

**NPL REPORT
DQL-AS 034**

**The 2006-2009 VAM-Physical
Programme:
Version for public release**

November 2006



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National Physical Laboratory
Hampton Road, Teddington, Middlesex, TW11 0LW

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Approved on behalf of the Managing Director, NPL
by Dr Stuart Windsor, Business Leader, Analytical Science Team

EXECUTIVE SUMMARY

This document summarises the content of the 2006-2009 VAM–Physical Programme. The Programme has been developed following a thorough formulation process that identified the key drivers and developed detailed requirements for the work.

The Programme is presented in four Technical Themes containing a total of 16 projects. These projects were prioritised by the VAM Working Group at a Decision Conference held on 23 May 2006.

The projects described in this document include a number of deliverables that do not form part of the initial contract. These deliverables (*highlighted in red italics*) may be introduced into the Programme if the contract is revised at a later date.

CONTENTS

Executive Summary	3
1. Introduction	6
1.1 Introduction to the VAM & VAM-Physical Programmes	6
1.2 Aim and objectives of the VAM-Physical Programme	7
1.3 Key drivers for the VAM-Physical Programme	8
1.4 Ensuring international comparability through traceability	9
2. Formulation of the 2006-2009 VAM-Physical Programme	10
3. Programme themes	12
Gas analysis Theme	13
Particulate and trace chemical analysis Theme	18
Surface and nano-analysis Theme	22
Management and knowledge transfer Theme	26
4. Projects	27
References	60
Annex: List of abbreviations and acronyms	62

1. INTRODUCTION

1.1 Introduction to the VAM & VAM-Physical Programmes

The Valid Analytical Measurement (VAM) Programme supports UK industry to ensure that analytical measurements are carried out competently and accurately. These measurements have a major impact on important areas of UK life such as innovation and competitiveness, air quality (emissions and pollutant monitoring), pharmaceuticals, vehicle exhaust testing, breath alcohol testing, medical devices and personal care.

Analytical measurements are vital to the UK economy as they are required to ensure product quality, to monitor impact on the environment and to satisfy legal requirements. It is estimated that the UK spends approximately £8 billion on analytical measurements every year. The VAM Programme underpins the reliability and integrity of these analytical measurements by supporting the provision of capability of the reference methods and standards required for traceable, quantitative measurement. It enables the UK to demonstrate the comparability of analytical measurements with those of its trading partners.

The Programme has two main technical themes: Physical measurement ('The VAM-Physical Programme') and Chemical measurement ('The VAM-Chemical Programme'). The VAM-Chemical Programme (operated chiefly by LGC) consists of an integrated set of projects designed to develop the methods, capabilities and facilities to provide reference materials and standards to enable laboratories to make measurements that are traceable to internationally recognised standards.

The VAM-Physical Programme supports accurate physical analytical measurements. These are fundamental in a wide range of industrial and legislative processes and are the crucial measurement issues in scientific fields such as gas, particulate, trace chemical, environmental, surface chemical, electroanalytical, single molecule and nanotechnological analysis. They are particularly important in a number of emerging scientific areas where analytical measurements currently lack sufficient traceability (e.g. measurement of the physical characteristics of nanoparticles, and the characterisation of novel, miniaturised sensing devices). A recent report on nanotechnologies by the Royal Society and Royal Academy of Engineering [1] highlighted the need for standardisation in nanoscience by recommending that the Department of Trade and Industry (DTI):

"...supports the standardisation of measurement at the nanometre scale required by regulators and for quality control in industry through the adequate funding of initiatives under its National Measurement System Programme..."

A Government research report on the potential risks posed by engineered nanoparticles [2] specified a key research objective as *"To identify the most suitable metrics and associated methods for the measurement and characterisation of nanoparticles"*, and highlighted NPL as the key laboratory developing such methods and techniques.

The Programme also supports measurement requirements for a number of issues of increasing public concern such as greenhouse gases, and detection and identification of pollutants in ambient and indoor air. Air quality has a large effect on quality of life and health – in the UK,

it is estimated that airborne particles contribute to the premature death of 32,000 people per year. [3]

A recent independent review of the long-term measurement needs across the National Measurement System (NMS) Programme portfolio [4] revealed that the VAM-Physical Programme had the largest number of ‘measurement needs’ per unit cost. In addition, a Government review of the NMS [5] revealed the VAM-Physical Programme to have the highest innovation content of any Programme in the NMS Portfolio. The Programme is therefore the ideal vehicle to support the Government’s stated aim [6] of increasing UK innovation, resulting in ‘prosperity for all’.

This document describes the content of the 2006-2009 VAM-Physical Programme, which aims to advance the work carried out in previous Programmes. The National Measurement System Directorate (NMSD) of the DTI have advised that the Programme should have an increased focus on research-based projects, and that the benefits of the Programme should continue to be disseminated through a series of successful knowledge transfer routes.

1.2 Aim and objectives of the VAM-Physical Programme

The aim of the Programme is to provide the technical and administrative infrastructure required to ensure valid and traceable analytical measurements in the UK and to establish the equivalence of analytical measurements with our trading partners.

The objectives of the Programme are:

- To enhance wealth creation, prosperity, innovation and industrial competitiveness by improving analytical measurements of input, process and output parameters and to provide leadership amongst the UK analytical science community in the application of leading-edge science and technology.
- To underpin the requirements for stable and accurate analytical measurements to support fair regulation and to support the process of developing national and international regulations on a sound and cost-effective measurement basis.
- To support measurements in the healthcare and environmental sectors intended to improve the quality of life throughout the UK and to contribute towards the monitoring and control of climate change.
- To carry out a range of activities to transfer the outputs of the programme in terms of knowledge and technology to UK users, including industry, SMEs, regulators and trade bodies.
- To support trade and the comparability of UK measurements by participation in international comparisons and the development of an infrastructure for the global acceptance of measurement results.

1.3 Key drivers for the VAM-Physical Programme

A review of independently produced reports has identified four high-level drivers for physical analytical measurements. These drivers, which are closely linked to the proposed objectives of the VAM-Physical Programme, are detailed below:

(a) Industrial competitiveness and trade

Industrial production and innovation depends on the capability to measure, characterise and understand new processes and novel devices, as well as to control efficiency in manufacture. This is only possible when access is available to valid measurement methods and a comparable basis for measurements. Innovative new technologies pose requirements that are at the cutting edge of measurement capability. The optimisation of process performance depends on the ability to monitor control parameters on a stable basis. Import and export of manufactured goods depends on the acceptance of a uniform basis for measurements.

(b) Regulation

Regulations developed at both European and UK level ensure that emissions from industry are controlled within agreed limits. Such regulations are most effective when they define performance levels that are both achievable by industry with available technology and operate at levels that provide adequate protection for society. In cases where protection is required that goes beyond that which can be achieved with available technology, regulation can act to stimulate innovation in the development of improved technology. The imposition of such regulation on a basis that is fair to regulated industry and society requires an infrastructure for traceable measurements at a level of uncertainty appropriate for the application.

(c) International representation of the UK's interests

The effective achievement of the objectives of the VAM Programme requires the UK's interests to be represented and defended on the various international bodies where international documentary standards are developed (e.g. ISO and CEN) and where the validity of the UK's national measurement standards must be demonstrated (e.g. CCQM). Activities of this type have become more intense as a result of the drive to provide a single set of standards across the EU and to provide a measurement infrastructure that can support global trade.

(d) Environmental protection and quality of life

The continued protection of human health and the environment depends on the capability to monitor accurately the amounts of harmful species in the environment. These measurements can be used to determine whether the most damaging species are below acceptable levels, and subsequently whether a reduction in their concentrations is required. These objectives can only be achieved if both regulators and regulated industry have access to measurement standards that are valid at the very low levels appropriate for environmental monitoring.

1.4 Ensuring international comparability through traceability

The VAM-Physical Programme ensures that stakeholders in the UK have direct access to traceable measurement standards for gases, particulates and surface analysis. Much of the demand for traceability of these measurements is driven by two requirements:

- The internationally-accepted standard for test and calibration laboratories (ISO 17025) requires that they make use of traceable measurement standards where available. Whilst it is not possible to provide traceable measurement standards for every analytical quantity that is measured, the range of measurement standards with the greatest applicability across sectors may be provided.
- Fair and free international trade requires that the results of measurements be accepted around the world without additional measurement. This can only be met by ensuring that measurements made in the UK are made on a basis that is transparent and recognised internationally.

These two drivers are the justification for the UK's involvement in the international measurement system based on traceability to the international system of units (SI), demonstrated through international comparisons. This is organised under the CIPM Mutual Recognition Arrangement (MRA) [7] agreed between 45 nations around the world. The MRA is based on the technical capability of individual laboratories to disseminate measurements that are traceable to the SI and is underpinned through a series of international intercomparisons. [8]

2. FORMULATION OF THE 2006-2009 VAM-PHYSICAL PROGRAMME

In order to formulate the project proposals presented in this document, the requirements of the Programme have been evaluated through a substantial consultation exercise. The following methods have been used to gain input from key stakeholders:

- A one-day gas and environmental analysis focus group held in the Midlands and attended by invited representatives of industry, trade associations, academia, Government organisations and UKAS. A large number of draft project ideas were presented to, and discussed by, the group.
- A one-day Surface and nano-Analysis Measurement Steering (SAMS) Workshop at NPL. The workshop, attended by key experts in the field of surface analysis used responses to an in-depth questionnaire to discuss and prioritise a number of key measurement issues and proposed projects.
- A one-day conference, ‘The Measurement of Engineered Nanoparticles’, held at NPL under the auspices of the Micro and Nanotechnology Measurement Club. The conference, with over 90 attendees, allowed formal and informal discussion of issues relating to the physical measurement and sampling of nanoparticulates.
- Development of a VAM-Physical formulation website to allow interested parties to input their views and download relevant documents.
- Feedback through three on-line questionnaires available through the formulation website.
- Continuous consultation with collaborative partners in existing VAM projects, other NMS Programmes, the Measurement for Innovators Programme and contacts established through knowledge transfer activities in previous VAM Programmes.
- One-to-one discussions with key individuals through invitations to meet key staff at NPL, visits to the contacts’ organisations, and telephone and e-mail discussions.

Representatives from the following groups of stakeholders have contributed to consultation:

- Government departments
- Industrial trade associations
- Major UK companies in appropriate sectors (e.g. gas companies, motor vehicle industry)
- UK and European regulatory bodies (e.g. the Environment Agency)
- BSI
- UKAS
- UK SMEs and instrument manufacturers in appropriate scientific sectors
- Leading academics
- Analytical laboratories
- UK Regional Development Agencies

- Experts within other Teams at NPL involved in the delivery of other NMS Programmes
- Other UK Laboratories delivering NMS Programmes and projects (LGC, NEL & AEA Technology)
- Other National Metrology Institutes
- Members of NPL clubs
- Contacts on NPL mailing lists
- Members of the Royal Society of Chemistry, Institute of Physics, and Institute of Materials, Minerals and Mining
- Serco Assurance
- EPSRC Programme Managers
- Representatives of the UK food industry
- UK electrochemistry experts

Full details of the process undertaken to formulate the Programme presented here are given in the Public Consultation Document '*Proposals for the 2006-2009 Valid Analytical Measurement (VAM) – Physical Programme: Version for public comment*'. [9] This includes:

- A summary of the 'trend spotting forward look' review
- Responses from on-line questionnaires
- The results of NMSD's needs analysis study
- Results of a patent mapping study
- Details of, and statistic from, the VAM formulation website
- Details of discussions with LGC staff formulating and delivering the VAM-Chemical Programme
- Examples of method used to promote the formulation process

Additional information is also available on the available on the VAM-Physical formulation website: www.npl.co.uk/formulation/vam. This includes:

- A list of the source documents consulted
- Focus group and consultation meeting details, reports and presentations
- Online questionnaires
- Other background information

3. PROGRAMME THEMES

The 16 projects that comprise the 2006-2009 VAM-Physical Programme (detailed on p.27) are presented under four Technical Themes:

Theme G:	Gas analysis
Theme P:	Particulate and trace chemical analysis
Theme S:	Surface and nano-analysis
Theme M:	Management and knowledge transfer

An outline of each Theme is given in the following pages, including:

- The aims and objectives of the Theme
- A summary the key drivers
- An overview of the major measurement issues
- A Theme roadmap.

GAS ANALYSIS THEME

Introduction to Theme

Measurements of gases are fundamental to the control of emissions, the quality of ambient and indoor air, and to many aspects of industrial process control. These measurements are applicable across a wide range of industrial sectors including power generation, chemicals/petrochemicals, oil and other fuels, aerospace, vehicles, electronics, water, waste incineration and landfill, public health, analytical instrumentation (including sensors), metal and non-metal processing, and pharmaceuticals.

The VAM-Physical Programme has carried out work to fulfil the requirements for valid gas and particulate measurements in the UK, which has resulted in the development of:

- Primary gas concentration standards prepared by absolute gravimetric techniques, validated comprehensively and with demonstrated international comparability, covering industrial emissions, natural gas, flammability, occupational exposure, forensic applications, and ambient air quality.
- Absolute gas calibration facilities, which employ dynamic methods where gas standards cannot be prepared gravimetrically with known concentrations.
- National calibration and test facilities to evaluate the performance or type-test analysers for certain industrial emission, process control and ambient air quality applications.

Where the requirements for these are still strong, it will be necessary to replace standards and maintain facilities as they are used. Further, the UK is signatory to the Mutual Recognition Arrangement (MRA) between National Measurement Institutes (NMIs) worldwide. As a consequence, key international comparisons have been carried out, that enable the UK to demonstrate acceptable international comparability. These have continuing benefits - by facilitating UK industry's trade with our international partners.

In addition, strong UK inputs have been made to a number of important European (CEN) and worldwide (ISO) standards, some which are now published, and others are advanced drafts. These have major impacts both on UK regulations and on industrial efficiency, and technical input has been made to ensure that the UK's interests are supported and protected.

Theme aim and objectives

The aim of the Theme is to underpin the requirements of UK industry and regulators for traceable measurements of ambient, emission level, forensic, occupational health and indoor air gases.

The objectives of the Theme are:

- To develop and disseminate primary and secondary standard gas mixtures and dynamic measurement facilities to underpin UK industry and regulators.
- To promote the use of new and advanced analytical instrumentation to improve the validity of measurements of process efficiency, air quality, emissions and trace species.

- To provide a focus for the development and application of leading-edge technologies and innovative analytical approaches.
- To transfer knowledge and technology developed in the Theme to UK industry, regulators and trade bodies.
- To represent the UK in CCQM, EUROMET and international standardisation bodies, and to participate in international scientific collaborations in order to ensure the global comparability of UK measurements of gases and particles.

Key drivers

Wide ranging consultations involving UK industry, regulators and government, have resulted in the identification of four drivers:

(a) Industrial competitiveness and trade

There are continuing requirements to increase the enterprise, innovation, and competitiveness of the UK's manufacturing industries. Gas measurement contributes to this strongly through the optimisation of industrial process efficiency, and by providing cost-effective environmental monitoring technologies. These can both be achieved by the utilisation of advanced on-line instrumentation, calibrated with valid standards. In addition, there is a move towards 'self-calibrating' and 'remotely calibrated' instrumentation, which need to be implemented accurately to be of benefit to industry. The field of analytical instrumentation is highly competitive, and includes many SMEs.

National and international trade is also facilitated by accurate gas measurements, for example, to enable valid natural gas trading between different organisations and countries (towards a single European natural gas market), and for aspects of emissions trading that require measurement.

In addition, there is an increasing emphasis on product certification and type approval in Europe and elsewhere to control emissions from aircraft and other vehicles and to ensure the performance of analytical instrumentation. These activities must be underpinned by valid calibration and measurement techniques, which are acceptable across the single European market to enable international acceptance and facilitate trade.

(b) Regulation

The field of gas measurements is the subject of a large and increasing range of regulations. These include both national regulations, and increasingly, new EC Directives (requiring Member states to enact them into national law). They include the following:

- EC Directives that limit the emissions of industrial sources to the environment (e.g. Large Combustion Plant);
- EC Directives that seek to control the quality of ambient air in both urban and rural locations, and related CAFE requirements;
- National regulations for the routine measurement of gases covered by international legal metrology regulations (e.g. breath alcohol and vehicle MOT tests);
- EU requirements (Euro IV and V) and future ones covering emissions from cleaner vehicles using new technologies;
- EC proposals for a single European market for natural gas;

- EU regulations on trace contamination in the environment, food etc;
- International (ICAO etc) requirements on aircraft emissions;
- International protocols (e.g. Kyoto climate change, UN/ECE trans-boundary pollution, OECD toxicity) to which the UK is a signatory leading to controls on greenhouse gas emissions and pollutant emissions trading;

In addition, new mandatory CEN standards are being drafted to underpin all the EC Directives and provide prescriptive measurement methods that require traceability to National standards. Furthermore, the accreditation standard ISO EN 17025 has now been implemented across Europe – this emphasises the requirement for national traceability.

The VAM-Physical gas analysis Theme enables industry to demonstrate compliance with regulations and statutes in a fair and cost-effective manner. It ensures the acceptability of results by regulators accreditation bodies and the public, and provides support to regulators to enable them to enforce legislation in a technically sound and impartial way.

(c) International representation of the UK's interests

The UK's measurements of gases must be accepted internationally to enable fair and free trade. The Mutual Recognition Arrangements established by the CIPM between metrology institutes across the world facilitates this. This MRA requires key comparisons and research studies in the gases area to sustain agreements, and to develop mutual acceptance in further aspects, where needed for trade and for dissemination of results that are traceable to SI units.

The recent progress in the organisation of International Key Comparisons within the CCQM Gas Analysis Working Group is shown in Figure 1.

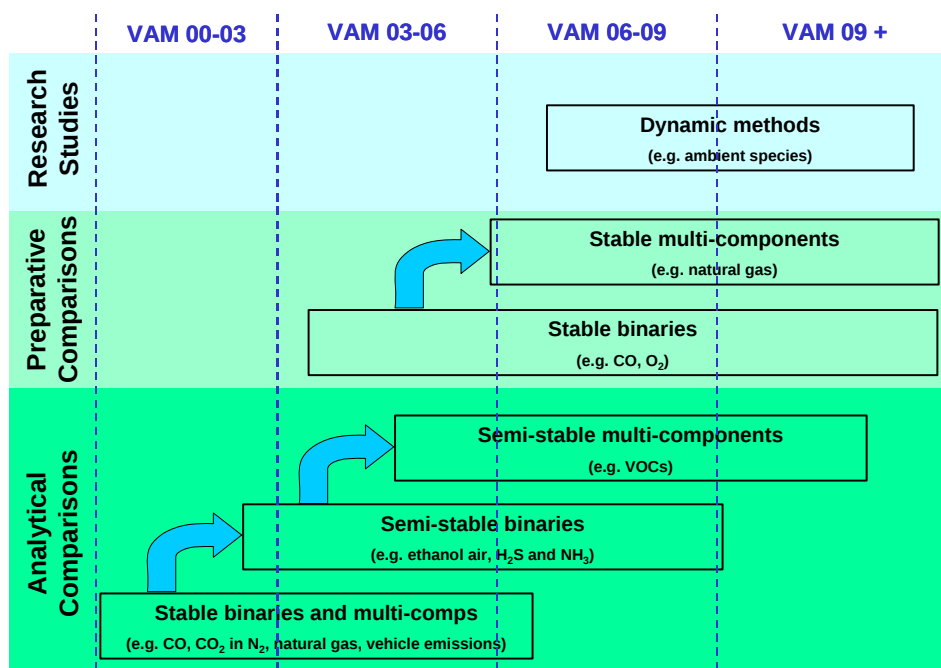


Figure 1: Diagram showing a timescale for CCQM gas analysis international intercomparisons

(d) Environmental protection and quality of life

The protection of human health and the natural environment depends strongly on the ability to measure harmful, flammable, toxic and carcinogenic substances cost-effectively, and with satisfactory validity to be fit for purpose. European research studies [10] have estimated that approximately 6% of annual deaths are caused, or precipitated, by outdoor air pollution. A range of measurement applications (including those not covered by current and planned regulations) are involved:

- Emissions (direct and fugitive) from certain industrial and agricultural sources
- Determination of odours and the identification of odorous species
- Air quality in indoor air, vehicles, healthcare establishments, etc.
- The quality of alternative fuels being developed to support sustainable development
- Trace gases, including explosives detection.

Measurement issues

A number of significant advances in gas metrology were developed by NPL to address industrial requirements during the 2003-2006 VAM-Physical Programme. These include:

- Improvements in the verification of the performance of passivated gas cylinders, allowing the dissemination of standards for unstable species (e.g. sulphur odorants).
- Development of an automated gas analysis system, which has reduced comparison uncertainties from 1.5% to better than 0.5% with substantially reduced gas usage.
- Implementation of a single-pan balance procedure, which has reduced the time required for weighing to an uncertainty of 0.01% from 2 hours to less than 10 minutes.
- The development of the ‘preparative comparison’ for international comparisons which has improved the uncertainty of comparisons from 0.2% to better than 0.05%.

The 2006-2009 VAM-Physical Programme proposes to implement further technological advances in order to reduce the cost and uncertainty of traceable gas mixtures, including the exploitation of:

- NPL’s IPR covering dynamic dilution methods
- Microcylinder technology
- Absolute optical absorption methods
- Improved cylinder passivation chemistry.

The central projects in the gas analysis Theme make use of common facilities and technologies. The underpinning traceability and synergies between the projects are highlighted in Figure 2:

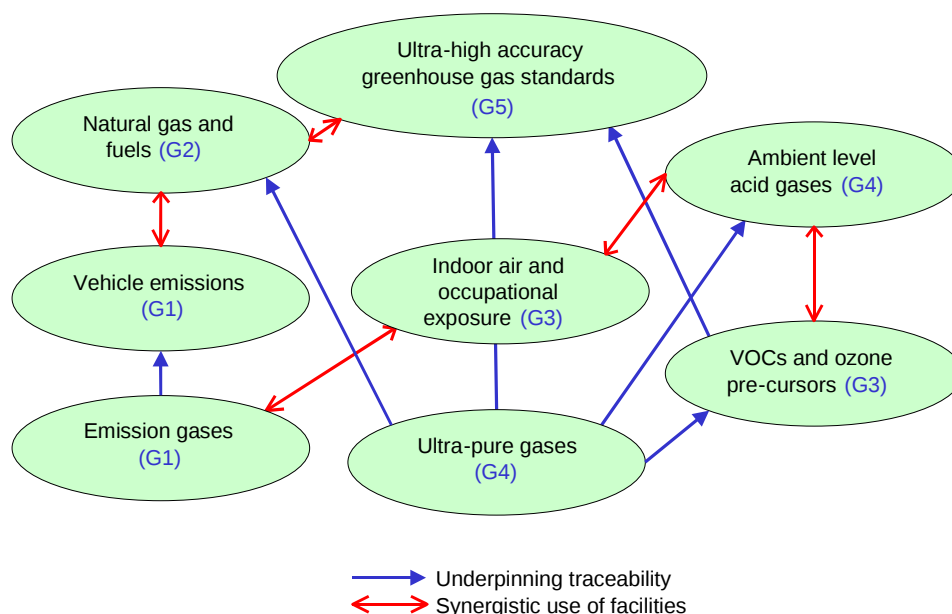


Figure 2: Diagram showing the synergies and underpinning traceability between key components in the gas analysis Theme (project numbers in brackets)

Theme roadmap

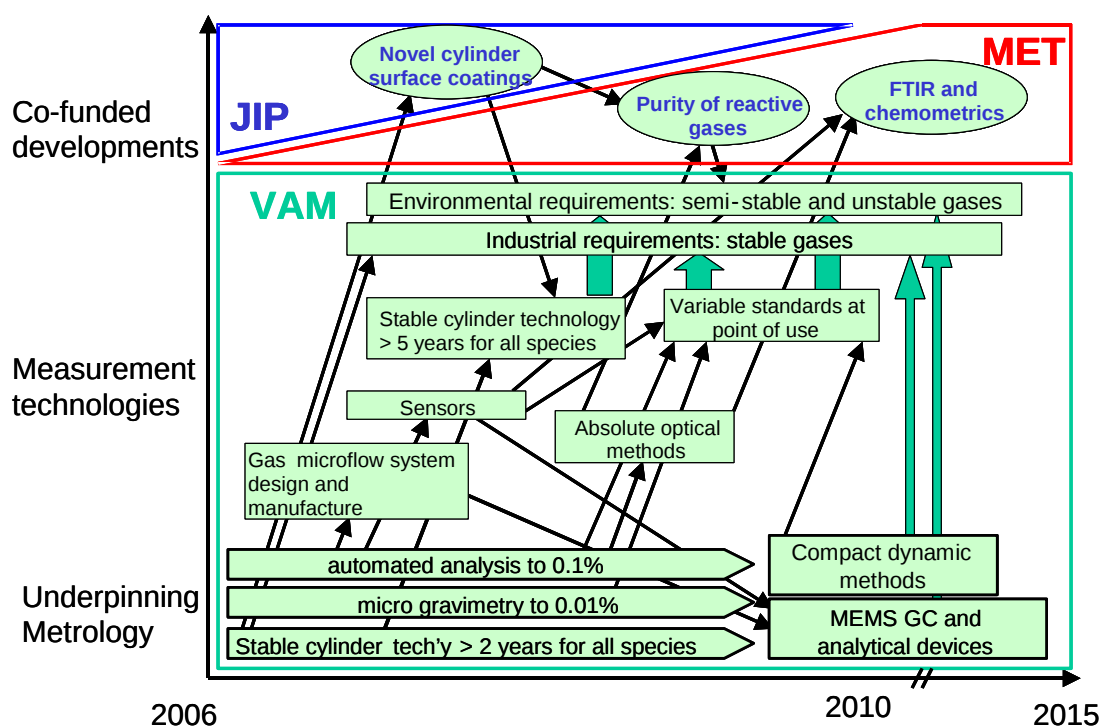


Figure 3: Gas analysis roadmap showing the strategic development of research within this Theme. It illustrates the feed through of underpinning metrology in VAM through to collaborative industry JIP and MET projects. The timings in the roadmap are indicative and show relative order.

PARTICULATE AND TRACE CHEMICAL ANALYSIS THEME

Introduction to Theme

The Particulate and trace chemical analysis Theme is centred on the measurement issues relating to airborne particles, and includes the related areas of Surface Enhanced Raman Spectroscopy (SERS), pH and ionic content. Many of the techniques for handling particle-laden air are similar to those for handling gas mixtures, addressed by the Gas Analysis Theme. The chemical analysis of small particles is also close in concept to some of the work included in the Surface and nanoanalysis Theme.

Airborne particles are the single most dangerous component in air pollution in the United Kingdom, causing an estimated 32,000 premature deaths here annually [3]. They are also a major factor in climate change, both directly through their absorption and reflection of radiation, and indirectly through their effect on the formation of water droplets. They have a much more local and immediate effect on the climate than greenhouse gases such as carbon dioxide.

Airborne particles are extremely diverse, varying in size, composition and origin. Sooty particles from diesel engines are just a few nanometres in size, while windblown dust particles, typically rich in silicon, can be tens of micrometres. Some particles originate from natural processes, such as sea salt particle formation, while others arise from human activities. Many particles are formed by the reaction of gases in the air, for example the gas ammonia (from agricultural sources) reacts with nitrogen dioxide (from vehicle exhausts) to form particles of ammonium nitrate.

The diverse physico-chemical characteristics of particles lead to many measurement issues. The components and properties most relevant to health have not been determined. Current legislation refers only to total mass of particles below 10 μm in size (PM_{10}), or below 2.5 μm ($\text{PM}_{2.5}$). Projects P1 and P2 in this Theme are aimed directly at measuring and characterising airborne particles as a necessary part of understanding their health and climatic effects.

The most common technique for analysing ionic components of airborne particles such as ammonium, sulphate and nitrate is ion chromatography. Project P3 contains underpinning work in pH and related ion analysis topics which builds on existing strengths in these areas.

SERS shows great promise as a tool for ultra-trace analysis. The technique relies on the enhancement of Raman signals from target molecules, sometimes down to single molecule levels, using a nanostructured metallic substrate. The technique has potentially wide applications to the detection and identification of ultra-low levels of chemical components in the atmosphere and the environment especially when in the particulate phase. However, to achieve reproducible enhancement levels to make SERS genuinely useful as a trace analysis tool, more regular and reproducible metallic substrates are needed. Project P4 is a more forward-looking project focussed on achieving these goals.

Theme aims

The aims of the Theme are:

- To provide underpinning traceability for airborne particle number density measurements and develop methods that can measure characteristics of particles (such as surface area) that are not readily measurable with existing technology.
- To provide capability for measurement methodologies, standards and facilities required for robust measurements of airborne particle size and number density.
- To underpin measurements of airborne particle mass, and provide metrological support for measurements of organic and elemental carbon, and for relevant properties such as reflectivity and non-volatile mass.
- To develop novel analytical methods to perform accurate measurements of mercury vapour and of the chemical composition of airborne particles.
- To provide capability for the UK's link to primary standards of pH and solution conductivity, and develop focussed research into practical pH measurement in on-line environments, particularly fuel cells.
- To develop efficient and reproducible nano-structured surfaces to underpin the use of Surface Enhanced Raman Spectroscopy (SERS) as an ultra-trace analysis tool.

Key drivers

Four high-level drivers for physical analytical measurements were identified during the formulation process. These are:

(a) Industrial competitiveness and trade

Industrial competitiveness is strongly influenced by the measurement techniques for particulates used to enforce the regulation being reliable and cost-effective. The same techniques are also crucial to allow innovation in production methods or vehicle engines, for example, to be properly evaluated. More specifically, the emerging industrial applications of manufactured nanoparticles, within the field of nanotechnology, require measurement techniques that will be closely related to those developed within these projects, aimed at ambient air and emissions. These issues have led to a strong market for particulate instrumentation, which again requires reliable, internationally recognised validation and calibration.

The determination of pH is the most commonly made analytical measurement throughout the world. An increased understanding, particularly at end-user level, of the measurement science underpinning electrochemical techniques and the need for traceability in valid electro-analytical measurements, would make process pH measurements more accurate, therefore benefiting UK competitiveness reducing barriers to trade.

There is an increasing requirement in the analytical community to detect and characterise target molecules at ultra low and even single molecule levels, especially in environmental matrices. Optimised procedures and analytical techniques would increase the UK's ability to perform accurate low level quantification, thereby improving efficiency and increasing analytical throughput, and providing the UK with a competitive advantage in these areas.

(b) Regulation

Regulations developed at both European and UK level ensure both that particulate emissions from vehicles and industry, and ambient particulate concentrations, are controlled within agreed limits. Such regulations are most effective when they define performance levels that are both achievable by industry with available technology and operate at levels that provide adequate protection for society. The imposition of such regulation on a basis that is fair to regulated industry and society requires an infrastructure for traceable measurements at a level of uncertainty appropriate for the application. The measurement infrastructure for airborne particles is notably immature and requires measurement science to develop.

Many areas of regulation require accurate pH measurements; for example the monitoring of ambient air quality, water quality and food quality. These lead to transparency in measurements used to inform policy making (at local, national and international levels) and to determine compliance with limit values set for pollutants.

The use of optimised trace analysis techniques is a vital step towards the technical capability required to assess compliance with ever more exacting regulatory limits, for example for allowable pollutant levels in environmental matrices. Accurate, traceable measurements at low levels with low uncertainties will enhance the tools available to regulatory authorities for accurately judging compliance against limit values which exist in the environmental field.

(c) International representation of the UK's interests

The above regulatory and standardisation issues, and the international nature of air pollution and climate change, emphasise the importance of international representation as part of this project. NPL has been very active in the writing of European standard methods for air pollution by CEN, such as CEN TC264/WG15 (PM₁₀ and PM_{2.5}) and WG 25 (Mercury). Particle counting and sizing standardization is addressed through ISO TC24/SC4 (Sizing by methods other than sieving). The practical implementation of PM legislation has involved the detailed description of what is meant by 'equivalent' methods, and NPL will continue to play a prominent part as this develops. Issues of PM measurement in national networks are addressed through the European AQUILA group. At the metrological level, representation for particle measurements will take place through EUROMET and CCQM, and for pH through CCQM's Electrochemical Analysis Working Group.

(d) Environmental protection and quality of life

Benefits to environmental protection, through climate change, and quality of life, through both climate change and the health effects of airborne particles, are central to the work of this theme, as described in the Introduction. There would also be less direct but very pervasive benefits through the capabilities to be established through the pH and SERS work.

Measurement issues

Some of the key measurement issues are summarised below:

Airborne particulate sampling - Characteristics of size selective inlets; Flow control and measurement; Sample conditioning effects; Transport losses in pipework; Characteristics of

dilution devices; Reactions on and with filters (in polluted air); Treatment of semi-volatile particles.

Measurement of particle number concentration, size distribution, and other properties - Characteristics of condensation particle counters; Characteristics of particle charging methods; Characteristics of electrometer charge counters; Characteristics of electrical mobility size selection; Definition and determination of surface area.

Measurement of total mass, and mass of specific components - Factors affecting filter weighing reference methods; Equivalence of on-line or indirect methods for total mass (e.g. oscillating microbalance, beta attenuation, optical); Definition and determination of elemental and organic carbon content; Methods for ionic composition (e.g. ion chromatography); Equivalence of on-line methods for ionic composition; Methods for mercury and other metals.

pH and ionic content - Reducing the uncertainty of the primary Harned cell; Methodologies for on-line measurements in various environments.

SERS - Design and production of optimised nano-structured surfaces; Application of SERS techniques to environmental and other measurements.

Theme roadmap

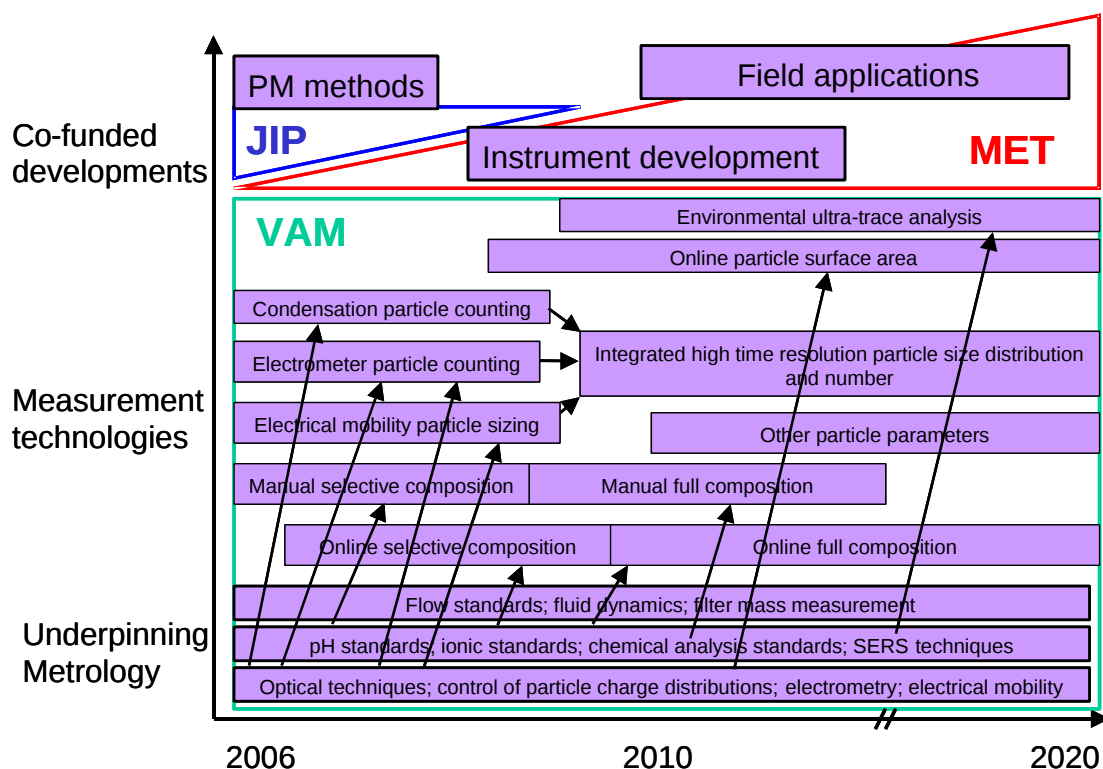


Figure 4: Particulate and trace chemical analysis roadmap showing the strategic development of research within this Theme. It illustrates the feed through of underpinning metrology in VAM through to collaborative industry JIP and MET projects. The timings in the roadmap are indicative and show relative order.

SURFACE AND NANO-ANALYSIS THEME

Introduction to Theme

The successful, modern knowledge-based economy is based on growing innovation for the development of high added value products that have a strong competitive edge in the global market place. Central to the correct operation and novel properties of many of these products is the surface chemistry. Surface chemical analytical techniques are key to understanding and characterising these surfaces from the microscale to the nanoscale. The frontline industry-favoured techniques for surface chemical analysis are x-ray photoelectron spectroscopy (XPS), static secondary ion mass spectrometry (SSIMS) and atomic force microscopy (AFM). These complementary techniques provide key quantitative information on atoms and molecules at surfaces, providing high specificity, identification of complex molecules and analytical measurement of materials at the nanoscale.

Work supported under previous VAM Programmes has led to significant benefits in these areas providing revolutionary new methods, major improvements in measurement reproducibility and repeatability, an infrastructure to ensure valid interpretation and fit-for-purpose measurements and frontier research for challenging measurements at the nanoscale. The proposed new programme builds significantly on this, developing key measurements needed by industry and begins the development of strategically important new areas.

Theme aims

The aims of this Theme are:

- To support innovation and competitiveness through the development of reliable leading-edge measurement.
- To develop, strategically, the measurement capabilities and infrastructure to meet the needs of knowledge-based industries and for quality of life.
- To ensure that UK measurements are fit-for-purpose, provide international comparability of measurements and ensure that the measurement infrastructure is in place to underpin systems for accreditation and quality control.
- To provide leadership in frontier issues in surface and nano-analysis measurement in the UK and internationally.
- To conduct key knowledge transfer activities including national and international comparisons, representation on international bodies to ensure international uniformity and traceability of UK measurements and to ensure that knowledge outputs are promulgated effectively and impact the key audiences.

Key drivers

In the recent DTI Innovation Report [6], the Government urges that: “innovation, the exploitation of new ideas is absolutely essential to safeguard and deliver high quality jobs, successful business, better products and services and more environmentally friendly processes”.

The DTI's business-led Technology Strategy Board vision [11] is for the UK to be a global leader in innovation and a magnet for technology-intensive companies. UK industry is restructuring from traditional heavy industry, such as processing bulk chemicals etc, to a high added-value, knowledge-based economy. Consequently, there is a major growth in the need for measurement, characterisation and understanding of new complex products.

The UK has major strengths in the new knowledge-intensive areas including, nano- and micro- technology, and emerging technologies. These cover a wide range of industry sectors which rank amongst the highest value-added companies [12] including health and personal care (£5.1bn added value per year), pharmaceuticals (£22.9bn), chemical additives (£7.6bn), and aerospace and defence (£10.4bn). Major sectors in the global economy include Advanced Materials (£200bn) and Medical Devices (£115bn) [11]. The annual value for all nanotechnology-related products is estimated, by 2011, to be \$1000bn [13].

The innovative technologies in these sectors which rely on surface chemistry are wide-ranging, including drug delivery and controlled release systems, anti-fouling implants, high-efficiency detergents, natural fibre coatings, cosmetics, technical textiles with applications from wound healing to protection from chemical warfare, functionalised microfabricated devices, organic electronics, displays and ink-jet fabrication.

A major goal in medical research is to enhance people's well-being and quality of life. This also reduces the burden on the healthcare system. For many medical devices, the surface molecular chemistry is critical, including drug delivery systems, diagnostic arrays, coronary stents, catheters, artificial implants, wound healing and tissue engineering. The Materials Foresight report 'Priority Topics for Biomaterials' [14], highlights the need for surface chemistry, the surface design, molecular orientation and functionality for anti-microbial, anti-thrombogenic and analgesic capabilities. The OST Foresight project 'Detection and Identification of Infectious Diseases' [15] highlights the need to characterise surface chemistry for molecular binding and recognition for healthcare applications. The Chemicals Foresight report 'A Chemical Renaissance' [16] similarly highlights that the development of pharmaceuticals (including drug delivery) depends on chemistry at the molecular level. This has a major impact on quality of life, over 2.5 million coronary stents and more than 100,000 heart valves are fitted annually but many of these fail to be effective through lack of control of surface aspects. With the age-shift in the population (by 2020 there will be one million more people aged 45 to 64 than in their 20s and 30s [17]), there is a growing and urgent need for long-life implants with improved and new medical devices.

Urgent societal issues are sustainable consumption and production as well as energy efficiency. New materials and processes are enabling end-of-life management and product recycling to be built into product design to reduce waste. Advanced materials and their surface properties are key to many renewable and clean energy technologies including, hydrogen storage, carbon sequestration, fuel cell membranes and photovoltaics. Innovative modern products, for example those using nanotechnology, use less raw materials, have lower energy consumption and produce less waste. The requirement for work in these areas is brought out in the vision for key technology areas, such as Advanced Materials and Sustainable Production and Consumption, identified in a recent DTI Technology Strategy report [11].

The opportunities and areas for action in Nanotechnology have also been identified in a recent independent Royal Society and Royal Academy of Engineering report [1]. A key conclusion that was highlighted is the importance of metrology to underpin nanoscience and nanotechnology. This report specifically recommends the standardisation of measurement at the nano-scale through the National Measurement System portfolio of programmes. The VAM-Physical programme is central to underpinning many aspects of nanoscale metrology development from measurement of nanoparticles to the surface analysis of surfaces, fibres and particles with nanoscale resolution.

Measurement issues

Extensive consultation with industry has been conducted through a series of in-depth, one-on-one discussions with industry experts, BSI and other stakeholders as well as a detailed consultation workshop and survey of measurement needs [18].

The industry experts identified a growing need for surface analysis work in the UK that has major impact on innovation, global competitiveness, high added-value products, micro- and nano-technology, health and personal care and recommended that growth in this important VAM work is needed to keep up with demands.

Major measurement issues identified by experts include the need for analysis of surfaces with topography, quantitative analysis of compound layers, the development of a measurement infrastructure to support accreditation and quality systems, measurements of micro-scale wettability for microfluidics and ink-jet printing, molecular analysis of functional layers, underpinning measurements for new cluster ion beams, the analysis of delicate materials, quantification of lateral force and optimisation of high-resolution AFM and nanomechanics.

Consultation with industry has highlighted the need for comparable and traceable measurement with strong support for the development of ISO standards as well as commenting on standards proposed outside of the UK, conducting major international comparisons through VAMAS and the development of international comparability through CCQM.

Another growing need is to provide chemical analysis on surfaces that are not vacuum compatible such as creams for topological application, skin and tissues as well as rapid analyses of pharmaceuticals. In this Programme, we thus propose new work on ambient surface mass spectrometry in partnership with LGC. The proposed programme addresses each of these key issues and the strategic direction of the research is shown in the following roadmap.

Theme roadmap

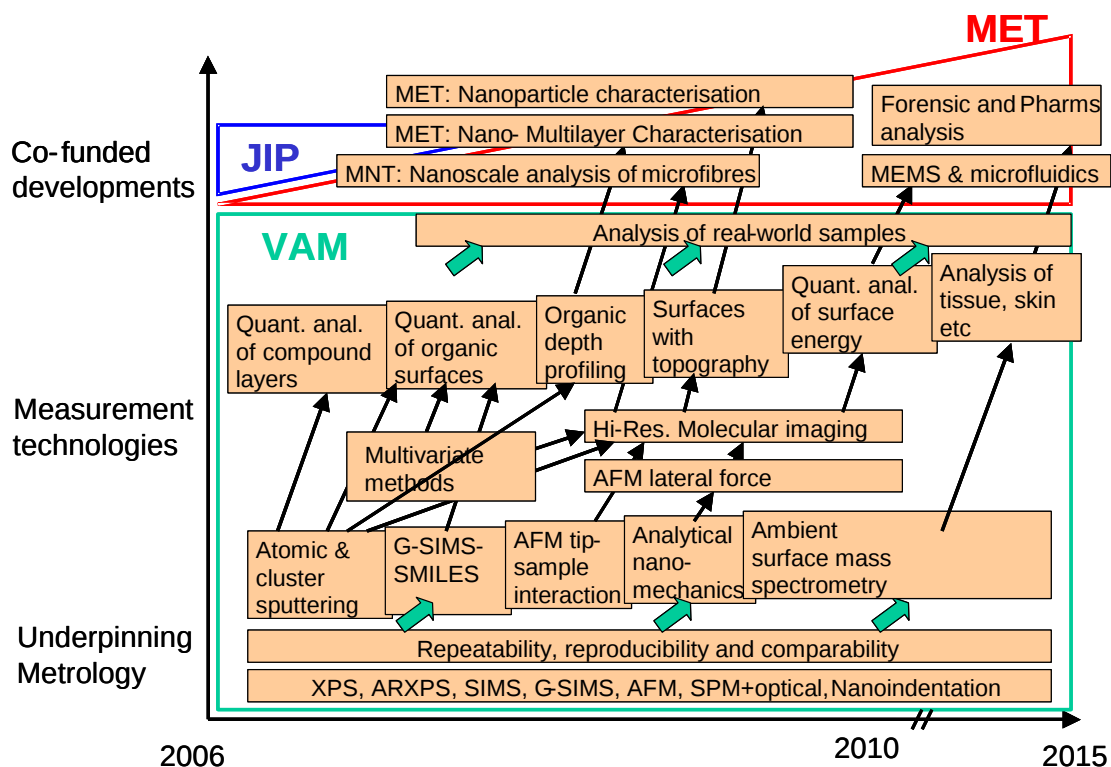


Figure 5: Surface and nano-analysis roadmap showing the strategic development of research within this Theme. It illustrates the feed through of underpinning metrology in VAM through to collaborative industry JIP and MET projects. The timings in the roadmap are indicative and show relative order.

MANAGEMENT AND KNOWLEDGE TRANSFER THEME

Introduction to Theme

Key to the success of any programme of work is the effective management and co-ordination of projects and activities within the programme. The management project in this Theme ensures the cost-effective delivery of all projects along with regular reporting of progress. Work in this Theme will co-ordinate both technical and knowledge transfer activities with the contractors delivering the VAM-Chemical half of the VAM Programme to ensure seamless delivery. Another key aspect of this Theme is the organising and managing of the transfer of all VAM-Physical supported facilities and services to new, purpose designed, laboratories which will occur during the lifetime of this Programme.

Dissemination of the knowledge developed and other outputs of the Programme to beneficiaries is of major importance to maximise the value added to the UK economy and society by work in the Programme. The majority of knowledge transfer is tightly bound up in the delivery of the outputs of specific technical projects, where particular audiences can be targeted. Typical activities in these projects might include: publications, presentations, participation in specific national or international standardisation activities, internet related delivery, best practice guides or measurement protocols, handling enquiries, etc.

While maximum benefit is often gained through dialogue and knowledge exchange with particular audiences at the project level, there is also a requirement to address a broader community which is the role of knowledge transfer activities within this Theme. Ensuring the impact of technical work within the VAM-Physical Programme reaches policy makers and other key stakeholders is an important feature along with representation and supporting of UK interests on major international bodies that directly affect UK industry, government, regulators and other end users.

In order to determine the future direction of work in the VAM-Physical Programme a dialogue with beneficiaries, technical experts in industry, government, regulators and other policy makers is continually underway. This knowledge exchange may well change the direction and content of the Programme during its lifetime if new, important requirements emerge. These activities will intensify midway through the Programme in order to focus on formulation of the next VAM-Physical Programme including the development of proposals of work to address future UK measurement requirements.

Theme aims

The Management and knowledge transfer Theme has the following aims:

- To manage the Programme successfully, thus ensuring cost-effective delivery.
- To ensure a successful decant into NPL's new laboratory facilities.
- To formulate proposals for the 2009-2012 VAM-Physical Programme.
- To maximise the impact of the VAM-Physical Programme through high-level knowledge transfer activities.

4. PROJECTS

A list of projects is given in Table 1:

Theme	PROJECT	
	No.	Title
G	G1	Emission gases
	G2	Natural gas and other fuels
	G3	Ozone precursors and indoor air
	G4	Ambient and ultra-pure gases
	G5	Stable and greenhouse gas standards
P	P1	Airborne particulate size, number and surface area
	P2	Airborne particulate mass, chemical composition and speciation
	P3	pH and ionic content
	P4	Ultra trace analytical methods (SERS)
S	S1	Quantitative analysis of surfaces with sub-micron topography
	S2	Development of quantitative analysis methods for compounds and multilayer structures
	S3	High resolution nanomechanics measurements using AFM
	S4	Ambient and imaging mass spectrometry
M	M1	Programme management and decant
	M2	Formulation of the next VAM-Physical Programme
	M3	Dissemination and representation

Table 1: Projects forming the 2006-2009 VAM-Physical Programme.

Full details of each project can be found on the following pages.

A number of the projects include deliverables that do not form part of the initial contract. These deliverables (*highlighted in red italics*) may be introduced into the Programme if the contract is revised at a later date.

Project G1	Emission gases
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Project aim and objectives

The aim of this project is to underpin the requirements of UK industry, the stack testing community and regulators for traceable measurements of emission level gases (including vehicle emissions) in order to ensure compliance with present and future EU Directives.

The objectives of the project are:

- To provide capability for existing national standards and facilities for the supply of gaseous binary and multi-component emission level standards.
- To ensure the demonstrable international acceptability of UK standards through the CIPM MRA for emission level gases.
- To provide traceable and internationally-recognised gas standards to underpin the requirements for MOT emission tests and to support the UK vehicle testing industry (through the BTC) in improving their exhaust gas sampling and analysis methods..
- To provide traceable and internationally-recognised gas standards to underpin the requirements for UK breath alcohol measurements to ensure compliance with present and future UK legislation.
- To extend the scope of NPL's binary gas flow dilutor technology to facilitate the delivery of standards at 'non decade' values.

Background and rationale

The control of emissions from industrial processes is essential for the protection of the UK's environment and the health of the population. Continuing reductions in emissions from industrial processes are also a central part of the UK's move towards sustainable development and production and will make a significant contribution to the improvement of air quality in the UK.

An important part of the regime for controlling industrial emissions is the accurate measurement of gases from emission sources. For example, emissions from combustion plants and waste incineration are limited by EU Directives 2001/80/EC and 2000/76/EC respectively. Monitoring of emission levels is then carried out according to agreed CEN standards that specify the use of traceable calibration standards for each of these sectors.

This proposed project will support the capability to provide standards to underpin existing measurement requirements as well as extending the range to include new species specified by forthcoming changes in legislation (e.g. HF). It will also focus on improved automation to reduce the cost and delivery time of standards to UK customers. Further use will be made of NPL's patented binary gas flow dilutor technology to facilitate the delivery of standards at 'non decade' values.

Gaseous emissions from road and air transport also continue to be carefully regulated. In particular, emissions from motor vehicles are regulated by the Euro IV regulations. These are

implemented through routine UKAS-accredited MOT testing of vehicles against traceable calibration gas mixtures.

There is an requirement to extend NPL's range of automotive emission standards driven by EU Auto Oil II, Euro V and other EC directives. The demand for a reduction of harmful engine emissions has led to improvements in engine test house sampling methods of exhaust gases, and these are required to be underpinned by traceable gas standards.

There are requirements to underpin present UK road and marine breath alcohol measurement legislation (35 µg alcohol per 100 ml of breath, Road Traffic Act & Transport and Works Act) and future lower levels for safety critical aircraft personnel and air traffic controllers (9 µg alcohol per 100 ml of breath). Additionally, a new generation of mobile evidential breath analysers will be brought into use during the course of the 2006-2009 VAM Programme.

Summary of technical work

This project will involve the preparation and analysis of binary and multi-component standards containing compounds relevant to process emissions e.g. by-products of combustion and other industrial processes such as HF. Standards could be prepared in high-pressure gas cylinders or dynamically using appropriate dilution technologies.

New gas filling facilities and gas sampling / analysis equipment will be implemented where required in order to support the preparation and analysis of binary and multi-component gas standards. This will include the development of an innovative Mini Automatic Gas Analysis System by reducing its uncertainty and gas consumption.

A range of gas standards and facilities for the measurement of vehicle exhaust emissions will be provided and extended where necessary. Breath alcohol gas standards and associated 'interfering substances' will be prepared as necessary, to underpin present and future requirements, including new type approval. Analysis and comparison of breath alcohol standards will be carried out using a GC and a gas blending rig for type approval work will be constructed.

Deliverables

No.	Description	Start	Finish
G1.1	Provision and extension of current gas filling and analysis facilities (including the automated gas analysis system and the binary network).	Oct 06	Sep 09
G1.2	Provision and development of primary gas standards to underpin measurements of stack emission species including CEN hydrocarbon requirements.	Oct 06	Sep 09
G1.3*	<i>Development of a primary capability for the certification of HCl and HF standards.</i>	<i>Jan 09</i>	<i>Sep 09</i>
G1.4	Provision and preparation of high accuracy gas standards to underpin present and future MOT vehicle exhaust emission testing in the UK.	Oct 06	Sep 09
G1.5	Provision and preparation of high accuracy gas standards to underpin present and future breath alcohol testing in the UK.	Oct 06	Sep 09
G1.6	Preparation of 'interfering substance' and associated ethanol breath alcohol standards, and development of a gas blending rig to underpin type approval of next generation of breath alcohol analysers.	Jan 07	Dec 07
G1.7	Participation in CCQM comparisons to underpin the comparability of UK standards, and dissemination of technical advances to ISO TC158 (Gas analysis and gas standards).	Oct 06	Sep 09

* see note on p. 27

Project G2	Natural gas and other fuels
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Project aim and objectives

The aim of this project is to provide capability for measuring components of natural gas and other hydrocarbon fuels including artificial odorant species and higher molecular weight hydrocarbons.

The objectives of the project are:

- To provide capability to extend the range of primary national standards for natural gas, refinery gases and other fuels.
- To develop new sampling and analytical methods for quantitative measurements of sulphur odorant species, refinery gases. alternative fuels (e.g. LPG, LNG and bio-diesel).
- To support the UK natural gas industry through a study of the methods used to measure the hydrocarbon and water dewpoints of natural gases.
- To participate in international comparisons in order to support the recognition of UK standards through the CIPM MRA and to organise a PT scheme.
- To disseminate best practice on the measurement of natural gas through ISO TC193, journals and conferences.
- To develop and disseminate a method for combining the results of natural gas analysis using micro-GC, where direct 'bridging' between channels is not possible.

Background and rationale

The UK natural gas industry is a multi-billion pound business – the value of natural gas transferred across the UK network is more than £2million per hour. The immense and wide-reaching impact of natural gas on the UK economy has recently been highlighted due to the fact that the UK is now a net importer of natural gas. The fiscal value and physical properties (hydrocarbon dewpoint, density, etc.) of natural gas are calculated directly from accurate determination of its composition. This necessitates high-accuracy primary standard gas mixtures and analytical methods. Such capabilities have been developed in previous VAM Programmes and there is a pressing need for these to be further improved and expanded.

One particular area of increasing importance to UK industry is the analysis of gas from refineries. The EU Gas Emission Trading Scheme (based on European Directive 2003/87/EC) will require large industrial producers of carbon dioxide to have access to traceable measurement of their gas emissions, and support of emissions trading schemes is identified as a key requirement in a number of Government strategy documents. There is also a need to investigate and develop industry requirements for standards for alternative fuels (e.g LPG, LNG and bio-diesel).

A complementary requirement that the project will address is the general challenge of making best use of analytical data from two or more instruments that measure complementary sets of gases, e.g. fusion of data from two columns on a gas chromatograph. Whilst this has been successfully addressed in the previous VAM Programme for the special case where a

‘bridging’ compound can be measured with good repeatability on both columns, the strongest requirement is to extend the approach to the general case where a straightforward direct bridging compound is not available. An important application of this is to ‘micro-GCs’ now used for routine laboratory analysis of natural gas.

Summary of technical work

A key growth area will be the development of a new set of traceable standards to support analysis of refinery gases (such as blast furnace, oven and reformer gases). The development of these and other standards for natural gas and alternative fuels will be supported by the development of new analytical methods – GCs method to measure accurately the composition of refinery gases and LPG / LNG, and a GC-MS method for the quantitative analysis of sulphur odorant species.

A study will be undertaken to compare the methods used by the natural gas industry for the determination of hydrocarbon and water dewpoints. Comparison of the most-commonly used instruments and methods will be supported by the preparation of a set of traceable gas standards. NPL will also participate in a CCQM international intercomparison, as well as co-ordinating a CCQM study to apply its ‘harmonisation’ method of natural gas analysis to a range of standards used in a previous intercomparison. A third NPL proficiency testing scheme will be arranged for UK natural gas analysis laboratories.

A protocol for fusing data from a micro-GC will be developed, and the results will be evaluated in routine applications, and disseminated through a new standard published by ISO TC 193 (Natural Gas), where NPL will continue to represent the UK’s interests.

Deliverables

No.	Description	Start	Finish
G2.1	Expansion of the UK’s gas standards facility for natural gas, high hydrocarbons and sulphur odorant species.	Oct 06	Sep 09
G2.2	Development of validated, quantitative methods for the high-accuracy analysis of natural gas by GC, and sulphur odorant species by GC-MS.	Oct 06	Sep 09
G2.3	Development of a robust infrastructure to underpin the traceable measurement of refinery, reformer and blast furnace gases.	Oct 06	Mar 08
G2.4	Rigorous comparison of methods to measure the hydrocarbon and water dewpoints of natural gases in order to support UK industry.	Jan 07	Dec 08
G2.5*	<i>Development of gas standards to underpin measurements of emissions from alternative-fuelled (e.g. LPG, LNG and bio-diesel) vehicles.</i>	<i>Jan 09</i>	<i>Sep 09</i>
G2.6	Participation in CCQM international intercomparisons to support the recognition of UK standards through the CIPM MRA; organisation of a proficiency testing scheme in order to support UK natural gas analysis laboratories.	Oct 06	Sep 09
G2.7	Development of a protocol for ‘fusing’ data from multi-column gas chromatographs where ‘direct bridging’ is not possible.	Feb 07	Jan 08
G2.8	Dissemination of the project’s achievements through peer-reviewed articles and presentations at conferences. Support of the UK’s interests through input into international fora.	Oct 06	Sep 09

* see note on p. 27

Project G3	Ozone precursors and indoor air
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Project aim and objectives

The aim of this project is to provide capability for measuring ambient ozone, ambient concentration gases known to play a role in ozone and particle formation, and gaseous species encountered in indoor air and through occupational exposure.

The objectives of the project are:

- To develop and disseminate standards for ozone precursors, and measurement of indoor air and occupational exposure.
- To organise a comparison for ozone precursors for EUROMET laboratories, and a proficiency testing scheme for laboratories working on materials emissions testing.
- To validate, or delimit, common manual techniques for ambient hydrocarbon and ammonia measurement.
- To upgrade the UK standard ozone photometer for dissemination and participation in an international comparison.
- To investigate methods for sampling and accurate measurement of semi-volatile organic compounds.
- To extend the range of nationally available primary standard gas mixtures to underpin measurements of indoor air quality and occupational exposure.

Background and rationale

The gaseous pollutant in ambient air that has most effect on human health, in both urban and rural locations, is ozone. Ozone is a secondary pollutant that is formed photochemically by the reaction of sunlight, oxygen and nitrogen dioxide in a complex process in which volatile organic compounds (VOCs) play a critical role. Ozone is regulated by the EC Directive 2002/3/EC, which includes a requirement to measure ambient concentrations of both ozone and 30 specific ozone precursor compounds.

Particulate matter (PM) in the atmosphere has a greater impact on human health, and it also has a major role in climate change. The secondary components can be organic, formed from volatile or semi-volatile organic compounds, or inorganic such as ammonium nitrate, formed from ammonia and NO_x. A revision of EC Directive 1999/30/EC issued in September 2005, introduced a requirement to measure the composition of the PM - adherence to this will depend on accurate measurements both of particle composition and of gaseous precursors.

Gaseous pollutants in indoor air have been strongly linked to public health issues: 5% of the UK workforce is estimated to have suffered from illness resulting from indoor air pollution. Concern over the health effects of these pollutants has led to the formulation and implementation of wide-ranging EC directives requiring the identification and monitoring of the most prevalent toxic species. The EU's proposed regulatory framework for the Registration, Evaluation and Authorisation of Chemicals (REACH) also necessitates the accurate measurement of harmful species.

In order to meet this increasing volume of legislation, there is a strong requirement for standards and validated methods to measure accurately the key pollutant species such as formaldehyde, VOCs, chlorinated, and other (e.g. brominated) hydrocarbons.

Summary of technical work

The NPL primary ozone photometer will be maintained and upgraded by implementation of changes to the temperature control system that are now recognised to be best practice. A new 'family' of cylinder standards of ozone precursor hydrocarbons (at levels below 50ppb) will be prepared, and their analysis refined documented as a UKAS procedure.

Pumped and diffusive sampling techniques will be validated for ambient concentration ozone precursor and particle precursor hydrocarbons. An intercomparison for ozone precursors will be completed and the results of the scheme disseminated. Methods for measurement of ammonia at ambient concentrations (~5ppb), including denuder techniques, will be investigated using on-line generation techniques. The issues associated with sampling and analysing semi-volatile organic compounds will be reviewed.

A facility for the measurement of formaldehyde and other similar pollutant species will be developed and validated. Standards of VOCs, and chlorinated and other hydrocarbons at levels down to 10ppb will be developed and supported by GC-FID analysis. The STAG and CATFAC controlled atmosphere test facilities will be used extensively to support the development of these standards. The scope of NPL's time division dilution (TDD) facility will be expanded in order to validate the measurements of chlorinated hydrocarbons.

A proficiency testing scheme will be organised in order to test UK labs' capabilities of performing the measurements required to support the European legislation described above.

Deliverables

No.	Description	Start	Finish
G3.1	Upgrade the UK national Standard Reference Photometer for ozone and disseminate traceability to UK laboratories.	Oct 06	Sep 09
G3.2	Research and development of standards and analytical techniques for ozone and particle precursor VOCs, leading to new cylinder standards and accredited techniques.	Oct 06	Sep 09
G3.3	A review of sampling and analysis issues for semi-volatile organic compounds in ambient air.	Jan 08	Dec 08
G3.4	Validation of common manual techniques for measurement of hydrocarbons and ammonia (e.g. by pumped or diffusive sampling or denuders).	Oct 06	Sep 08
G3.5	Provision and development of standards and facilities for the accurate measurement of volatile organic compounds and chlorinated hydrocarbon species. Participation in a bilateral comparison with a leading NMI.	Oct 06	Sep 09
G3.6*	<i>Development and validation of a capability for the accurate measurement of formaldehyde (and similar species) in ambient and indoor air.</i>	<i>Jan 08</i>	<i>Sep 09</i>
G3.7	Development of the time division dilution facility to cover new species at reduced levels of uncertainty, supported by development and provision of capability of the STAG and CATFAC controlled atmosphere test facilities.	Aug 07	Jul 08
G3.8	Organisation of a proficiency testing scheme to assess the measurement capabilities of UK analytical laboratories. Dissemination of the project outputs.	Jan 08	Sep 09
G3.9	Participation in a comparison of ozone precursor standards (through EUROMET in collaboration with the JRC). Dissemination of project outputs through international fora including AQUILA, and via the publication of a peer-reviewed article.	Oct 06	Sep 09

* see note on p. 27

Project G4	Ambient and ultra-pure gases
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Project aim and objectives

The aim of this project is to extend the capability of the current trace gas analysis and trace water vapour facilities to address the metrology needs of the specialty gas and micro-electronics industries, and to underpin the UK's capability for measuring ambient concentrations of CO, SO₂, NO and NO₂.

The objectives of the project are:

- To provide capability for the trace gas analysis and primary trace water vapour facilities, and to develop a validated source of zero gas.
- To provide and develop facilities for regulated ambient measurements of CO, SO₂, NO and NO₂.
- To participate in a European comparison of purity analysis and to provide capability for the international acceptability of UK standards through participation in CCQM and EUROMET.
- To extend the capability of the trace gas facility to alternative matrices (e.g. NF₃).
- To investigate the feasibility of generating ambient concentrations of sulphur dioxide by dilution from stable cylinder standards.

Background and rationale

The manufacture of semiconductors and microelectronics depends on the availability of pure gas-phase precursors with impurity levels well below 10 ppb. Similar requirements exist for the source gases used for the preparation of high-accuracy standard gas mixtures and there is therefore a requirement for measurements of these ultrapure gases to support the special gas industry and their customers.

As part of the 2003-2006 VAM Programme, NPL developed a unique facility capable of the analysis of inert trace gases (including oxygen, carbon dioxide, methane, hydrogen and carbon monoxide) and water vapour at the ppb level. The increasing requirement for reduced wastage rates in the semiconductor and microelectronics industries is imposing even more stringent requirements on the suppliers of source gases. In particular, for the measurement of trace impurities in reactive process gases and progress towards the measurement of impurities at the sub-ppb level. These will require a validated source of 'zero gas' and a complete understanding of the associated sampling and analysis issues.

A further requirement is for the demonstration of the comparability of NPL's standards with those maintained by other NMIs in Europe. It is proposed that this be investigated by studying the stability characteristics of selected ultra-pure gas mixtures and the scope for using them as transfer standards between laboratories and between companies.

The exposure of the population to carbon monoxide, sulphur dioxide and nitrogen dioxide, primarily originating in combustion sources, has decreased dramatically in recent decades, but it is still a cause for concern. EU directives regulate ambient concentrations of these

gases. These directives require routine automatic monitoring to be carried out by networks of stations across each nation in Europe.

The project will improve the mechanisms used for providing capability for and disseminating standards to contractors appointed by Defra and to local authorities throughout the UK - dissemination of standards for sulphur dioxide and nitrogen monoxide is complicated by their limited stability periods in high-pressure cylinders. It is proposed to carry out a feasibility test into the replacement of NPL's existing primary permeation facility for sulphur dioxide, with a more cost-effective dilution system based on an NPL patented dilution method (for example, time-division dilution) and stable, higher concentration SO₂ standards. If successful, this will lead to a reduction in maintenance costs and delivery times from this facility.

Summary of technical work

Provision and development of the trace gas and trace water vapour facilities will include the replacement of the current oil circulation bath system on the trace water vapour generator with a Peltier-based unit. This will result in improved transportability and a facility that is easier and cheaper to maintain with a reduced risk of contamination. Work will be undertaken to extend current facilities to generate and measure trace impurities in alternative matrices.

A validated zero gas generation system will be developed and will include the construction of a purifier and gas distribution system. This will facilitate the preparation of gas standards at parts-per-trillion levels to support the validation of trace gas analysers.

Primary standard cylinders of CO and NO at concentrations necessary for calibrating ambient analysers (typically 10 ppm and 720 ppb respectively) will be prepared and validated. The stability of cylinders for NO, and similar concentrations of NO₂ and SO₂, will be assessed as part of ongoing QA/QC. The facilities and procedures for certifying cylinders of NO, NO₂, and SO₂ will be refined, and in particular there will be an investigation into replacing the current system of generating primary SO₂ mixtures by an on-line permeation system with a system based on, for example, time-division dilution.

International comparisons will take place through, for example, CCQM and EUROMET, and technical experts will directly represent the UK's interests on National and International standardisation activities.

Deliverables

No.	Description	Start	Finish
G4.1	Upgrading of the trace gas facility and trace water vapour facility to achieve sub-ppb specification.	Oct 06	Sep 09
G4.2	Development of validated zero gas generation and measurement capability to contain all key species at sub ppb levels.	Oct 07	Sep 08
<i>G4.3*</i>	<i>Development of new, low gas consumption facility for purity analysis of reactive and stable species.</i>	<i>Apr 08</i>	<i>Sep 09</i>
G4.4	Provision and development of facilities for regulatory ambient measurements of CO, NO _x and SO ₂ .	Oct 06	Sep 09
G4.5	Investigation of the feasibility of generating ambient concentrations of sulphur dioxide by novel dilution methods.	Oct 06	Sep 07
G4.6	Dissemination of project outcomes through international intercomparisons (including a purity analysis intercomparison), papers, conference presentations and dissemination to SEMI and AQUILA.	Oct 06	Sep 09

** see note on p. 27*

Project G5	Stable and greenhouse gas standards
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Project aim and objectives

The aim of this project is to provide stable primary standard gas mixtures of the major components of atmospheric composition with a gravimetric uncertainty of better than 0.1%, and standards of reactive species at concentrations below 10 parts-per-million, in order to support monitoring of the composition of the global atmosphere. The use of innovative methods developed for this project will lead to increased cost-effectiveness in NPL's provision of standards to UK industry.

The objectives of the project are:

- To investigate the potential of microfluidic dosing and micro-cylinder technology for preparation and storage of high accuracy standards.
- To develop novel accurate and stable on-chip calibrator systems for use on MEMS gas analysis devices.
- To provide capability for standards of carbon dioxide and methane (with uncertainties of better than 0.1%).
- To disseminate the standards and technologies to the WMO laboratories through participation in a CCQM comparison.
- To provide the capability for the preparation and purity analysis of gas standards supporting measurements of process and aircraft emissions (e.g. NH₃, SO₂ and H₂S).
- To trial recent industrial developments in passivated cylinder technology and to report on their application to gas metrology.

Background and rationale

The monitoring of global climate change and the development of a global consensus as to its causes and consequences presents a major challenge for the metrology community. A key parameter used to indicate the extent of global warming is the concentration of atmospheric gases with strong 'global warming potentials'. The two principal species monitored for this reason are carbon dioxide and methane.

A comparison carried out under the auspices of the CCQM between the leading metrology laboratories in the world and the WMO's Global Atmospheric Watch (GAW) network showed a significant discrepancy of 0.5% for one important component of the atmosphere (methane). This result underlines the requirement for leading NMIs to play a larger role in underpinning the scales used to monitor long-term trends in atmospheric gas composition. There is also a related requirement from UKAS-accredited laboratories for the supply of more accurate standard gas mixtures. An output from the work in this project aimed at high-accuracy standards for greenhouse gases will be the development of methods that also meet this wider requirement.

There is an ongoing requirement for standards with improved stability for a range of gases at concentrations below 10 ppm - this project will provide the capability to deliver such standards more cost-effectively.

The development of MEMS devices capable of carrying out analytical functions on single chips has enormous future potential for analytical science. For example, complete systems have been reported capable of VOC measurements by GC, and the measurement of sulphur compounds by fluorescence. Similarly ‘ink-jet printer’ technology is capable of dispensing accurate pico-litre volumes of analyte.

Summary of technical work

This project will improve NPL’s gravimetric capability so that the cost-effectiveness of the service can be improved through the preparation of standards with fewer dilution steps that exploit the low mass and volume of micro-cylinders. This will decrease the time taken to prepare standards and also reduce the number of ‘parent’ standards stored at NPL to maintain dilution hierarchies. A consequence of this will be a reduction in the cost of standards (whilst maintaining the same uncertainty).

The development of a facility for preparing high-accuracy standards using micro-cylinder technology may require manufacture (externally) of pressed aluminium parts and welding (in-house or on contract). It will also involve experimentation with the effectiveness of crimped seals (and other options) and work on passivation of the end products. The new facility will be used to prepare primary standard gas mixtures of carbon dioxide and methane close to the background atmospheric levels. These will be used to participate in a CCQM comparison of binary carbon dioxide and methane mixtures in air.

Standards and cylinder treatment technologies for gas mixtures of sub-100 ppm NH₃ and low concentration H₂S and SO₂ will be developed. This will require some investigation of the passivation of cylinders for these and other species. Alternative strategies for gas standard storage through the development of a micro-cylinder filling facility will also be explored. The work on calibration of MEMS GC systems will be carried out in collaboration with a UK university.

Deliverables

No.	Description	Start	Finish
G5.1*	<i>Provision of capability for standards of carbon dioxide and methane at atmospheric levels (with uncertainties better than 0.1%).</i>	Jan 09	Sep 09
G5.2	Results of the evaluation of gravimetric preparation based on samples in ‘micro-cylinders’ or balance gas in larger cylinders, leading to single-step gravimetry with uncertainties less than 0.1%.	Oct 06	Oct 07
G5.3	Provision and development of the current primary gas standards facility including preparation, purity analysis and quality control to ensure efficient and effective processes including development of improved GUM and ISO Guide 34 compliant software.	Oct 06	Sep 09
G5.4	Development of new standards supporting measurements of process emissions (e.g. agricultural) and aircraft emissions: sub 100 ppm NH ₃ , and low concentration SO ₂ and H ₂ S in cylinders.	Oct 06	Sep 09
G5.5	Research and development of alternative gas standard preparation and storage technologies including a prototype micro-cylinder filling facility.	Sep 07	Sep 08
G5.6	Research to establish the accuracy and stability achievable with on-chip calibrators with MEMS systems for gas analysis.	Oct 06	Sep 09
G5.7	Dissemination of project outcomes including the application of the micro-cylinder developments to gravimetry and storage of primary gas mixtures, and the introduction of a new work item at ISO TC158.	Oct 06	Sep 09

* see note on p. 27

Project P1	Accurate particulate size, number and surface area
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Project aim and objectives

The aim of this project is to provide the capability for measurement methodologies, standards and facilities required for robust measurements of airborne particle size, number density and surface area.

The objectives of the project are:

- To quantify factors affecting instrument sampling.
- To compare particle counting methods (such as condensation particle counting and electrometry) and size selection techniques (such as impactors and electrical mobility).
- To construct a particle generation mixing chamber for assessing particle monitoring instruments with a variety of size and composition distributions of particles.
- To investigate the influence of particle charge and size on the performance of Differential Mobility Analysers (DMAs) to assess the validity of physical assumptions and software used in determining size distributions with this method.
- To review and investigate methods for measuring the surface area of ambient nanoparticles.
- To develop a prototype device for diluting flows of nanoparticles using NPL's patented 'time division dilution' method.

Background and rationale

Airborne particles are currently of great scientific interest. They have a major impact on human health, larger than any gaseous pollutant, and they also have a major role in climate change. Although current European legislation is based on total mass (e.g. Directive 1999/30/EC), knowledge of the particle size distribution and composition is also necessary. Instruments to measure these properties of particles are available, but their measurements are poorly supported within the measurement infrastructure.

Common methods to determine the size distribution of nanoparticles, such as Differential Mobility Analysers (DMAs), rely on applying an electric field to the stream of particles. However, it is unclear whether assumptions regarding the charge distributions, required for determining sizes, are always accurate. This is especially true at the lowest size ranges. Measurements using these instruments need validation, and accepted measurement protocols.

Recently, there has been a strong move towards the use of counting methods that can be used to determine the number density of nanoparticles. These make use of detection systems based on either the condensation particle counter (which measures number density directly) or the electrometer (which measures the charge carried by particles and converts this into a number density). Although these methods provide the basis for measurements used to monitor public exposure, there is no framework for traceability in place for either approach. Consequently, measurements made by these methods are not generally comparable.

Defra's 'Characterising the potential risks posed by engineered nanoparticles' [2] identified surface area as the most important measurand for determination the toxicity of particles as it most closely represents the capability of particles to catalyse chemical reactions. There are a very small number of instruments in use that are capable of measuring the total surface area of nanoparticles, however, they depend on different physical mechanisms and therefore do not measure the same property. There is therefore a strong requirement for an experimental investigation into the comparability of these techniques.

Summary of technical work

Operational and metrological aspects of techniques used for ambient particle counting and sizing will be assessed. A particle generation facility (incorporating a sampling chamber) will be developed and validated, providing a mixture of carbonaceous and inorganic particles in air of variable humidity, and at variable concentration. Best practice will be assessed and disseminated to the relevant communities.

The efficiency of DMA columns, particularly at the extremes of their size ranges, will also be investigated. Common to both electrometry and electrical mobility is an assumed knowledge of the particle charge distribution. This aspect will be specifically investigated for various particle compositions and 'neutraliser' techniques, in collaboration with electrical experts at NPL, with emphasis on the performance of Differential Mobility Analysers.

The project will also develop a robust infrastructure providing traceability to the SI for measurements of numbers of nanoparticles at number densities appropriate to ambient and emission (rather than manufactured) levels. A well-characterised electrometer system with quantifiable efficiency will be developed, giving traceability to the ampere through a calibrated ultra-low current meter. The range over which traceability is disseminated will be extended by developing a novel device for diluting flows of nanoparticles using NPL's patented time division dilution (TDD) method which has the benefits of the 'absolute' traceability of the TDD approach.

Methods that have the potential for measuring the area of particles (such as the epiphaniometer) will be reviewed. Their performance will be investigated and consideration given to how the requirements for standards for these methods could be met.

Deliverables

No.	Description	Start	Finish
P1.1*	<i>Construction of a particle generation mixing chamber for versatile assessment of particle monitoring instruments.</i>	<i>Jun 08</i>	<i>Sep 09</i>
P1.2	Result of a comparison of sampling, and size and number measurements, for different types of particle using different techniques.	Jan 08	Sep 09
P1.3	Evaluation of the performance of DMA columns and software at extremes of size ranges, and with non-ideal charge distributions.	Oct 06	Mar 08
P1.4	Facility for disseminating traceable calibration of particle number density.	Jan 07	Mar 08
P1.5	System for providing accurate dilutions of nanoparticle number density for nanoparticles in the size range 2 to 500nm.	Oct 06	Dec 07
P1.6	Report and experimental investigation into the mechanisms for measuring the surface area of nanoparticles and possible methods for providing standards.	Mar 07	Aug 09
P1.7	Production of a peer review article and representation at key European or International conferences.	Oct 06	Sep 09

* see note on p. 27

Project P2	Airborne particulate mass, chemical composition and speciation
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Project aim and objectives

The aim of this project is to underpin measurements of airborne particle mass, chemical composition and speciation and provide metrological support for measurements of organic and elemental carbon.

The objectives of the project are:

- To support UK regulatory measurements of particle mass in the PM₁₀ and PM_{2.5} ambient air fractions including standardisation and equivalence procedures.
- To develop valid methods for quantifying the mass of organic and elemental carbon within particulate matter.
- To develop an accurate measurement methodology for mercury in ambient air
- To develop improved methodologies for the measurements of the anionic and cationic composition of ambient particulates.

Background and rationale

Airborne particulate matter (PM) is currently of great scientific and public interest. The mass, size, abundance and composition of PM has a major impact on human health, and also on climate change. Unlike vehicle exhaust or engineered particles, airborne PM is a highly variable mixture of components. The 2005 Defra Air Quality Expert Group report on Particulate Matter in the UK highlighted the gaps in our understanding of PM sources, formation and evolution, and it is clear that improved measurement techniques and results are needed. Existing legislation is based on the total mass of PM, but emphasis is moving towards smaller particles and determining their broad chemical composition. The organic and elemental carbon component is seen as important but inadequately defined.

The proposed revision to relevant EU Directives moves the emphasis from particles less than 10 microns in diameter (PM₁₀) to those less than 2.5 microns (PM_{2.5}). It also includes the requirement to characterise PM for chemical species including sulphate, nitrate, chloride, ammonium, elemental carbon and organic carbon. However, the measurement science underpinning all these measurements is not well defined and this project will address these issues.

Issues also remain with determining total particle mass, where the reference method involves weighing filters under conditions of controlled temperature and humidity.

Measurement of the metallic composition of particulate matter is required as part of EU Directives, but standard methods for mercury are not yet available. Data from Defra suggests that mercury emissions will increase by 65% by 2020. This project will also produce accurate measurement methodology for speciated mercury in ambient air.

Summary of technical work

Scientific investigations supporting regulatory measurements of PM₁₀ and PM_{2.5} especially relating to the revision of the CEN standards for these measurands, or to the equivalence of non-reference methods, will be carried out. Evaluation of organic and elemental carbon analysis will continue using the reference instrument purchased in the previous programme, using samples taken at NPL and elsewhere, and samples generated at NPL, and making comparisons with UK Network instruments.

This project will also include development of a robust methodology to measure mercury in ambient air, and develop methods to measure the soluble fraction of particulates.

Deliverables

No.	Description	Start	Finish
P2.1	A report detailing research into the measurement science issues surrounding PM ₁₀ and PM _{2.5} (particle mass), including standardisation and equivalence procedures in support of regulators.	Oct 06	Sep 07
P2.2	Production of collaboratively-developed valid methods for quantifying the organic and elemental carbon components of PM	Oct 06	Aug 08
P2.3	Production of an accurate measurement methodology for speciated mercury in ambient air	Oct 07	Sep 09
P2.4	Development of improved methodologies for the measurements of the chemical composition of ambient particulates	Oct 06	Dec 08
P2.5	Support of the UK's interest on CEN TC264/WG25 (mercury) and the production of three peer review papers. Dissemination of the results of a comparison of Network instruments with EMEP instruments.	Oct 06	Sep 09

Project P3	pH and ionic content
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Project aim and objectives

The aim of this project is to provide the capability for the UK's link to primary standards of pH and solution conductivity, and develop focussed research into practical pH measurement in on-line environments, particularly fuel cells.

The objectives of the project are:

- To provide the capability for the UK's link to primary standards of pH by undertaking research into the role of the Ag/AgCl electrode in the uncertainty of Harned Cell measurement and to disseminate the results to CCQM's Electrochemical Analysis Working Group.
- To develop suitable methodologies for on-line pH and ion measurement in environments such as the direct methanol fuel cell.
- To participate in a collaborative European project on pH measurement.

Background and rationale

The measurement of pH remains an important and widely undertaken analytical measurement. The development of improved technologies, such as more efficient direct methanol fuel cells, and the production of international standards for on-line water quality monitoring has meant that there is a growing requirement to underpin the validity of these measurements in end-user communities such as the environmental, food, water, nuclear and semi-conductor industries. These industries have pH measurement requirements that are still not fully underpinned by robust measurement procedures and standards. Improved procedures and traceability in these areas will increase process efficiency, improve process control and thus provide substantial economic benefits.

More specifically, accurate pH measurement techniques are required to underpin the measurement of the soluble component of ambient air particulate matter (PM), in order to work towards a full description of the chemical composition and physicochemical properties of these particles. Measurements of pH in this arena are also complementary to ion chromatography measurements of the soluble fraction of PM as they provide a direct indication of the quantity of ammonium salts within the particles. These measurements will also help contribute to a more accurate mass closure model for ambient air particulates.

These pH measurements also require improved underpinning traceability by working to improve the primary method for the measurement of pH. There are still unresolved discrepancies in pH comparisons at the CCQM level and research is required to identify areas for improvement in the methodology.

Summary of technical work

The technical work in this project will include input into the drafting of a new international standard for the performance of on-line pH measurements. It will also include research into the role of the Ag/AgCl electrode in the uncertainty of Harned Cell measurement by testing the voltage response, drift, and memory effects of alternative Ag/AgCl electrode designs. Additionally, this project will develop suitable methodologies for on-line pH and ion measurement in environments such as the direct methanol fuel cell. This will include development of laboratory-based procedures for measurement, calibration and quality assurance, followed by demonstration in a suitable real environment.

Deliverables

No.	Description	Start	Finish
P3.1	Participation in Euromet project 843 to develop on-line sensors and analysing equipment for pH measurement in water.	Oct 06	Apr 08
P3.2	A report detailing research into the role of the Ag/AgCl electrode in the uncertainty of Harned cell measurement.	Oct 06	Sep 08
P3.3	The development and publication of suitable methodologies for the on-line pH and ion measurement using glass electrodes and ion selective electrodes.	Oct 06	Sep 09
P3.4	Attendance at the Society of Chemical Industry's Electrochemical Technology Group Committee, and the publication of two peer review papers.	Oct 06	Sep 09

Project P4	Ultra trace analytical methods (SERS)
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Project aim and objectives

The aim of this project is to develop efficient and reproducible nano-structured surfaces to underpin the use of Surface Enhanced Raman Spectroscopy (SERS) as an ultra-trace analysis tool.

The objectives of the project are:

- To design an optimal metal surface for reproducibly enhancing Raman signals.
- To produce (in collaboration with Imperial College) and test optimised nano-structured surfaces using a suitable micro-/nano-fabrication technique.
- To disseminate the outcomes at meetings of the UK SERS Forum and to produce a peer-reviewed article and a paper at a relevant major European or international conference.

Background and rationale

There is an increasing recognition that ultra-trace measurements that have hitherto only been available in sophisticated laboratory environments may have wide applications to the detection and identification of ultra-low levels of chemical agents released into the atmosphere, and ensuring safe water, food, and medicines, by detecting dangerous or toxic contaminants at ultra-low levels.

SERS shows great promise as an analytical tool for ultra-trace analysis. Despite the availability of a full theoretical description of the SERS process, it is known that more regular and reproducible metallic substrates are needed to achieve reproducible enhancement levels, hence providing a greater possibility of producing meaningful quantitative SERS analysis at the ultra-trace level. There are several drivers for the proposed body of work, including: homeland security (the need to detect and identify ultra-low levels of chemical agents); public safety (ensuring safe water, food, and medicines, by detecting dangerous or toxic contaminants at ultra-low levels); and applications in forensic science where ultra-trace detection is required.

The requirements for these measurements are highlighted in several recent strategy documents [19, 20] and the Chemical Vision 2020 Roadmaps [21]. These highlight the need for the development of robust analytical techniques with ultra-high sensitivity, particularly for the analysis of nanomaterials.

Summary of technical work

Successful research at NPL [22, 23], and elsewhere, has been based on the use of silver colloids to achieve very large SERS enhancements, but it has not been possible to achieve sufficient stability within colloidal suspensions to make them useful as SERS substrates for trace analysis studies. This work has included the joint organisation of a highly successful Faraday Discussion meeting on SERS with the Royal Society of Chemistry. This project will design and develop nanostructured metal surfaces and achieve the correct balance between

reproducibility and enhancement to ensure that these surfaces are applicable to quantitative trace analysis using SERS methodologies. These structures will be designed for optimum practical enhancement using computer modelling techniques, fabricated in collaboration, probably with a leading UK university, and then tested for performance in SERS applications.

This project will also include the organisation and hosting, by NPL, of a further UK SERS Forum meeting, following on from successful meetings over the last three years, which have provided a focus for UK activities in this area.

Deliverables

No.	Description	Start	Finish
P4.1	Design of the optimal practical metals surface for reproducible enhancing Raman signal by electromagnetic modelling procedures.	Oct 06	Sep 07
P4.2	Production of optimum nanostructured surfaces using a suitable micro-/nano-fabrication technique, and initial testing of the surface.	Jan 08	Sep 09
P4.3	Collaboration with a relevant academic group to develop and characterise the nanostructured surface for SERS applications.	Oct 06	Sep 09
P4.4	Organisation and hosting of a UK SERS meeting, possibly as a session within an ICORS conference, and also the production of four peer review articles.	Oct 06	Sep 09

Project S1	Quantitative analysis of surfaces with sub-micron topography
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Project aim and objectives

The aim of this project is to investigate and resolve quantitative issues on the effects of surface topography for three principal industry techniques: XPS, SIMS and AFM.

The objectives of the project are:

- To complete a systematic study of the effects of surface topography for XPS and SIMS with AFM to define the effects of topography from flat surfaces to rough surfaces, cylinders and spheres.
- To provide a fundamental method for in-depth quantification of chemical composition non-destructively by angle resolved XPS, and development of the ‘thickogram’ method for coating thickness measurement from samples with topography.
- To develop procedures and guides to interpret topography effects and reduce these effects for practical analysis.
- To perform quantitative analysis of high information density three-dimensional static SIMS images.
- To develop micro- and nano-scale mechanical evaluation of fibres by scanned probe microscopy (SPM) to allow correlation of mechanical properties with, for example, macroscopic personal care treatments.

Background and rationale

Surface topography is a crucial issue for the analysis of innovative devices such as microfluidic systems, MEMS devices, fibres, composite materials, sensors, organic electronics and biomedical devices. For particles in both advanced manufacturing and pharmaceuticals, the surface may have anti-agglomeration, anti-static, dispersants and surfactant coatings and for drug delivery systems may have specific controlled release layers and molecular targeting surfaces. The strength and durability of these components is critically dependent on the surface molecular interaction of the fibre and the matrix. Surface chemical analysis of these systems is critical to relate treatments to product performance.

A major issue identified by surface analysts during consultation was that practical samples have important surface topography and are not atomically flat. This surface topography in real life samples causes many unwanted artefacts in surface analysis. These artefacts, introduced into spectra and images, lead to ambiguity, difficulty in interpretation and reduced clarity to process engineers and R&D scientists developing new products and processes. In XPS, topography modifies the equations that would be used to determine a layer thickness.

Summary of technical work

A systematic study will be made of the effects of surface topography for model systems for the principal techniques XPS and SIMS, together with AFM for topography mapping. Model archetypal systems will be developed building from flat surfaces to rough surfaces, cylinders and spheres. Work will also be undertaken to improve the quantitative analysis of SSIMS

images. A method will be developed for rapid processing of high-resolution raw spectral data in SIMS images using multivariate methods.

In addition, methods will be developed for characterising fibres by nanomechanical analysis using AFM. The effect of fibre curvature on nanomechanical measurements will be studied theoretically and experimentally. The ‘thickogram’ method for XPS for calculating the thickness of ultra-thin layers at surfaces, developed by NPL for flat surfaces, will be extended to cope with the topography of cylindrical fibres.

Deliverables

No.	Description	Start	Finish
S1.1	Development of a model archetypal system building from flat surfaces to rough surfaces, cylinders and spheres.	Oct 06	Dec 08
S1.2	Development of methods for quantitative analysis of surfaces with topography for XPS and SIMS with topography defined by AFM and practical guides for analysts.	Jan 07	Mar 08
S1.3	Development of thickograms for fibres and a guide to Angle Resolved XPS Depth Profiling as draft for ISO TC201.	Mar 07	Jun 08
S1.4	Development of a protocol for the characterisation of fibres at the nanoscale using nanomechanical analysis.	Oct 06	Aug 08
S1.5	Development of multivariate methods for quantitative analysis of SSIMS images.	Oct 06	Dec 08
S1.6	Knowledge transfer including provision of expert advice to UK industry and academia, key input into BSI CII/60 and ISO TC201, presentations at meetings, website material and the hosting of an NMAET workshop on Fibre Analysis.	Oct 06	Sep 09

Project S2	Development of quantitative analysis methods for compounds and multilayer structures
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Project aim and objectives

The aim of this project is to develop valid methods for industrial analysis by XPS and SIMS for inorganic and organic coatings and the development of a standards infrastructure. This project will also develop the knowledge base for frontier measurements using new cluster ion beams.

The objectives of the project are:

- To develop methods, data and an ISO standard for the quantitative analysis of compounds at the outer surfaces of solids.
- To develop methods and data for quantification of contaminated solid surfaces, and the depths of different layers when sputtering to generate the depth profile.
- To develop a new draft ISO standard for calibration of the mass scale and progress a draft standard for repeatability and constancy to publication in ISO/TC 201.
- To develop procedures to establish the linearity of the intensity scale and relative quantification using SSIMS and to conduct an interlaboratory study.
- To develop methods for molecular depth profiling of thin organic and biomaterial layers at surfaces.
- To provide essential metrology of sputter yields of organic and biomaterials for cluster beams, and to define the fluence limit to avoid damage for molecules and delicate materials by electrons and cluster primary ion beams.
- To provide methods to quantitatively analyse nanometre-scale molecular coatings.
- To further develop NPL's novel method to determine molecular structure using the SMILES fragmentation system.

Background and rationale

High added-value products are key to both economic prosperity as well as improved healthcare. Major growth areas include molecular engineered surfaces for medical devices to improve biocompatibility and anti-fouling properties (for example catheters and coronary stents). The rapidly growing healthcare and personal care sectors are driving the requirements for laboratories to be accredited and follow quality systems.

UK industry experts have also identified major growth in pharmaceuticals, drug delivery, functional coatings for personal care applications, diagnostic arrays and point-of-care diagnostics, fragrances, smart packaging, technical textiles, processed foods and multilayer laminate systems for aerospace and defence and speciality adhesives.

The Materials Foresight report on priority topics for biomaterials [14] highlights the need for surface and interface morphology and chemistry, the surface design, molecular orientation and functionality for anti-microbial, anti-thrombogenic and analgesic capabilities. In addition, flexible displays and plastic electronics will have major impact with the global market for organic LED displays expected to be worth between \$3 bn and \$5 bn by 2009. The use of

ink-jet systems to cheaply and rapidly create high-resolution molecular assemblies for organic LED displays and organic electronics (including FETs, RFID tags) as well as array diagnostics and sensors is predicted to grow rapidly [24].

The importance of surface chemical analysis for innovation and product development is highlighted in many key reports including the DTI's UK strategy for nanotechnology [25]. This project addresses measurement needs, identified by direct consultation through site visits with leading analysts in UK industry.

Thin and ultra-thin compound layers and their integrity are key across the whole gamut of applications involving protective and optical films, functional and sensor layers and the corrosion and degradation of products. Analyses of these films are conducted mainly by x-ray photoelectron spectroscopy (XPS) using a non-destructive route, for ultra-thin films < 10 nm thick, and a sputtering route for thin films between 10 nm and some microns thick. Here, a lack of known sputtering yields and a general theory of sputtering in compounds leaves analysts with errors in composition and the depth. Definitive data are required to start to put in place these corrections for quantitative analysis in depth profiling compound layers more than 10 nm thick.

Static SIMS is a powerful frontline technique used by industry for surface chemical analysis. It has excellent spatial resolution of up to 100 nm, sensitivity of better than ppm and specificity of the chemical structure at the surface far exceeding other methods. There is an urgent need to develop ISO standards suitable for use in quality systems and accreditation to ISO 17025.

The topics in this project were ranked, by industry, as top in a recent ISO survey of needs. Consultation has clearly shown that the analysis of functional surfaces with sub-monolayer and nanometre molecular films is a growing requirement for many sectors. New cluster primary ion beams have revolutionised the capability for the analysis of molecular and complex organic surfaces by static SIMS and NPL is playing a leadership role in the international development. This project will develop the urgently needed measurement base for the analysis of organic and molecular layers from 0 to 100 nm to provide the essential foundations for interpretation.

Continued overleaf...

Summary of technical work

This major project has a significant amount of technical work that is at the frontiers of metrology. This is described in more detail in an NPL report [26]. In brief:

- New general methods will be developed and tested for their accuracy on selected groups of compounds for quantification by XPS and for the relevant sensitivity factors using an improved background. Reference data will be made available in the usual way as well as on the NPL website. An ISO standard draft will be developed to cover contamination correction.
- The capability to provide relative quantification using SSIMS will be developed and the reasons for poor negative ion repeatability will be studied and a methodology developed to improve repeatability. A draft ISO standard will be developed for calibration of the mass scale for TOF-SIMS instruments based on foundation science developed in the 2003-2006 VAM Programme. The issues of linearity of the intensity scale and massive sputter yield events will be studied and a method and procedure developed to establish the linearity of the intensity scale using micro-channel plate detectors.
- The metrology and understanding of organic profiling using cluster ion beams will be developed to give clear guidance to industrial users. The energetics of the collision cascade will be studied using organic (sensor-like) layers for different cluster ion beams for a range of energies and materials. This will be developed into a methodology so that practical guidance for analysts can be provided.
- A key part of this project is to advance the analysis of nanometre molecular coatings by investigating the effect on the ion intensities of different atomic and cluster primary ions (Bi_n and C_{60}) at different energies. A framework will be developed to understand the differences providing guidance for optimal use.

Deliverables

No.	Description	Start	Finish
S2.1	Development of a method and procedure for the compositional correction for contamination.	Oct 06	Sep 09
S2.2	Development of a method and procedure for the sputtering yields for oxides for depth scale calibration.	Oct 06	Dec 07
S2.3	Development of theory for extrapolation and interpolation to other ion energies and other materials.	Oct 06	Dec 08
S2.4	Development of Standards for ISO TC 201/SC6 Static SIMS: (a) calibration of the mass scale for TOF-SIMS instruments and (b) repeatability and constancy of the relative intensity scale.	Oct 06	Sep 09
S2.5	Development of a method to establish linearity of the intensity scale and characterise massive sputter yield events from new cluster ion sources.	Oct 06	Mar 08
S2.6	Development of a procedure for relative quantification using SSIMS, improved negative ion repeatability and testing in an interlaboratory study.	Sep 07	Sep 09
S2.7	Development of a method and model for cluster primary ion beam sputtering of organic materials.	Oct 06	Mar 09
S2.8	Sputtering yields for cluster primary ion beams for organic materials – development of theory and experimental data.	Sep 07	Sep 09
S2.9*	<i>Development of a method and procedure to define a fluence limit where surface damage limits the optimal resolution for cluster and atomic primary ion beams for organic and biomaterials. Development and web dissemination of a practical guide for analysts for optimal operation.</i>	<i>Jul 08</i>	<i>Sep 09</i>
S2.10	Quantitative molecular analysis of sub-monolayer and nanometre molecular films (0-100 nm) using cluster ion beams Bi _{1,3,5} and C ₆₀ .	Jan 07	Dec 08
S2.11	Development of NPL's SMILES fragmentation system to provides a framework for automated systems for interpreting molecular structure from mass spectra.	Oct 06	Sep 08
S2.12*	<i>Assembly of a SMILES fragment architecture library for determination of molecular structure.</i>	<i>Oct 08</i>	<i>Sep 09</i>
S2.13	Knowledge transfer including publications, presentations, participation in national and international standardisation activities (key input into BSI CII/60 and ISO TC201) and the production of reference data for the website. Organisation of the 46th IUVSTA Workshop 'Sputtering and Ion Emission by Cluster Ion Beams'.	Oct 06	Sep 09

* see note on p. 27

Project S3	High resolution nanomechanics measurements using AFM
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Project aim and objectives

The aim of this project is to develop measurement methods in order to resolve quantification issues using atomic force microscopy (AFM) to optimise operating conditions, improve reproducibility and additionally of the measurements.

The objectives of the project are:

- To provide traceable calibration of lateral force in AFM for the first time.
- To develop a method to calibrate AFM tip shape and provide a procedure.
- To evaluate the imaging capabilities, resolution and durability of carbon nanotube AFM tips.
- To improve the reproducibility and consistency of normal force and modulus measurement at the nano-scale via an interlaboratory study.
- To optimise operating conditions for force modulation microscopy and phase imaging.
- To develop methods for depth profiling using AFM.

Background and rationale

Atomic Force Microscopy has emerged strongly from industry consultations as of increasing importance in surface and nano-analysis, even relative to the increasing importance of surface analysis as a whole. The reasons are technological (ambient analysis, and very high-nm scale-spatial resolution) and economic (relatively cheap and compact).

Growth in applications is inhibited by the presently very modest metrology infrastructure that needs development. The growth areas where innovation plays a key role are in high value-added products such as MEMS devices, microfluidic systems, sensors, diagnostic arrays, organic electronics and fibre treatments which rely on surface structure and chemical composition on the micro and nano-scale. Major UK industries such as pharmaceuticals (£22.9bn), chemicals (£7.6bn), health and personal care (£5.1bn) and aerospace and defence (£10.4bn) [12] are increasingly dependent on product innovation on the nanoscale for competitive advantage in the global economy. However, analysis at the sub-100 nm scale is still a key metrology challenge as identified in the DTI's UK strategy for nanotechnology [25]. A recent EPSRC report [27] also highlights this requirement. AFM is one of the only techniques that can successfully address these measurement challenges at the high resolution required.

The 2004 RS/RAE report 'Nanoscience and nanotechnologies: Opportunities and uncertainties' [1] recommends supporting the standardisation of measurement at the nanometre scale required by regulators and for quality control in industry. The Government response to this report endorsed the development of traceable methods related to dimensional, chemical and functional aspects of nanotechnologies.

Summary of technical work

Lateral force measurement by AFM is extremely sensitive to information on chemical composition of the first atomic layer at resolutions approaching 10 nm, but suffers from poor repeatability, absent traceability and difficult-to-use calibration methods. The 2003-2006 VAM Programme developed a prototype MEMS device capable of quantifying the lateral force of an AFM cantilever quickly and traceably and in this project the efficacy of this device will be established.

This project will also examine the use of carbon nanotubes as AFM tips to enable a step change in AFM imaging quality by offering high resolution and well defined tip radii. Problems with reliability, sturdiness and fabrication methods will be investigated. AFM tip shape and size are the main sources of uncertainty in nearly all aspects of AFM based measurement. The tip shape is very difficult to characterise at the required level and work in this project will be undertaken to address this problem, which will result in methods and guidelines for AFM users.

Issues regarding the optimisation of operating conditions of several AFM modes for high-resolution nanomechanical measurements for end users will be resolved via an interlaboratory study. Surface sensitivity is greatly increased using dynamic modes of AFM operation. Force modulation and phase imaging can provide quantitative nanomechanical information and guidelines will be developed for the analyst to optimise the instrumental set-up for quantitative force modulation mode and phase images, and to evaluate the associated uncertainties. Previous VAM work on nanoindentation has shown that commonly applied rules can be grossly in error and this project will investigate this further.

Deliverables

No.	Description	Start	Finish
S3.1	Interlaboratory study of lateral force calibration; refereed publication as the basis for a possible ISO draft.	Jan 08	Sep 09
S3.2	Development of structures to calibrate AFM tip shapes and development of a procedure to calibrate AFM tip shape for use as a future draft ISO standard.	Dec 06	Aug 08
S3.3*	<i>Investigation of and recommendations for carbon nanotube tips for use as AFM probes.</i>	<i>Oct 08</i>	<i>Sep 09</i>
S3.4	Development of a procedure for and carry out an interlaboratory study of normal force / modulus leading to a future draft ISO standard.	Dec 06	Sep 08
S3.5	Development of a method and procedure to determine the optimal parameters for quantitative force modulation and phase imaging.	Mar 07	Sep 09
S3.6	Development of a method and procedure for the analysis of thin layers and coatings on substrates by AFM.	Dec 06	Dec 07
S3.7	Knowledge transfer including publications, key input to ISO TC201 and TC229, presentations at meetings and the production of reference data for the website.	Oct 06	Sep 09

* see note on p. 27

Project S4	Ambient and imaging mass spectrometry
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Project aim and objectives

The aim of this project is to begin the establishment of a metrology infrastructure for an important and powerful new ambient mass spectrometry technique Desorption Electrospray Surface Ionisation (DESI) and related methods.

The objectives of the project are:

- To configure a DESI instrument (this will be done at LGC who already have the necessary equipment).
- To develop a method and models to evaluate the projectile-surface interaction to develop an understanding of the process.
- To compare the resulting mass spectra with SSIMS, G-SIMS and electron impact mass spectra.
- To evaluate the repeatability of the method for test materials.
- To identify the mass range over which the desorption or ‘chemical sputtering’ event is effective.

Background and rationale

There is a major requirement for analytical techniques with high chemical specificity and sensitivity that can operate in ambient conditions and in a portable unit from such key UK industries as pharmaceuticals (£22.9bn), chemicals (£7.6bn), health and personal care (£5.1bn) [12] and other high innovation sectors. In these industries innovation is essential for the UK's competitiveness and prosperity in the global economy. For many of their devices and products the surface chemistry is critical but the samples are not compatible with vacuum based surface chemical analytical techniques. The need for operation in vacuum has inhibited the development of mass spectrometry relating to surfaces for these important products and sectors including direct analysis of pharmaceutical creams, high throughput analysis of tablets as well as the analysis of pharmaceuticals and cosmetics on skin and hair. Many reports and roadmaps [e.g. 16, 21, 25, 28] identify the need for new techniques and tools for the chemical analysis of surfaces. In addition, the Royal Society report ‘Making the UK safer’ [20] highlights the need for detection of chemical agents by first responders at the scene using mass spectrometry.

In 2004 a powerful new mass spectrometry technique was developed – Desorption Electrospray Surface Ionisation (DESI) [29]. Whilst a very new technique, its unique capability to provide highly sensitive mass spectrometry of surfaces without the need for vacuum has caused significant interest and rapid development. At least three academic groups in the UK have commenced work in this area and two UK instrument manufacturers are actively looking at possibilities for exploitation. In this project, we begin the basic characterisation of the method to evaluate its applicability for industrial analysis and application for forensics, law enforcement and homeland security. Recent publications have illustrated the power of the method to study the elution of ingested pharmaceuticals through

the skin, pharmaceuticals as tablets, creams and liquids as well as transdermal patches. Another key application is for the secure environment; excellent sensitivities of better than 1 pg/cm² to plastic explosives such as RDX, TNT and PETN, on a variety of substrates have been reported. Clearly, if the technique is to flourish the basic metrology needs to be in place. This work would form part of the VAM forward-looking research.

Summary of technical work

The first stage of this project will be to configure a DESI instrument at LGC using an existing 'nanospray' electrospray source onto a Q-TOF MS/MS spectrometer. This will be undertaken by LGC with input from NPL so that experiments may be appropriately configured. In order to develop a method and models to evaluate the projectile-surface interaction and develop an understanding of the process; surfaces with molecular assemblies of varying binding energies will be developed to allow the effect of electrospray source voltage, droplet size and type to be mapped out. The mass spectra from DESI will be compared with cluster-SSIMS and G-SIMS to elucidate the DESI ionisation and desorption process. A similar approach will be used to evaluate the maximum sized intact or large fragment molecules that can be detected using this method.

Deliverables

No.	Description	Start	Finish
S4.1	Development of a method and model to evaluate the projectile-surface interaction, and information depth in order to gain an understanding of the process.	Dec 06	Mar 08
S4.2	Comparison of the resulting mass spectra with SSIMS, G-SIMS and electron impact mass spectra.	Dec 07	Sep 09
S4.3	Identification of the mass range over which the desorption or 'chemical sputtering' event is effective.	Mar 08	Sep 09
S4.4	Knowledge transfer including publications, presentations at meetings and the production of reference data for the website.	Oct 06	Sep 09

Project M1	Programme management and decant
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Project aim and objectives

The aim of this project is to ensure effective coordination of the VAM-Physical Programme in order to deliver maximum benefit to the UK. In addition, this project has the aim of successfully managing the decant of facilities to new laboratories such that the minimum of disruption occurs.

The objectives of the project are:

- To ensure cost-effective delivery of the Programme.
- To provide reports on progress on a monthly and annual basis.
- To successfully decant all facilities and projects to new laboratories.

Background and rationale

The VAM-Physical Programme consists of a number of projects whose delivery is dependent on efficient use of resources and facilities. The complexity of the technical and knowledge transfer activities will require close monitoring of progress and a flexible approach to resourcing. This project coordinates activities in the Programme to ensure that all projects are completed in a timely and cost-effective manner and that all reporting requirements to the DTI and its advisors are met.

During the lifetime of this Programme, the facilities and projects that comprise the Programme will move to new laboratories. Such a move is a major undertaking, requiring careful coordination as well as supporting the actual decant and setting up of facilities in new laboratories. A substantial part of this project will support the move to new laboratories.

Summary of work

This project will ensure the timely and cost-effective delivery of all milestones in the VAM-Physical Programme through the provision of monthly progress reports and invoices (to the DTI) and annual progress reports (to the VAM working group and the DTI).

The successful move of facilities supported by the VAM Programme to new laboratories will be a major objective of this project. Work will support and oversee the dismantling, moving and re-build and testing of facilities.

Deliverables

No.	Description	Start	Finish
M1.1	Report progress in the Programme to the DTI through a series of monthly invoices and summary reports.	Oct 06	Sep 09
M1.2	Provide annual reports of progress in the Programme to the DTI and the VAM Working Group.	Oct 06	Sep 09
M1.3	Ensure the successful and timely decant of all VAM-supported facilities to NPL's new laboratory.	Mar 07	Aug 07

Project M2	Formulation of the next VAM-Physical Programme
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Project aim and objectives

The aim of this project is to produce a proposal of work for the next VAM Programme.

The objectives of the project are:

- To conduct a detailed consultation exercise with industry, regulators, government and other end users to determine current and future measurement requirements.
- To draw together all inputs received during formulation into a new Programme of work that will form the next VAM Programme.

Background and rationale

As the UK economy evolves and technology trends develop, new measurement requirements emerge. To underpin growth in the economy these measurement requirements must be successfully addressed as early as possible. Also new regulatory controls on the environment, health and transport demand new or better measurement techniques. In order to determine the present and future measurement requirements, it is important that stakeholders' views are sort through a wide-ranging consultation process. This includes examining independent evidence expressed in reports, foresight activities, industry roadmaps, etc., as well as conducting meetings, surveys and interviews focusing on specific topics of interest. Collation and assessment of information from all sources enables a list of activities to address the measurement needs to be formulated. An independent prioritisation of these activities enables the optimum programme of work to be developed which will maximise the impact of available funding on UK measurement requirements.

Summary of work

This project will ensure the successful formulation of the 2009-2012 VAM Physical Programme.

The direction and strategy of the Programme will be determined by a 'trend spotting forward look' review of measurement requirements and a subsequent Orientation meeting. Technical projects will then be developed and presented to the VAM Working Group at its Annual Review. After the scope of the Programme has been focussed further, the remaining portfolio of projects will be presented for public comment before being prioritised by the Working Group. The projects selected by the prioritisation process will comprise the final Programme, which will developed into a form suitable for ministerial approval before commencement of the technical work of the Programme in October 2009.

Deliverable

No.	Description	Start	Finish
M2.1*	<i>Production of a proposal of work for the 2009-2012 VAM-Physical Programme.</i>	<i>Apr 08</i>	<i>Sep 09</i>

* see note on p. 27

Project M3	Dissemination and representation
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Project aim and objectives

The aim of this project is to maximise the impact of the VAM-Physical Programme through high level knowledge transfer activities and to represent UK interests through participation in high level metrology and standardisation committees for the benefit of UK industry and regulators.

The objectives of the project are:

- To support organisation of and participation in key science conferences that have a broad scope, covering the interests of a technical area or the whole Programme.
- To manage active and relevant contributions to high level national and international standardisation bodies and aid in formulating UK views to the benefit of UK industry.
- To represent UK interests on international measurement committees.

Background and rationale

Knowledge transfer (KT) is the vehicle through which the knowledge and benefits developed in the VAM Programme are disseminated to industry, government, regulators and other end users. As such it is an essential component of the Programme. For maximum effectiveness, KT activities are embedded within each technical project, however, there are several, cross-cutting, KT activities that are essential in order to gain the maximum benefit from the Programme. A key role for the VAM Programme is the support for representation of UK interests on many international measurement and standardisation committees such that UK industry and government benefits from: the prevention and reduction of trade barriers (support for the MRA); better informed regulation; and the harmonisation of industry standards. The benefit of these activities is demonstrated in a recent DTI report 'The Empirical Economics of Standards' [30] which showed that standardisation activity had contributed around 13% of post-war productivity growth in the UK. This project will cover relevant participation in the work of the high level and influential CCQM and EUROMET metrological committees as well as supporting work in top level technical committees under the auspices of ISO, CEN and VAMAS.

Much of the work of the VAM Programme is disseminated through presentations and papers at both national and international meetings and this work is largely included within technical projects. However, there are two events that cut across many different projects and as such they sit outside any individual project. These are the ISO Gas Symposium (a high profile, high impact, international meeting in the area of gas standards) and the highly successful Nano-Molecular Analysis for Emerging Technologies meeting. These events are highly effective dissemination vehicles for knowledge generated in the VAM-Physical Programme.

Summary of work

This project will support dissemination of knowledge through support of participation at two key events: the ISO Gas Symposium and the Nano-Molecular Analysis for Emerging Technologies (NMAET) conference. These meetings have previously been extremely successful and have demonstrated substantial impact. This project will support participation in one ISO Gas Symposium and organisation of two NMAET conferences.

High level international committees such as: CCQM plenary and its working groups; ISO and CEN Technical Committees (TCs); and BSI EH2 and PTI/015 committees are core metrology activities for the VAM Programme. This project will support UK representation on the high level CCQM committees and TC level work under ISO, CEN and BSI.

Deliverables

No.	Description	Start	Finish
M3.1	Support the organisation of, and participation in, key conferences that have a broad scope (covering the interests of a technical area or the whole Programme).	Oct 06	Sep 09
M3.2	Ensure that active and relevant contributions are made to high-level national and international standardisation bodies. Aid in formulating UK views which will benefit the nation's industry.	Oct 06	Sep 09
M3.3	Representation of the UK's interests on international measurement committees.	Oct 06	Sep 09
M3.4	Annual reporting of KT activities in the VAM-Physical Programme.	Oct 06	Sep 09

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ANNEX: LIST OF ABBREVIATIONS AND ACRONYMS

AFM	Atomic Force Microscopy
AQUILA	Ambient Air Quality Reference Laboratories
BSI	British Standards Institute
BTC	British Technical Council for the Motor and Petroleum Industries
CATFAC	Controlled Atmosphere Facility
CCQM	Consultative Committee for Amount of Substance
CEN	European Committee for Standardization
CIPM	International Committee for Weights and Measures
Defra	Department for the Environment, Food and Rural Affairs
DESI	Desorption Electrospray Surface Ionisation
DMA	Differential Mobility Analyser
DTI	Department of Trade and Industry
EC	European Commission
EMEP	Programme for Monitoring and Evaluation of the long-range transmission of air pollutants in Europe
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
EUROMET	European Collaboration in Measurement Standards
FET	Field Effect Transistor
FID	Flame Ionisation Detector
FTIR	Fourier Transform Infrared
GAW	Global Atmospheric Watch
GC	Gas Chromatography
G-SIMS	Gentle Secondary Ion Mass Spectroscopy
GUM	Guide to the expression of Uncertainty in Measurement
ICAO	International Civil Aviation Organization
IPCC	Intergovernmental panel on Climate Change
IPR	Intellectual Property Rights
IUVSTA	International Union for Vacuum Science, Technique and Applications
JRC	Joint Research Centre
KT	Knowledge Transfer
LED	Light Emitting Diode
LGC	Laboratory of the Government Chemist
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
MEMS	Micro Electro Mechanical Systems
MET	Measurements for Emerging Technologies
MNT	Micro- and Nanotechnology
MRA	Mutual Recognition Arrangement
MS	Mass Spectrometry
NEL	National Engineering Laboratory
NMAET	Nano-molecular Analysis for Emerging Technologies
NMI	National Metrology Institute
NMS	National Measurement System
NMSD	National Measurement System Directorate
NPL	National Physical Laboratory
OECD	Organisation for Economic Co-operation and Development
OST	Office of Science and Technology
PM	Particulate Matter
PT	Proficiency Testing
QA	Quality Assurance

QC	Quality Control
RAE	Royal Academy of Engineering
REACH	Registration, Evaluation and Authorisation of Chemicals
RFID	Radio Frequency Identification
RS	Royal Society
SAMS	Surface and nano-analysis measurement steering
SEMI	Semiconductor Equipment and Materials International
SERS	Surface Enhanced Raman Spectroscopy
SI	International System of Units
SIMS	Secondary Ion Mass Spectroscopy
SME	Small and Medium Enterprise
SMILES	Simplified Molecular Input Line Entry Specification
SPM	Scanning Probe Microscopy
SSIMS	Static Secondary Ion Mass Spectroscopy
STAG	Standard Test Atmosphere Generator
TC	Technical Committee
TDD	Time Division Dilution
TOF	Time Of Flight
UKAS	United Kingdom Accreditation Service
UNECE	United Nations Economic Commission for Europe
VAM	Valid Analytical Measurement
VAMAS	Versailles Project on Advanced Materials and Standards
VOC	Volatile Organic Compound
WG	Working Group
WMO	World Meteorological Organisation
XPS	X-Ray Photoelectron Spectroscopy