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|-----------------------|-----------------------------|--------------------------|--|
| Proposal # | 01 | Price to DIUS | |
| Proposal Title | Dimensional Refresh Project | Co-funding Target | |
| | | Start Date | |
| | | End Date | |
| Lead Scientist | | WG Champion | |

Vision

A new high accuracy, multi-functional dimensional calibration facility for high precision artefacts such as length bars, step gauges, ring gauges, plug gauges and long linear scales.

Impact & Benefits

Provide advanced manufacturing industry with traceable, high accurate measurement standards that support quality control and international trade in precision engineering. A flexible facility will enable faster response to changing calibration needs. Replacing ageing equipment will reduce cost to the NMS for maintenance and simplify staff training to sustain long-term capability - UKAS labs rely on these facilities for traceability.

Support for Programme Challenge

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Support for Government Strategies

Support advanced manufacturing industries, such as aerospace, automotive and medical devices, where precision engineering is critical to product quality and regulatory requirements.

The Need

Many of the current dimensional measurement facilities are 15-20 years old and need much attention to keep functioning. Their unreliability makes it difficult to support UK industry and respond to changing needs. Ongoing improvements to manufacturing processes and machines requires new calibrated standards (e.g. ball gauges) that do not fit well with current facilities leading to slow turnaround. A new facility will make the services more efficient and sustainable.

Current State of the Art (NPL and elsewhere)

Currently there are several bespoke systems (e.g. secondary length bar interferometer, metroscope) that are dedicated to a particular length standard. Although their accuracy is good, the instruments are 15-20 years old, rely on obsolete computing technology and the risk of failure is high.

The Solution

A frame, jiggling, alignment and interferometer system to fit on a commercial CMM to provide traceable linear dimension calibrations with sub-micrometre accuracy. The design will be based on the lessons learnt in developing the NPL step gauge

measurement system, with modifications to broaden the range of artefacts that can be accommodated.

Metrology Capability to be Delivered

High accuracy, multi-functional dimensional calibration facility for high precision artefacts such as length bars, step gauges, ball gauges, ring gauges, plug gauges and long linear scales.

Project Description

Design a facility to meet the best possible measurement accuracy whilst having a broad and versatile capability. Ease of use and long-term sustainability will form part of the design criteria. Construction of hardware and development of software. Testing and verification of system. Development of best practice and measurement procedures. UKAS accreditation and introduction to the measurement services. Phase out of old systems.

Exploitation/Spin Offs

The calibration facility and software should be replicable enabling duplication if demand increases and potentially could be licensed to a metrology organisation to market.

Project Partners

Cofunding

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| Proposal # | 02 | Price to DIUS | |
| Proposal Title | Force new 5MN | Co-funding Target | |
| | | Start Date | |
| | | End Date | |
| Lead Scientist | | WG Champion | |

Vision

New national standard 5MN hydraulic force capability to meet UK long-term industrial and legal metrology needs. This project is the first stage in developing the capability. It will establish UK needs and produce specifications of a new facility.

Impact & Benefits

Delivery of class 0.5 force calibrations to UK companies and calibration labs to enable them to deliver high quality products that enable them to compete internationally. The facility will enable companies, e.g. in the energy, offshore and construction sectors, comply with health and safety legislation through traceable assessment of safety critical parts under load.

Support for Programme Challenge

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Support for Government Strategies

Force is a critical measurement for advanced manufacturing sectors such as aerospace and automotive, where accurate measurement underpins material and component testing and underpins safety.

The Need

Delivery of traceable calibrations of high capacity load devices to UK companies, such as Instron and BAE Systems, who are currently forced to go abroad as there is no capability with the required level of accuracy in the UK. The facility will also be available to assist UK companies develop new instrumentation. The NPL facilities are ageing and there are increasing risks of breakdowns that would seriously inconvenience UK industry.

Current State of the Art (NPL and elsewhere)

The UK's current capability is degrading, performance is slipping relative to other NMIs such as PTB, putting UK at a competitive disadvantage. Equipment from UK has to go to PTB for calibration & companies are unhappy to do this.

The Solution

A new state of the art force calibration system with a capacity in tension and compression of at least 5 MN to replace the current national standard 5MN force machine. Options will be explored for increasing the load range as this would expand the service available to UK companies. The facility would deliver world class calibrations and be available for hire by UK industry.

Metrology Capability to be Delivered

New national standard machine for force calibrations. This work is the first stage and will define the scope of requirements and recommend design specifications for a new system.

Project Description

Feasibility study for developing new facility

- (i) Engage with UK users to identify optimum requirements.
- (ii) Review capabilities in other NMIs and commercial labs
- (iii) Document design specifications for a new system and identify of potential off-the-shelf solutions.

Exploitation/Spin Offs

Continuation of the only UK force calibration facility operating above 3 MN in tension and compression. Maintain and increase measurement services work (currently > 60 calibrations, >£100k pa income).

Project Partners

Cofunding

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| Proposal # | 03 | Price to DIUS | |
| Proposal Title | Jamin | Co-funding Target | |
| | | Start Date | |
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| Lead Scientist | | WG Champion | |

Vision

To provide a versatile, user friendly, compact, robust, high resolution, high accuracy, traceable, optical interferometer that is commercially exploitable as a stand alone unit with complementary input optics and signal processing for traceable displacement metrology over the metre to sub nanometre range.

Impact & Benefits

This work will lead to improved displacement measurement capability with lower uncertainty, thereby benefiting areas such low force, AFMs micro thrust measurement, photonics, micromachining, sensor and transfer artefact calibration and thermal expansively. These are of generic benefit to all sectors within the UK.

Support for Programme Challenge

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Support for Government Strategies

Supports all areas of displacement metrology, particularly nanometrology; a need highlighted by Royal Society review.

The Need

Optical interferometry is the prime tool for traceable displacement measurement at nano and micro scale. This NPL interferometer is used on many instruments around NPL with several more potential NMS and third party applications. With the demand for lower measurement uncertainties, particularly associated with smaller distance measurement eg AFMs, low force and thrust measurement, there is a need for improvement in the performance of the interferometer.

Current State of the Art (NPL and elsewhere)

This interferometer is NPL's state of the art displacement interferometer. Other NMIs are developing much larger interferometer systems that will not be commercially exploitable or as versatile. Commercial solutions suffer from higher non-linearity, lower resolution and are not as compact.

The Solution

To develop a dedicated fringe optimization and counting system for the interferometer together with improved input optics and error compensation. A quantification of the components of non-linearity will facilitate their reduction via improved optics and alignment. Testing of alignment methods to optimize performance.

Metrology Capability to be Delivered

State of the art compact displacement measuring optical interferometer with picometre non-linearity together with alignment strategy to ensure optimum performance for a range of input optics suited to various applications eg fibre, collimated and direct laser illumination.

Project Description

Enhanced performance of interferometer, rigorous modelling and characterisation of interferometer using x-ray interferometry to identify and quantify sources of non-linearity. Development and testing of an FPGA based fringe counting and optimization of system both over short and long measurement range. Development different input optics such as telescopic collimation of input beam and fibre feed system that would increase the versatility of the interferometer and to reduce measurement errors.

Exploitation/Spin Offs

NPL already has already had discussions with regard to licensing and exploitation.

Project Partners

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| Proposal # | 04 | Price to DIUS | |
| Proposal Title | vCMM | Co-funding Target | |
| | | Start Date | |
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| Lead Scientist | | WG Champion | |

Vision

Improved CMM measurement capability to increase the international competitiveness of UK PLC. By developing and promoting better measurement practice the state of the art in machine performance verification and uncertainties analyses, UK industry maximise the value and return of their CMM measurement facilities. NPL will gain the knowledge to better support companies to adopt best practice and provide advice and training to expand the UK skill base.

Impact & Benefits

Advanced manufacturing companies, particularly precision engineers such as Rolls-Royce and Airbus, will be able to improve quality and product performance through more rigorous uncertainties estimates, based on Monte Carlo simulation. Guidance from NPL will help companies (particularly SMEs) understand and implement uncertainties, helping them to comply with OEM demands and adopt best practice. Guidance on the new update to ISO 10360-2 will help companies implement new verification methods.

Support for Programme Challenge

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Support for Government Strategies

Supports advanced manufacturing by providing means of achieving tighter tolerances and improved validation of innovative designs or manufacturing processes.

The Need

Calculation of uncertainties with respect to CMMs is poorly understood by industry. Implementing VCMM would enable NPL to give guidance on best practice with regard to state of the art uncertainty calculations on CMMs. GPG on 10360-2 (one of the most downloaded GPGs from NPL web site) is in need of an update to reflect changes to the standard Virtual CNC machine tool correction is a growing field that would benefit from improved metrology.

Current State of the Art (NPL and elsewhere)

Virtual CMMs as implemented by CMM manufacturers and third party packages such as Pundit. International standards relating to CMM uncertainties. Virtual CMMs are implemented fully at other NMIs but not in the UK. Guidance on the use of new performance verification methods in ISO 10360-2 is needed.

The Solution

Implement Calypso VCMM at NPL, understand its use. Use in conjunction with hole plate to maintain necessary information for use with the software. Compare with

other methods for calculating uncertainty. Compare hole plate measurements with those from NPL Laser Tracer to develop and verify efficient error mapping techniques. Carry out case study measurements on real components to demonstrate the benefits of performance verification and uncertainty analyses.

Metrology Capability to be Delivered

Extension of existing CMM capabilities by automatically producing task specific uncertainties that are currently calculated by hand. Delivery of good practice to industry. Validation of new technologies for performance verification of CMMs. Enhanced understanding of virtual modelling for measurement and the increasingly important field virtual CNC control and correction.

Project Description

1 Install Calypso VCMM on NPL Zeiss UPMC550, receive training and maintain through use of hole plate.

2. Develop case studies of measurements on real components.

3 Use experience gained to update and promote the NPL GPG on ISO 10360-2, reflecting changes in standards and the estimation of uncertainties.

Exploitation/Spin Offs

Update good practice guide on ISO 10360-2 and CMM measurement uncertainties. New content for NPL Dimensional Training. Enhanced measurement services at NPL. Possible spin-off in virtual CNC apps.

Project Partners

Cofunding

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| Proposal # | 05 | Price to DIUS | |
| Proposal Title | AFM | Co-funding Target | |
| | | Start Date | |
| | | End Date | |
| Lead Scientist | | WG Champion | |

Vision

A UK metrological infrastructure for AFMs enabling reliable, traceable measurements to be made using both metrological and commercial AFMs at NPL, universities and in industry. A greater understanding of the properties and theory of an AFM and how they affect its use thereby giving confidence in these instruments, best practice of operation, leading to ISO standards, greater efficiency of use and lower measurement uncertainty with closer collaboration with industry and internally at NPL.

Impact

Valid, calibrated AFM measurements for UK industry, lower measurement uncertainties benefiting all AFM users, along with improved measurement practice and more efficient AFM usage, resulting in cost savings and improved production quality. Results will feed directly into future ISO standards in ISO TC201/SC 9 (scanning probe microscopy), TC229 (nanotechnologies) and TC213 (dimensional). the project will develop cross divisional NPL collaboration and closer ties with industry leading to future projects.

Support for Programme Challenge

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Support for Government Strategies

The Royal Society has highlighted the critical need for improved nanometrology and results from this work will enable the UK to contribute and take the lead in developing ISO standards in this area.

The Need

As the window on the nanoworld, there are several thousand AFMs in use in the UK in areas as diverse as micro manufacturing including, healthcare, defence, aerospace, photonics, materials science, biotechnology and agriculture. The majority are not calibrated and give inaccurate results. Many factors affect AFM performance and there is a need for a fundamental study of these factors to improve reliability and give greater confidence in these instruments.

Current State of the Art (NPL and elsewhere)

NPL has a metrological AFM, a unique AFM purpose built for studying effects of tip sample interactions on dimensional metrology and state of the art commercial AFMs. NPL has a EURAMET collaboration with PTB and CMI for work in this area and has already made contributions to improving AFM metrology.

The Solution

To highlight the importance of metrology for AFM users and to undertake a study both on metrological and commercial AFMs at NPL in a controlled environment to quantify factors affecting metrological capabilities of AFM performance. This together with a comparison with surface texture measuring instruments will work towards the extraction of 3D surface texture parameters from AFM measurements.

Metrology Capability to be Delivered

Improved operation of metrological and commercial AFMs for dimensional metrology, reduced measurement uncertainty and information for incorporation in ISO standards. An understanding of factors affecting the extraction of 3d surface texture parameters from AFM measurement data. The results will enable NPL to maintain its position at the top of the measurement chain in this area and equip it for supporting UK SPM user.

Project Description

An initial comparison of AFM measurements made by industry, universities and NPL will highlight common pitfalls for AFM users. At NPL studies will be made using specialized metrology AFMs and commercial AFMs to measure of effects oscillation amplitude and set point, tip wear drift and tip sample interactions in general on dimensional measurements. Additionally, various methods for tip shape reconstruction will be critically studied to determine the optimum method leading to a future ISO standard.

The Benefits

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Exploitation/Spin Offs

Refereed publications, conferences presentations, good practice guide, future ISO standards. Increased awareness by industry of AFM metrology leading to further collaboration, eg JIPs TP, FP7.

Project Partners

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| Proposal # | 06 | Price to DIUS | |
| Proposal Title | DVD | Co-funding Target | |
| | | Start Date | |
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| Lead Scientist | | WG Champion | |

demonstrated.

Vision

A suite of low cost high precision sensors for AFM sensing, vibration measurement and control, angle measurement, low force thrust measurement and dynamic metrology based on cheap mass produced off the shelf components.

Impact

Improved measurement and control for many sectors including micro and large scale manufacturing aerospace, defence, space and automotive. Increased information on instrument performance leading to more efficient production, less waste, less energy usage, exploitation of nanotechnology that in turn impinges on many sectors.

Support for Programme Challenge

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Support for Government Strategies

The Royal Society review of nanotechnology highlighted the need for improved nanometrology. The improvements in manufacturing efficiency would also be of environmental and economic benefit.

The Need

Nanometrology requires low cost robust compact displacement, angle and vibration sensors to enable measurement and control at the nanometre level to be developed in a cost effective manner. This would meet the needs of in process metrology and lead to a better understanding and control of external factors affecting systems.

Current State of the Art (NPL and elsewhere)

Current sensors suffer from high cost, poor sensitivity, bulk, inflexibility and multiple sensors (displacement and angle) are often needed for a single application. They are limiting improvements in the areas of low force, micro thrust, vibration sensing, microscopy (AFMs) and interferometry.

The Solution

DVD pickups have high sensitivity, robustness, speed and low cost. Their potential for a variety of sensing applications has been demonstrated, but they are yet to be exploited for high top-level metrology applications. Blu Ray pick up technology offers improved performance but has not been investigated. A suite of sensors based on these devices for a range of applications will be developed and applications

Metrology Capability to be Delivered

Work will concentrate on development of an AFM head where the pick up potentially offers enhanced sensing for detection of cantilever angle and displacement. In addition a compact high sensitivity differential 3 axis accelerometer will be developed. To explore the potential further the feasibility of developing further sensing applications will be rigorously investigated and reported.

Project Description

Following an initial practical assessment of their drift, sensitivity, bandwidth and signal to noise ratio, a compact versatile AFM head and an accelerometer will be developed from DVD/Blu ray heads, together with control systems to optimize the head's versatility, range of operation and potential applications. These could either be free standing or integrated into existing pieces of equipment to provide on board active sensing.

The Benefits

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Exploitation/Spin Offs

The sensors developed will be used in several applications within exiting and future projects to improve instrument performance. There is the potential for commercial exploitation through licensing

Project Partners

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| Proposal # | 08 | Price to DIUS | |
| Proposal Title | PTcal | Co-funding Target | |
| | | Start Date | |
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| Lead Scientist | | WG Champion | |

Vision

To demonstrate the practicality of a dual-parameter continuous calibration method, applicable to a wide range of mechanical sensors and associated industrial sectors.

Impact & Benefits

Cost savings for transducer manufacturers, end users, and calibration laboratories. End users benefit from having transducer calibration data that relates more closely to the conditions encountered during their use.

Support for Programme Challenge

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Support for Government Strategies

The project supports the UK Technology Strategy's Key Technology Areaa of "Design Engineering and Advanced Manufacturing / Lean manufacturing and processes" (resource efficient, low cost).

The Need

Pressure transducers are generally calibrated in a static manner, often having to adjust both pressure and temperature in a step-wise manner over the operating range of the transducer. This is very time-consuming (a calibration can take 30 hours or so) and can limit the amount of devices sold as the pressure facilities and ovens needed for calibration are expensive.

Current State of the Art (NPL and elsewhere)

Transducers are calibrated statically, varying both parameters independently to cover the whole calibration envelope - as stated above, this can take over 24 hours and be the major bottleneck in the manufacturing process.

The Solution

To develop a system in which pressure and temperature are cycled throughout their ranges at the same time but at different rates, and correlating the output from devices under test to reference values obtained from a range of calibrated sensors spread throughout the working volume.

Metrology Capability to be Delivered

Develop a system in which pressure and temperature are cycled continuously, and use it to calibrate a set of transducers within a specified uncertainty in a significantly shorter period than is possible at present.

Project Description

Development of equipment to deliver metrology capability as specified above, followed by analysis of data to determine optimum cycle rates for the two parameters and number / positioning of reference sensors within the working volume.

Exploitation/Spin Offs

Publication of methodology, with supporting evidence for its efficacy, in relevant scientific journal and trade publications.

Project Partners

Cofunding

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| Proposal # | 09 | Price to DIUS | |
| Proposal Title | XCT | Co-funding Target | |
| | | Start Date | |
| | | End Date | |
| Lead Scientist | | WG Champion | |

Vision

To investigate the feasibility of a National Centre for X-ray Computed Tomography

Impact & Benefits

New methods for both research and in-process measurement of dimensions and material properties over a large size range

Support for Programme Challenge

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Support for Government Strategies

TSB - High Value Manufacturing, Advanced Materials, Energy

The Need

Many manufacturing and research areas are investigating the use of XCT methods. XCT offers the capability of measuring through a structure rather than attempting to measure the surface. This allows internal structure such as hidden materials, defects and voids, and high aspect ratio parts to be measured. The range of industries is large, for example, high value manufacturing, micosystems and archaeology. The range of size is also large, from tens of nanometres to several metres.

Current State of the Art (NPL and elsewhere)

There are now several manufacturers that produce an XCT system. PTB are actively involved in developing calibration methods and artefacts.

The Solution

The project will investigate the need and technicalities of a National Centre

Metrology Capability to be Delivered

A feasibility study into requirements for XCT measurement

Project Description

The project will conduct a feasibility study into the setting up of a National Centre for XCT possibly at NPL. This will involve:

1. A review of the available technology and research base.
2. A review of existing calibration techniques and artefacts.

3. A review of the UK industry needs for XCT including potential for growth

4. Visit academic institutions and industry site with XCT capability

5. Propose future programme of work in XCT including the potential of a National Centre

Exploitation/Spin Offs

Feasibility into new capability

Project Partners

Cofunding

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| Proposal # | 10 | Price to DIUS | |
| Proposal Title | Increased flexibility service | Co-funding Target | |
| | | Start Date | |
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| Lead Scientist | | WG Champion | |

Vision

Revitalisation of gauge block and length bar services to take full advantage of the new building opportunities and remediate the new building problems. Services to be speeded up, made more reliable and offer SOA uncertainty levels. Work with UKAS laboratories to identify future cheaper upgrade routes for existing ageing equipment.

Impact & Benefits

Better service availability and throughput for customers. Better use of new building facility (better environment) to offer reduced uncertainty. UKAS labs able to continue offering services when current light sources fail.

Support for Programme Challenge

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Support for Government Strategies

Underpins Engineering and Advanced Manufacturing. Primary traceability route for much of engineering industry in UK.

The Need

Gauge block and length bar services operated on minimal maintenance for last 3 Programmes. Struggling to work in new building environment (vibration, low freq acoustics). Some equipment elements now 20+ years old, yet still offering ~SOA service. Some customers requiring better uncertainty (20 + 0.2L), others demanding faster service. 7 UKAS labs using ageing Hilger GBIs now running out of light sources, unable to buy new commercial interferometers.

Current State of the Art (NPL and elsewhere)

NMS facilities are state of the art and commercial GBI copies still being sold. No other UKAS lab can match the accuracy. PTB offers better accuracy (20 + 0.2L, but more expensive, slower). GBI+LB services have lowest relative uncertainty of all NMS length services.

The Solution

Update some of the existing custom-made equipment (LBM electronics and software, several stabilised laser tubes) to be more reliable/flexible. Establish new working practices and procedures and reduce the uncertainties accordingly (GBI + LBM). Prepare vibration isolation for phase-stepping GBI and replace failed mirror drive; return to operational status. Survey Hilger use in UKAS labs. Work with other NMIs that have updated Hilgers recently to produce cheap update

option for UKAS labs.

Metrology Capability to be Delivered

Phase stepping interferometer returned to service, allowing parallel running; reduced uncertainty GBI service; secondary length bar interferometer service speeded up and more tolerant of new building. GBI services with better availability and reliability. Potential new services at UKAS labs which use Hilger interferometers.

Project Description

A refresh of the most out-of-date/least reliable parts of the gauge block and length bar services, coupled with a reduction of the achieved uncertainty through optimisation to suit the new building environment. Temperature control <0.1 °C now possible but at the expense of increased vibration and pressure effects (low-frequency sonic and infra-sonic). As well as enabling NMS facilities to match current worldwide SOA, allow UKAS labs to offer services into the future past the lifetime of discharge lamps.

Exploitation/Spin Offs

Possible new upgrade for existing Hilger users. Exploit better measurement service.

Project Partners

Cofunding

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| Proposal # | 11 | Price to DIUS | |
| Proposal Title | Revitalisation of thermal expansion | Co-funding Target | |
| | | Start Date | |
| | | End Date | |
| Lead Scientist | | WG Champion | |

Vision

Consolidation and development of NMS facilities for coefficient of thermal expansion (CTE) measurement, as enabling technology for dimensional metrology (micro-to-macro) and establishment of new flexible facility for CTE measurements on larger samples over bigger temperature ranges. This will then lead to new supply of reference CTE samples usable in many commercial dilatometers or as reference samples in R&D developments and for modelling of precision instruments and structures.

Impact & Benefits

Enable next generation longer range nano tools (needing controlled metrology frames), better knowledge of and design for stable metrology platforms, new data for R&D efforts, improved inputs to FEA modelling, applications in aerospace and energy generation industries (stable platforms, gas turbines, aero engines, etc). Improved operating efficiency is critically dependent on using new materials, but dimensional stability/tolerance depends on CTE accuracy.

Support for Programme Challenge

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Support for Government Strategies

CTE is an enabling technology on 3 of 4 Dimensional Metrology EMRP roadmaps. Supports KTAs: Design Engineering and Advanced Manufacturing, Advanced materials; & aerospace industry, improved modelling.

The Need

NMS has no traceable high accuracy CTE capability away from 20 °C. Lack of accurate information on modern engineering materials, especially low CTE materials for use in metrology frames, space environments, precision metrology equipment, next generation nanometrology tools. Strong demand for reference CTE samples & bigger range accurate flexible service; inconsistency in results of commercial dilatometers and across different equipment - CBTLTM report (Yacoot 2001).

Current State of the Art (NPL and elsewhere)

NMS: PLBI (~20 °C , gauge blocks only, currently N/A); Materials - comparator- bigger temperature range but not high accuracy. PTB, NMIJ - interferometer only for gauge block shapes at high accuracy. VSL - simple box, low accuracy, ~20 °C only.

The Solution

Resurrect PLBI service (as benchmark) and extend its temperature range and type of materials catered for. Comparison with Materials comparator (over restricted range). Update the survey of explicit demands from UK plc & Europe. Design study on proposed design for flexible, increased range, interferometric dilatometer utilising outputs of NPL differential Jamin interferometer developments. Consider alternative design for nano-scale work using AFM technology. Survey of existing CTE RMs.

Metrology Capability to be Delivered

Consolidation of existing services. Reinstatement of service using PLBI, including low accuracy on small CTE samples (e.g. Zerodur). Survey into latest needs and design study for future build of a new, flexible, dilatometer and range of CTE RM samples to be provided. New dilatometer would be a larger follow on project taking outputs of the design study, survey and Jamin developments into account.

Project Description

Consolidation and design for development of thermal expansion facilities within the NMS as a provider of certified reference materials, consultancy services and new capability for CTE metrology. This work will underpin several roadmaps where ultra-stable or highly-characterised structures and materials are necessary to achieve longer term metrology goals.

Exploitation/Spin Offs

Resurrected measurement service (PLBI) plus future measurement services and supply of CTE RMs and consultancy. New NMS facility.

Project Partners

Cofunding

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