to ask our stakeholders what problems they have with the volt. We need to be proactive and demonstrate how we can contribute through our R&D and associated activities to the wider effort involved in the grand challenges. We need to confidently talk about the contribution we can make through our intellectual capability, with our tools and experience and the facilities we can bring to bear. We need to focus on impact, offer holistic solutions, and be able to do so in language that is understood by the decision makers. Whilst the core role of the NMI, that is the development, realization and dissemination of the SI Units, is unchanged, we must be prepared in parallel to rise to the grand challenges and provide the metrology for sustainable development.

REFERENCES

- [1] Convention of the Metre, <http://www.bipm.fr/en/convention/>
- [2] N. Fox, J. Aiken, J. J. Barnett, X. Briottet, R. Carvell, C. Frohlich, S. B. Groom, O. Hagolle, J. D. Haigh, H. H. Kieffer, J. Lean, D. B. Pollock, T. Quinn, M. C. W. Sandford, M. Schaeppman, K. P. Shine, W. K. Schmutz, P. M. Teillet, K. J. Thome, M. M. Verstraete, E. Zalewski “Traceable Radiometry Underpinning Terrestrial – And Helio- Studies (Truths)”, *Adv. Space Res.* Vol 32, pp 2253-2261, 2003.
- [3] Obtained from Physikalisch-Meteorologisches Observatorium Davos, <ftp.pmodwrc.ch>.
- [4] Andy Henson, Michael Kuhne, Wolfgang Schmid, “Implementing Metrology in the European Research Area- the iMERA Project”, *Proc. 2005 NCSL International Workshop and Symposium, National Conference of Standards Laboratories International, Boulder, CO, USA, 2005.*
- [5] F Redgrave and A Henson, “Metrology...who benefits and why should they care?”, *Proc. 2005 NCSL International Workshop and Symposium, National Conference of Standards Laboratories International, Boulder, CO, USA, 2005.*
- [6] Proposals for a Seventh Framework Programme (FP7) for research, 2007-2013, and for a Seventh Framework Programme of the European Atomic Energy Community (Euratom), 2007 to 2011, COM(2005) 119 final, 6th April 2005.