



Scoping Workshop for Future Activities in Nuclear Power Research and Training

Date: June 15th 2009

Location: London

Background

The nuclear industry in the UK has undergone a major transformation over recent years. The Government announcement on new nuclear build has led to the potential for significant industrial growth and these opportunities are being reflected in the academic sector.

The Engineering and Physical Sciences Research Council through the Research Councils' Energy Programme is looking to encourage and support increased nuclear capacity in the academic sector through the identification of targeted activities.

Aims

- Generation of a map of UK capabilities.
- Identification of possible activities for the research councils to focus on.
- Input from the community into how to take the outputs forward.

Time and attendee constraints meant that the workshop did not attempt to define a fully accurate map of capabilities. The workshop also aimed to generate a list of possible activities and did not look to gain a consensus view on which were a priority. The aim was always to use this output as a starting point for wider community input.

Participants

A mixture of attendees were invited aimed at representing their respective organisations expertise and wider research community. Representatives from the university sector, national labs and other stakeholders were invited. A full list of delegates can be found in annex 1.

Agenda

This was a one day workshop focussed around three exercises

- Generation of a map of capabilities. Delegates were asked to summarise areas of UK capability/expertise on white A5 cards. These were then grouped to form themes which were used for group discussions in the afternoon. Blue cards were used to identify areas where organisations were looking to expand.

- Group discussions based around the themes identified above with a proforma to fill in leading to the identification of possible future activities. All the delegates were given the opportunity to comment on each proforma using post-it notes.
- Group discussions on how to take the output forward.

The raw output from each exercise is attached in annex 2-4.

Next Steps

In the interests of publishing the outputs of the workshop as soon as possible the following are a very quick summary of next steps. More detailed next steps (e.g. more detail on advisory group membership, more detailed timescales) will be incorporated as this document develops

- The outputs of this workshop will be published on the EPSRC web pages for comment by both attendees and the wider community. The opportunity to add too/comment on the workshop outputs will be highlighted to the wider community.
- Comments from the wider community will be incorporated into the text.
- Output will be prioritised using an advisory group (still in the process of being set-up) with a call / calls being identified by October 2009
- A separate small group will be set up to discuss the role of responsive mode in nuclear power.

Annex 1: Attendees – attendees were randomly assigned a table to sit at.
 Future Activities in Nuclear Power Research and Training Scoping Workshop

Surname	First name	Table
Abram	Tim	1
Ainsworth	Bob	7
Angeli	Panagiota	5
Beumont	Heather	2
Boston	Andy	4
Bouchard	John	3
Boxall	Colin	6
Burnell	Gary	1
Chegwin	Ray	6
Cywinski	Bob	4
Davie	Colin	7
Eaton	Matthew	1
Edwards	Michael	3
Eldridge	John	7
Evans	Nick	1
Fairhall	Graham	1
Fairweather	Michael	2
Farnan	Ian	2
Goldsworth	Aidan	7
Grimes	Robin	7
Grovenor	Chris	2
Harwood	Laurence	3
Heath	William	2
Holliman	Peter	3
Howarth	Paul	3
Howe	Joseph	1
Hyatt	Neil	4
Jackman	Richard	6
Joyce	Malcolm	5
Kaiser	Ralf	6
Lee	Bill	4
Livens	Francis	3

Surname	First name	Table
Lueders	Martin	6
Lunn	Rebecca	6
Macaskie	Lynne	4
May	John	2
McGuire	Michael	1
Mitchell	Rob	3
Morilhat	Patrick	7
Morris	Darrell	2
Mount	Andrew	4
Newby	Martin	7
Nuttal	William	4
Pimblott	Simon	6
Reeks	Michael	7
Regan	Patrick	1
Richardson	Ian	3
Ross	Keith	5
Scruby	Chris	5
Sharples	John	1
Shaw	Richard	5
Sherry	Andrew	5
Smith	David	6
Smith	Roger	5
Storey	Peter	5
Sugden	Mike	
Turnock	Stephen	3
Van-Duysen	Jean-Claude	4
Vazquez	Diego	6
Walker	Simon	5
Walsgrove	Steven	
Wang	Bin	7
Willey	Neil	2
Williams	Clive	2
Wren	Graham	4

Annex 2: Generation of a map of capabilities.

Delegates were asked to summarise areas of UK capability/expertise on white A5 cards. These were then grouped to form themes which were used for group discussions in the afternoon. Blue cards were used to identify areas where organisations were looking to expand.

The themes were very roughly done, cards could easily have gone into different theme areas. We did not worry too much about this as the most important aspect was to generate the cards themselves and roughly identify themes for the afternoon.

Re-Processing

- Actinide science (separations) and waste behaviour – Graham Fairhall NNL
- Nuclear fuel cycle – D. Morris NDA
- Processes involved in reprocessing – P. Angeli UCL
- Ligands for selective D- and F- block metal speciation – Andy Mount Edinburgh
- Selective separation of spent fuel – Andy Mount Edinburgh
- Chemistry of separations fuel cycle, analysis, waste treatment – Colin Boxall Lancaster
- Specific ligands capable of extracting actinides from reprocessing waste. Specific to Chemistry, reading worldwide Leader – Laurence Harwood Reading
- Transuranic Chemistry and Geochemistry Leeds and Manchester – Francis Livens Manchester
- Structure – activity relationship studies of actinide ligating agents Reading Chemistry key UK player – Laurence Harwood Reading
- Organic synthesis and route optimisation towards actinide selective ligating agents Reading Chemistry leading European Player – Laurence Harwood Reading
- Interaction of organics with radio nuclides, experimental and modelling i.e. fundamental radio chemistry – Nick Evans Loughborough
- Liquid – liquid separations in micro channels – P. Angeli UCL
- [Future activity examination of radiation damage Si C \(Pellet fuel, fusion\) Euratom FP7 'F-Bridge'](#)
- [Liquid – liquid separations in micro channels – P Angeli](#)

Sign up Reprocessing - WE Lee, P Angeli, CB, D Morris, Neil Hyatt, Francis Livens, Laurence Harwood, Andy Mount, GAF

Civil Engineering

- Dynamic structural models and testing – John May, Colin Taylor Bristol
- Seismic analysis (structures and soils) – Colin Davie Newcastle

Training

- High level skills (\geq PhD) NTEC, Nuclear EngD, Fission DTC (Better than 10 years ago but still small) – Francis Livens Manchester
- Nuclear training → DTC → MSC → Simulation Centre Sheffield, Liverpool, Manchester, Surrey, Birmingham, Strathclyde – A Boston
- Training of post – graduate manpower in health physics and radiation protection – MSc Course provision with high level radiation labs (at Surrey University) – Paddy Regan
- Training framework for measurement best practise – Ray Chegwin NPL
- Teaching experimental radio chemistry to undergraduates MSc PhD – Nick Evans Loughborough University
- Nuclear Fission DTC Manchester/Sheffield – Neil Hyatt Sheffield
- Training validation of MSc/Pg Dip/PhDs links to Naval nuclear programme – Michael Edwards Cranfield
- Training esp MSc, PhD → new SUPA MSc Course – R Kaiser Glasgow/SUPA
- Training physics of strong correlation is not part of normal curriculum Need for special training courses STFC (Hartree Centre) CECAM Psi-k - M Lueders
- Already have ~900 qualified engineers with nuclear experience and demand for more year on year future – Aidan Goldsworth Rolls-Royce
- Training MSc in safety and reliability engineering (15 years) 300+ graduates and PhD's - Aberdeen University
- Undergraduate MEng (now) and MSc course (2010) in nuclear engineering – Imperial
- Appointment in Low Carbon Research Institute (LCRI) Welsh Assembly supported. New work based learning MSc in decommissioning - Bangor University
- SUPA MSc in Nuclear technology (Glasgow, Strathclyde, UWS, SUERC, 2010)

Sign up for training PHR, JE, AJB, BW, RK, Martin Luorder, Francis Livens, M Edwards

Fuels and Reactor Systems

- Accelerator driven systems and transmutation. ThorEA grant 4 simulations cross section measurements - R Kaiser
- High T reactors for H2 production – P Angeli
- Fuel behaviour for long term storage and fuel in accidental situation – Peter Story HSE
- Future Systems ~2030s Cores, fuel cycles, fusion synergies, business and policy issues, process heat applications – WJ Nuttall Cambridge
- Uncertainty and nuclear data – Matt Eaton (Imperial)
- Better understanding of fuel performance, physical processes, that contributes to the development of next generation fuel performance codes for generators (Universities working directly with stakeholders) to make sure we are in the right place in a generations time – Robin Grimes

- Helium Resource modelling (future price and availability) → “Hydrogen cryomagnetics” Liquid hydrogen production and use – Bill Nuttall Cambridge
- Reactor thermal hydraulics and transient analysis – H Beaumont AMEC
- Accelerator driven thorium system (Core design + fuel and business issues)-Bill Nuttall Cambridge
- Aberdeen University Thermal Hydraulics (cooling/temperature/CFD)
- Fission/Fusion communities starting to work together in UK on similar problems – Grovenor (oxford)
- Reactor physics methods (advances reactors) Generation IV – H Beaumont AMEC
- Nuclear Thermal hydraulics/fault studies/reactor engineering/interaction with structural mechanism fuel behaviour (Imperial and Elsewhere) – Simon Walker Imperial
- Reactor physics and radiation transport – Matt Eaton Imperial
- Thermal hydraulics and heat transfer in fault condition develop numerical techniques – Peter Storey HSE
- Nuclear fuel technology, manufacture, properties and characterisation, in-reactor performance modelling – Tim Abram Manchester
- Neutron scattering techniques – active samples (ND) – Defect dynamics (Graphite) – solid state diffusion (T) – Keith Rolls Salford
- Use of reactor physics and fuel cycle modelling codes (for GEN II → GEN IV) PJA Howarth
- [Advanced accelerator technology for driving accelerator driven subcritical systems or energy amplifiers \(linked to facilities\)](#) Cywinski (Thorea) Huddersfield/Manchester

Sign up fuels and reactors Keith Ross, Ian Farnam, Tim Abram, John Eldridge, Neil Hyatt, Heather Beaumont, Aidan Goldsworth, R Kaiser, Matt Eaton, Cywinski, M Pollington, Robin Grimes, W Nuttall, R Smith

Structural Integrity

- Materials Understanding – PWR – EAC – SCC – Fracture – Irradiation damage – residual stress – Rob Mitchell R-R
- Advanced materials – modelling – test – characterisation – Ray Chegwin NPL
- More reliable accurate defect characterisation. Capabilities now available to quantify defect indicators for SI calculations – in UK universities e.g. Bristol and Imperial – Chris Scruby (RCNDE)
- Fracture mechanics and structural integrity Glasgow and Strathclyde Universities Working with Rolls-Royce and British Energy – Graham Wren
- NDE Techniques and Inspection qualification (Qualifying equipment and personnel) – J Sharples SERCO
- Structural health monitoring. Capabilities available but not fully developed in RCNDE Universities – Chris Scruby (RCNDE)
- Modelling and simulation – JC Van Duysen
- Materials Science from Nano (Measurement and Data, Liverpool, Surrey, Glasgow, Manchester) → Micro (Engineers Sheffield,

Imperial, Manchester, Leeds)→ Macro (advanced processing AFRC, Strathclyde)

- Structural Integrity of Nuclear systems and their life extension including waste containment. Many integrated programmes for civil and defence systems in UK involving Imperial/Bristol/Manchester/OU – David Smith Bristol
- Detection of precursors of crack growth. Capability currently under research in UK Universities – Nottingham, Imperial et al – Chris Scruby (RCNDE)
- NDE – JC Van Duyson
- PWR Fleet to support for next 35 years in UK (without considering nuclear new build) – Aidan Goldsmith Rolls-Royce
- Simulation and Measurement of Radiation damage → Effect on material Properties – Ian Farnan Cambridge
- Materials properties: tribology residual stress measurement (high UK level of expertise; track record if application to nuclear) Structural integrity assessment – Mike Fitzpatrick OU
- Advanced Tribology (nCATS) - materials technology, sensor systems for conditioning monitoring – corrosion/degradation – nano materials – metallurgy – Stephen Turnock Southampton
- Environmentally assisted cracking – plant lifetimes – Farnan(for Mat Sci) Cambridge
- Structural Integrity assessment (Creep fracture) Strong UK technical area across industry and academia – Bob Ainsworth British Energy
- Assessment if Materials properties and behaviour under in – service conditions (but not irradiation) (high T, creep, corrosion, scc) – Mike Fitzpatrick OU
- Property – structure relationships in Nuclear graphite (effects of radiation and weight loss on fracture mechanisms) – Mile McGuire Hull
- Material behaviour testing and modelling (under complex loading conditions) Relatively small number of Univs – T Hyde
- Predicting the long term behaviour of nuclear reactor materials for new designs of reactors being built in UK. Looking out towards operational life times of 60 to 100 years. Understanding phenomena and building new predictive models is a role for univs – Peter Storey ND HSE
- Development of an “effective” understanding of radiation damage processes in materials (a number of universities) * effective → useful to the development of new materials – Robin Grimes
- Materials (steels, structural integrity) National – Michael Edwards Cranfield
- Structural Integrity assessment – Mike Fitzpatrick OU
- Material engineering - Fracture mechanics – material behaviour – EDF P. Mor: LHAT
- Process modelling relatively restricted in relation to nuclear (we are good at this Nottingham) – T Hyde
- Fracture mechanics in metallic structures (development of defect assessment procedures) – J Sharples SERCO
- Aberdeen University structural integrity (reliability based analysis on fracture and fatigue, structures) – Bin Wang

- Whole – core structural modelling in relation to safety cases for magnox and AGR reactors – Mike McGuire Hull
- Structural integrity (we are good at this Nottingham). Generally strong in some areas but restricted in others – Tom Hyde
- Centre for ultrasonic engineering (CUE) Analytical and numerical modelling, signal and image processing, advanced sensor mfg, miniature robotic systems for inspection of nuclear plant – Graham Wren
- Corrosion in PWR environment (stress corrosion cracking and corrosion/fatigue) – J Sharples – SERCO
- Design and structural integrity of New Build System – including new welding technology – in-situ instrumentation – David Smith Bristol
- Nuclear Graphite – characterisation – modelling – waste management – Tim Abram Manchester
- Radiation effect on Materials – S Pimblott Manchester
- UK seems to have much strength in materials science/materials performance – Francis Livens Manchester
- Materials performance (irradiation embrittlement, aging) Weakening area of technical expertise in the UK from a former position of strength – Bob Ainsworth British Energy
- [OU investing in facility for characterization of nuclear structural materials \(high – T, residual stress\) New staff, students etc – Mike Fitzpatrick OU](#)
- [Small cluster and defect migration calculations in alloys \(part of EU perform project – Loughborough](#)

Sign up structural integrity MEF CTD Rob Mitchell, John Sharples, MAM, SM Pimblott, Robin Grimes, Neil Hyatt, Chris Scruby, Bob Ainsworth, Andrew Sherry, David Smith (Bristol) SRT, PM, Gary Burnell, BW, M Luedars, C Grovenor, Roy Smith, T Hyde, Ray Chegwin (NPL)

Facilities

- R&D user facilities – Active Labs Pu and high active – Graham Fairhall NNL
- Fully licensed radio chemistry lab – fully refurbished this summer – Loughborough
- Development of active research using specialist facilities and radio active materials – PJA Howarth
- Neutron scattering, radiography and tomography studies of materials – ILL/ISIS Facilities Huddersfield Cywinski
- Oxford hosts the most complete micro structure assessment capability in UK (Europe) – Grovenor (oxford)
- Strong University links and cross – corporate fertilisation – Rob Mitchell R-R
- UK Universities have excellent established collaboration in Nuclear – Grovenor (Oxford)
- Materials R&D capability – one of largest in UK – G Burnell AWE
- Sellafield Ltd Centres of excellence on metallic fuel behaviour underpinning processing operations until 2016 – John Eldridge

- Sellafield Ltd 60 yr history of delivering large/active/unique plants for processing nuclear materials. Strong in process/civils/stakeholder engagement – John Eldridge
- Sellafield Ltd. Nuclear site licence. Membership of world association of Nuclear Operators (WANO) – John Eldridge
- Comprehensive suite of Ionising Radiation Facilities: Radioactivity, Radiation Dosimetry, Neutrons – Ray Chegwin NPL
- Measurement Infrastructure for: - Environment monitoring – Nuclear decommissioning – Ray Chegwin NPL
- AGR boiler rig
- DCF – Radiation Science facility – Academic access to hot cells – Engineering decommissioning (NDA, UoM, NNL)– Andrew Sherry Dalton Cumbrian Facility
- Irradiation Effects (New Co60 source just bought) – Michael Edwards Cranfield University
- MPC – Materials Performance Centre – Andrew Sherry
- Heavy ion irradiation, i.e. H⁺, D⁺, 4HE²⁺ - γ irradiator – in situ irradiation – wet labs – UHV surface irradiation
- Need for larger scale testing of structural components – David Smith Bristol
- Manufacturing capability/capacity
- ATR?

Sign up Facilities SM Pimblott, JE, SW, Neil Hyatt, GAF. Andrew Sherry, Cywinski, W Nuttall, Ray Chegwin NPL

Instrumentation and Control

- Development of (sensor) systems for (in – line) nuclear monitoring/reprocessing – Andy Mount Edinburgh, Edinburgh Expertise
- Control systems – William Heath Manchester Electrical Engineering
- Radiation Detection Detector design, GBANT4 simulations – R Kaiser
- Electrical Engineering – Power electronics – systems engineering – (monitoring etc) Swansea University and Bangor University Electronics Engineering – Peter Holliman Bangor University
- Radiation Detection & (Chemical) Analytical science – Chris Boxall Lancaster University
- Sensor and activator devices/systems – Andy Mount Edinburgh
- Reactor control and optimisation – Farnan (for G Parks) Cambridge
- Development of Novel ligands sensors for selective. Speciation detection of uranium and other fission products/materials – Andy Mount Edinburgh
- X-Section measurement (Nuclear Data) Interest @ Liverpool, Surrey, Glasgow, Manchester – A Boston
- Validation and development of instruments and sensors (including software) – Ray Chegwin NPL
- Instrumentation and control – Sensor technology – Optical – Chemical. Image Processing – Cracking surface monitoring. – Control mechanical analogues centre for systems and modelling – M Newby City University
- In – process monitoring and in situ characterisation – Leeds

- British Energy Advanced Diagnostics Centre. Hosted @ Strathclyde University supporting all BE Plant – Graham Wren
- Low – background radioactivity assay and measurement assessment of nuclear (gamma – ray and electron) data. Expertise in Gamma – ray spectrometry. – Paddy Regan
- Robotics/remote sensing – Mike Reeks Newcastle
- Power systems – Operation – scheduling – control – William Heath Manchester Electrical Engineering
- In situ characterisation – Malcolm Joyce Lancaster
- Safety systems (e.g. protection systems), design and assurance and licensing (life extension. New build) (particularly digital systems) Bristol has >10years experience, British energy, NII, Quite a few other groups in the UK but not necessary nuclear sector – John May Bristol
- Electronics Interconnection – Modelling – testing – development – life cycle testing of new solders – Ray Chegwin NPL
- Automatic and control systems for reactor safety Sheffield and elsewhere – Neil Hyatt Sheffield
- Nuclear measurement – Instrumentation – sensors BE – advance diagnostics centre – Automatic control systems for reactor safety (design and simulation) – Graham Wren
- Condition monitoring – of materials – of control systems – of processes - imaging technology – William Heath Manchester Electrical Engineering
- Instrumentation and control – modern IT integration – wireless solutions – software dependability – safety critical software – P Morchaf EDF
- Nuclear instrumental development γ , n, B – A Boston Consortium of UK universities Liverpool, Manchester, Surrey, Glasgow
- Operational control – Formal software (verifiable) – control room team operations (- reactor physics and fuel cycle codes) – Stephen Turnock Southampton
- Nuclear spectroscopy and characterisation through measurement and metrology. Identification of new nuclear species and their decay properties (e.g. at GSI/FAIR facility – Germany) – Paddy Regan

Sign up Instrumentation and Control PHR, JM, PM, MF, RK, WPH, GW, ARU, MJJ, AJB, MJN, SRT, Aidan Goldsworth, CB. Ray Chegwin NPL

Process Modelling

- Whole process and individual unit design and optimisation - UCL and others P.Angeli
- Two phase flow in microunits. P Angeli
- Multiphase processes – separations, intensified units and modelling (particularly intensification) - UCL and others P.Angeli
- Co-ordination of UK monitoring and characterisation (including process and in situ)
- High performance computing and simulations (modelling etc) - Mark Pollington AWE
- Thermal/Fluid conductivity in Ground (soil and rock) – Colin Davies Newcastle

- GSE Nuclear Simulation centres – Hosted @ Strathclyde University, supporting industry Rolls-Royce, BE etc - Graham Wren
- Computational Fluid Dynamics - Modelling of complex multi-phase flows
– Tim Abram Manchester
- Thermodynamics Modelling and Provision of 'Valid' Data to support modelling – Ray Chegwin, NPL

Homeland Security and Non-Proliferation

- Civil links to Nuclear Weapon Technology , Non-Proliferation and Homeland Security – Mark Pollington AWE

Sign up Homeland Security – MAP, Neil Hyatt, MJJ

Environmental Issues and Energy Policy

- Interaction of Radionuclides with the Geosphere – Nick Evans Loughborough Uni
- Nuclear Power in Liberalised Energy Markets – WJ Nuttall – Cambridge
- Best Available Techniques for minimising radioactive and chemical discharges to the environment - Clive Williams Environment Agency
- Environment Conditions Modelling - Impact of plant on water, air, soil - Impact of the environment on the plant (weather forecast, flooding..) - Dry cooling. P Morilhar EDF
- Nuclear Governance and Regulation - Stakeholder engagement, Land Use Planning, Socio-Economic, Corporate Responsibility. Howe, UCLAN
- [Corporate Social Responsibility in Nuclear Industry and Research – Brass Cardiff](#)

Sign up Environmental Issues - LEM, PM, Joe Howe, WJN, Diego Vazquez, Clive Williams

Decommissioning

- Robotics for decommissioning – Lancaster University
- Analytical Radiochemistry – Nick Evans Loughborough
- Laser cutting and scabbling - Pipes, Concrete (technology demo project – TWI). D Morris NDA

Sign up Decommissioning – D Morris, MJJ

Corrosion Chemistry

- New sensors to measure water chemistry – Ray Chegwin NPL
- Corrosion within PWRs – range of corrosion species. Need to develop facilities eg for fuel oxidation. Also need to look at PWR decontamination issues – Peter Stoney – HSE
- CO₂ oxidation in AGRs
- Corrosion – (Reactor Coolant circuit chemistry) – Mike Reeks

- Corrosion Chemistry - Swansea University Materials Engineering School (centre for Steel Technology) – Peter Holliman, Bangor Uni
- Radiation Chemistry of Reactors and Waste - S. Pimblott Man Univ
- [Behaviour of Conditioned Waste \(LLW→ HLW\) under surface storage for 100+ years incl packaging design/materials/monitoring](#) JE
- [Long Term Behaviour of Spent Nuclear Fuel – \(Matnox/AGR/LWR/Others\) in Interim Stores](#) JE

Materials Modelling

- Nuclear Graphite Technology - Material properties in design of new reactors - decontamination and re-use. Peter Storey – HSE
- Multi-scale material behaviour modelling – T Hyde
- Models for main binding phase in hardened cements Leeds, Aberdeen – Ian Richardson – Uni of Leeds
- Modelling - Ion diffusion in glasses - Synchrotron studies of surface hydration of actinide glasses - Chemistry at Bangor Uni Materials Physics at Aberystwyth Uni - Centre for Advanced Functional Materials. Peter Holliman –Bangor Uni
- Multi-scale modelling - High level simulation require information from microscopic simulations – M Lueders
- Advanced Forming Research Centre – hosted @ Strathclyde University sponsored by: SE, SG, EPSRC Boeing, Rolls-Royce, Mettis GKN and others (9 total) – Graham Wren
- Microscopic Materials Modelling including f-electron systems “f-electron challenge” (no generally accepted ab initio methods for f-electron systems yet) Expertise in STFC – Martin Lueders
- In situ electron Microscopy and Implantation for validating radiation during modelling – Keith Ross Salford
- Coupled Multiscale, Multiphysics Modelling of Nuclear Systems – Matt Eaton Imperial
- High Level Modelling and Analysis Capability and High Performance Computing Computing Capability – G Burnell AWE
- HTM (Hygro Thermo Mechanical) Modelling of Concrete (Porous Media) (Ageing) – Colin Davie Newcastle
- Materials Theory and Simulation (UK strength esp. London/Oxbridge) – Bill Lee
- Multi-scale Modelling of Materials Supported by Measurement (UK-wide) R. Smith Loughborough
- [Development of Modelling Approaches that Engage with Industry Needs – many universities!](#)

Risk Assessment and Safety

- PWR – Design, Support and Justification – extensive experience – Rob Mitchell, R-R
- Systems Engineering (Large complex dangerous stuff) (human factors) – Michael Edward Cranfield
- Nuclear Safety – severe accidents – source term analysis (Fission product and nuclear aerosols) transport – Mike Reeks – Newcastle
- Human factors
- Quantitative risk and Reliability – Loughborough

- Probabilistic Safety analysis – level 1-3. H. Beaumont – AMEC
- Software C&I – Diversity in PRA, PSA, software. Centre for software reliability, City University (M. Newby) – Robin Bloomfield CSR
- Programmable Components, Assurance of, Licensing software reliability theoretical – John May (Bristol)
- Context of Nuclear Power – Proliferation, Regulation - Stephen Tumock – University of Southampton
- Nuclear Risk – Perception, Communication, Management, Appraisal – Howe, UCLAN
- Aberdeen Uni: Safety of Structures/System under IMPACT loading, R3 (pipewhip, energy absorption, Design Safety of Nuclear Power stations), Human factors, reliability - Bin Wand - Aberdeen
- Safety Systems Research - Interaction of many operating systems in Nuclear Power Plant. John May, David Smith – Bristol
- [Innovation and sustainability - Scenarios / pathways - Climate change and fast breeder reactors systems - Triplex Helix Governance - Risk and Uncertainty. D. Vaggez](#)

Waste

- Geomicrobial Solutions for Ground Sealing and Immobilisation of Radionuclides into Solid Phase Across UK (already funded)
- Chemical and Microbial Solutions for Remediation of Radionuclide Contaminated Sites (eg reactive barriers) – across UK
- Chemistry of collocation of HLW and ILW – Across UK
- UK Centre for Structural Ceramics (Wastes and Fuels) – Bill Lee
- Waste Management and Decommissioning and Associated disciplines (criticality, health physics, containers etc) – G Burnell AWE
- Waste Measurement and Characterisation – also, provision of reference materials - Ray Chegwin, NPL
- Decommissioning and Waste – M Pollington AWE
- Gas/Fluid Migration Through Low Permeability Geological Materials – BGS Richard Shaw
- Fuel Manufacturing and Waste Processing (particle flows) – Leeds
- Waste Disposal – soil science – Stephen Turnock Uni of Southampton
- Ion Exchange from aqueous solutions (Zeolites etc) (R.C. disposal licences) – Keith Ross/Salford
- Behaviour of Metals in GDF. – Universities Research Cos, Research Institutes – Richard Shaw
- Waste Form – Concrete, Ceramic, Polymer, Glass - D Morris – NDA
- Biochemical, Chemical and Radiation Stability of Nuclear Wastes and Nuclear Wasteforms – S Pimblott – Across UK
- Micro and Nano-structural Characterisation of cement-based materials used in ILW wasteforms – Leeds, Aberdeen, Sheffield – Ian Richardson – University of Leeds
- Characterising Spatial and Temporal Geosphere Evolution (Microbial/Chemical/Mechanical/Hydrogeological) for Radioactive Waste Disposal – Strathclyde/Glasgow

- Different conditioning options for 'challenging' intermediate level wastes – Clive Williams, Environment Agency
- Effect of organics in the GDF – Nick Evans Loughborough
- Waste Characterisation, Encapsulation/Immobilisation and Sentencing Route – Howarth
- Nanotechnology (Need to apply to Nuclear field) eg Monitoring sensors/in GDF – Bill Lee
- Improving confidence that conditioned/packaged radioactive wastes will be suitable for eventual disposal – Clive Williams, Environment Agency
- Mobility of radionuclides in geological environments – various universities BGS
- Materials (Waste) (ceramics and metallurgy). Decommissioning (encapsulation/lifetime/corrosion), Modelling, High T materials science (physics, chemistry, engineering) and power gen materials – Dr Peter Helliman – Bangor Uni
- Design of waste forms tailored for specific waste streams or types (a number of universities working with targeted stakeholders) * includes performance related to waste type – Robin Grimes
- Waste Immobilisation and Waste Management → Disposal - Graham Fairhall NNL
- Hazards reduction and passive safety for nuclear waste. Specifically waste forms and chemistry of immobilisation – Peter Storey HSE
- Encapsulation of Wastes – Leeds
- Waste treatment and nuclide retardation treatment of mixed and complex wastes UK plc. – L Macaskie
- Subjective risk in relation to nuclear waste management, particularly graphite – Mike McGuire Hull
- Encapsulation via Biominerals and waste stabilisation – Univ Birmingham and Uni Manchester L Macaskie
- Modelling Radionuclide Transport from Experimental Studies – Fundamental Radiochemistry – Loughborough University Nick Evans
- Materials engineering for waste and future fuels – Sheffield, Imperial, Leeds, Manchester – Neil Hyatt, Sheffield
- Oxford investing in new posts in nuclear materials and actinide Chemistry
- New Chair in Radioactive Waste Management at Sheffield, Eng, Mats – Neil Hyatt, Sheffield
- Structural Integrity of Waste disposal systems – David Smith Bristol
- Geomicrobiology Lab Facility and Expertise - Geo-environmental Labs (sem, min/PET, Geochemistry, ETC) and expertise – Richard Shaw
- Transport Properties Research laboratory (low perm geol. Materials). Geomechanical facility (being upgraded over next 2 years) – Richard Shaw
- Forge – (EU FP7 project) 2/2009 →4/2013. Gas generation and migration in context of radwaste GDF (source →EDZ → Near field → Far field 24 partners, 12 EU countries 12M euro (6M from EU) – Richard Shaw

(Sign up Waste) MF, D Morris, MAM, RPS, LEM, SMP, Neil Hyatt, IF, WE Lee, RJL, FRL, AF, NE, IGR, CTD, David Smith, Laurence Harwood, Gary Burrell, PH, Clive Williams

Life Cycle Assessment

- Environmental methods – life cycle analysis, sustainability appraisal, carbon accounting, sustainable procurement, waste + facilities management. Howe UCLAN
- “Systems” engineering – performance management, integrating hard and soft systems (human factors, predictive management), training (DTC). John May Bristol.
- Design under uncertainty. P Angeli UCL
- Applications (new?) commercial shipping, design process, full ship life fuelling, operational ports/safety. Stephen Turnock University of Southampton.
- Sustainability – life cycle analysis, carbon counting, environmental / geochem, raw materials usage (e.g. water). Welsh institute for sustainability and environment (WISE). Peter Holliman Bangor Uni.
- New build capability policy – overview – DECC
- Efficient design and operation of entire fuel cycle (manufacture – use – disposal) incorporating best available techniques to minimise waste arisings / discharges.
- Thorium as an alternative nuclear fuel. Cywinski Huddersfield, Manchester, Cambridge (THOREA)
- Managing Uncertainty. Project life cycle optimization – concept design make use disposal. Stochastic modelling e.g. crack growth maintenance inspection. Martin Newby – City university + others Loughborough, Strathclyde, Manchester.
- Life cycle assessment on nuclear supply chain (Impacts/benefits/resilience) stakeholders management – innovation failure. Sustainability. BRASS Cardiff Uni, business research accountability, sustainability and society. Diego Vazquez
- Uranium + thorium as a future strategic resource (we don't have natural UK reserves). EU recovery from disused mine run offs. L Macaskie.
- Graphite materials properties. Narrow technical area with limited expertise at selected universities. Bob Ainsworth BE.
- Capacity for new build – are there enough “build” companies to satisfy imminent global, demand? L Macaskie.
- Uranium mining and social conflict. Perceptions of risk, new technologies, governance, impacts on supply resilience. D Vasquez
- Resurrect the fast breeder programme? Waste Pu – new fuel. L Macaskie.

Annex 3: Group discussions based around the themes.

Proforma were provided to fill in leading to the identification of possible future activities. All the delegates were given the opportunity to comment on each proforma using post-it notes.

Sub theme name:
Materials Modelling

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Develop models which represent materials behaviour under operating conditions throughout life and post life (and accident)

Strengths

Large community that develop and apply codes that predict materials behaviour

Weaknesses

- Much of the this is not on nuclear materials
- Codes not always taken up by industry

Opportunities

- To re-engage many in the modelling community with nuclear problems.
- Strengthen the links between modelling over different length and time scales.

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Develop mathematical models and carry out simulation of nuclear related materials issues, i.e. radiation damage, IASCC, TMF, strain ageing radiation enhanced creep etc
- Model calibration

Post – it Materials modelling is intimately linked to structural integrity – importance of detail of model against required outcomes (David Smith Bristol)

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Research of this type is not effective if carried out in isolation

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Materials modelling is the best way to improve safety and maximising operational life and reducing cost of nuclear research. Other sources of funding (e.g. STFC computational infra..) exist

Lead Contact/s: T Hyde, J Sharples, R Grimes

Sub theme name:
Mechanics of structural integrity

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Assessment of structural components with defects under extreme and degrading operational conditions

Strengths

Historically world leading industry led, research capability in academia. Recent re-investment via MOD. Stronger academic nuclear community through NPCT and KNOO. Outputs are application relevant, Towers of strength in narrow topics

Weaknesses

Loosing the leading edge due to lack of investment, ageing workforce and closure of national facilities. Insufficient linkage between technical areas. Lack of broad capability . Loss of training capability

Opportunities

- Scope of interdisciplinary activities – mechanics materials, NDE Modelling
- Centres of excellence working together to provide solutions to generic problems
- Expertise of current systems (AGR,PWR) transferable to future systems

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Use capability generated under NPCT and KNOO as a basis for a collaborative programme
- Holistic analysis req'd to ensure parts of jigsaw fit together and most appropriate research groups included

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Responsive mode too fragmented need added value of community and critical mass

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

If intended to be >20% generation from nuclear research budget should reflect this. Need/explore collaborative funding models e.g. TSB

Lead Contact/s: David Smith, Mike Fitzpatrick, Tom Hyde, John Sharples. Chris Scruby, Bin Wang

Sub theme name:
New Build Reactor Systems

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Fault studies, Core Analysis, Experiments and Modelling

Strengths

- International vendors purported off the shelf solutions
- UK strong capability in core analysis & thermal hydraulics
- Some (few) strong university groups

Weaknesses

- Fault studies – perceived weaknesses/lack of people
- Nuclear data expertise in academia now weak
- Thermal hydraulic and core analysis strong, but not long – term secure

Opportunities

- Resurgence in light water reactor build/design requires supporting/complementary research activity/capability generation – cannot run/support/licence a new LWR fleet without
- Applicable also to future systems
- Reactor design – the ultimate multi – disciplinary area

Post – its Resurrect breeder programme

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Generic fault study method development and study of underlying phenomena
- Core analysis methods
- “Passive” and “simplification” the big themes/novel ties. This needs fostering (e.g. natural forces, ‘natural circulation flows, modelling and experiments)
- Methods – ‘best estimate plus uncertainty’ and improved data
- Synergy with novel new build/reactor design programme

Post – its UK Industry, supply chain, design community and trainers/educators would benefit from a MTR G Wren

Storage/Disposal new build wastes WEL

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- Capability building is at the core
- Large, coherent, balanced programme needed in such a big area
- Sustainability of skills in the area

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

- Highly technical industry base to collaborate with (serco, RB, AMEC, BE/EDF...)
- Regulator sees skills/analysis shortage as an issue
- Need to foster UK expertise: (we risked not even being an ‘intelligent customer’ as things were going)

Lead Contact/s: **Simon Walker Imperial Matt Eaton Imperial**

Sub theme name:
Process Engineering

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*

Strengths

- Broad range chemical/process skills across UK
- CFD, heat transfer, multi scale modelling, fluids, multi phase flows, modelling and optimisation

Weaknesses

- Lack co-ordination on nuclear activities
- Lack active/large scale facilities (or access to them)
- Lack of application to nuclear

Opportunities

Across fuel life cycle (Manufacturing, performance/optimisation, in-reactor process, separation, reprocessing, conditioning, disposal, environmental interactions)

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Integrated approach across life cycle of fuel (i.e. fuel design for efficient reprocessing/disposal)
- KT from non-nuclear research/network activity

Post – its Not certain where this should fit? The UK is struggling to deliver new nuclear facilities, Examples at Sellafield find lead times increasing. Example EPS2 store 6 years (???) 1996) and EPS store (almost identical) 7½ years (2012) Complex plants now considered 10years! Unsustainable situation should be investigating/incorporating alternative planning/funding/ongoing/legislation to ensure plant delivered in a timely manner JE

Many of these issues can be applied to mechanical engineering. It is the poor performance or mechanical plant that dictate the success/availability of the nuclear processing plants. So important that all disciplines are integrated (linked with training)

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Lack of current co-ordination on nuclear, isolation of current relevant (nuclear and non-nuclear) activities, need to integrate experiment/modelling, significant added value from across life-cycle activities

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Needs to be linked to active/large scale facilities e.g. NNL, DECC etc. Links to EC US Japan need to be fostered, plus OECD/NEA

Lead Contact/s:

Sub theme name:
Reprocessing (Separations)

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Recycle options for future - programmes

Strengths

- History of reprocessing metallic and oxide fuel
- R&D under pinning current flow sheets and advanced cycles
- Liquid/liquid separation (general chemical capability)
- Synthesis on new ligands/extraction
- Track record on pyro processes (inc molten salts)

Weaknesses

- Lack of policy commitment
- Lack of active testing facilities
- Stakeholder antipathy (dirty end of process links with weapons)
- Proliferation
- No rational design for current flow sheet (incls. Thorp, Vit etc)

Opportunities

- Develop pyro process
- Reduces radio toxicity burden of wastes (geological repository)
- Offers long term sustainability
- Reduce risk of proliferation (but must have be correct form of separation)
- Opportunity for treating orphan wastes and exotic fuels
- Link advances in computational and theoretical chemistry to understanding structure activity relationships
- Can apply these opportunities to dealing with waste (spin off)
- Potential non nuclear opportunity

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Closing the fuel cycle
- Supporting and under pinning of current separation platforms and development of future platforms
- Investment in active facilities
- Integration across disciplines theoretical studies/chemistry/chemical engineering
- Prepare robust (broad base) operational envelope
- Underpin future UK policy

Post – its Focus: Radiation chemistry of reprocessing systems

Nuclear data on going measurement programme needed spectrometry of minor actinides and activation/fission products Regan

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- Issue is considered to big for single group. Require consortium should include process engineering (consider integration with existing systems)
- UK does not currently have the community (has individual bits)

Post –it Consortium bids need clear criteria to ensure targets are met. Thus include all areas of required expertise (directed research) This will maximise ltd funds

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

- Requirement for large scale facility / supporting infrasture
- Must align with EU* (and US) programmes *Lead EU agenda

Lead Contact/s: **Graham Fairhall, Lawrence Harwood, Andrew Mount, Francis Livens, Angeli Panagioa, Colin Boxall**

Sub theme name:
Risk Assessment and Safety Management

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Understanding Nuclear Risk

Strengths

- New statistical models
- Risk management and communication (Relevant communities)

Post - it Formal software methods – provable performance Interaction with human-in-loop control

Weaknesses

- Lack of evidence in some areas. V. rare events
- Engineers lack probabilistic view – skills vulnerability
- Long term prediction
- How to accelerate tests?

Opportunities

- Application of 'Systems' engineering (Success in other sectors)
- Engagement with government and other communities DECC, DCLG, DEFRA, EA
- Risk-aware design – sustainable procurement

Post – it Subject risk and public attitudes to nuclear issues

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Assurance of programmable systems
- Replace obsolescence
- Risk Management strategies and design of systems to achieve this
- Not just engineering systems – wider 'systems' concerns including people.
- Statistics of extreme value events

Post-it Risk assessment and management should have a supply-chain approach and involve stakeholders perceptions of risk/risk tolerance standards/systems resilience and robustness

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

'Systems' – very cross disciplinary (does responsive mode work here?)
Critical industry need for this skill base

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Lead Contact/s: J Howe

Sub theme name:
Risk Assessment and Safety Management

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Facilities, Reactors and Repositories (New build and future systems and existing)

Strengths

- Good experience of current systems with applicability to new build
- Expertise in multiscale multiphysic modelling
- Structures and materials operational safety

Post – It Expertise exists in aerospace materials risk assessment

Weaknesses

- Not integrated into international programs
- Applicability to future systems (lack of knowledge/skills)
- Small scale academic participation (no co-ordination network)

Opportunities

- Building a core expertise and capability
 - Access to international databases of experiments
 - Improved computational methods and phenomenological understanding Linkage to other industries
- Assisting with safety case for waste and new build

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Improved mechanistic approaches/fundamentally based
- Linkage to other industries
- Development of accident management strategies
- Building expertise
- Phenomenological understanding

Post-it Risks and opportunities from increasing nuclear capacity and efficiency (i.e. fast breed generators) to reduce UK's carbon emissions

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- Capability building/developing expertise
- Sustainability of skills base
- Close relationship with industry/regulator

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Renewing academic capability/learning from international best practise
BE, AMEC, NII/HSE, Rolls, NNL, SERCO, NDA

Lead Contact/s: Joe Howe, Mike Reeks, Matt Eaton, Simon Walker(Imperial)

Sub theme name:
Structural Integrity: Materials

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*

Strengths

- Training of U/G and masters level
- Strong materials academic research base
- Recent strategic investment in University facilities for materials testing and characterization (relevant to nuclear)

Weaknesses

- Access to facilities for irradiation and testing of irradiated materials
- Access to 'library' of ex-service materials
- Historically (last 15 years) low activity in nuclear materials
- Low participation in EU Programmes

Opportunities

- FIB in a hot cell for production of micro-samples
- More European collaboration
- Joint Fission/fusion materials development
- Build on recent fission – related materials research finding

*Post – its Development of new test methodologies e.g. small samples for fracture toughness – effect of constraint.
Optimisation of weld design and welding techniques to minimise residual stresses J Sharples SERCO*

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Select the best science to underpin future nuclear power generation in the UK: new build; life extension: Gen IV
- Develop the UK Research Community for its nuclear materials research
- Help to improve international collaboration and UK participation in international programmes

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- Need core teams in nuclear materials research with complementary expertise
- Nuclear research needs large teams tackling the big difficult problems

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Lead Contact/s: Chris Grovenor (Oxford); Mike Fitzpatrick (Open U) James Marrow (Manchester)

Sub theme name:
Structural integrity: Non Metals

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Ceramics, Graphite, Concrete, Polymer, Rock

Strengths

- Expertise in materials modelling of graphite and concrete and ceramics
- Development of ceramics with long term radiation resistance
- Structural modelling (civil structures, graphite core)
- Structural ceramics centre is evolving

Post it – Leverage NPL Govnmt-funded research in all these areas, when applicable

Weaknesses

- Applicability of results of mechanical tests, paucity/scatter of data
- Difficulty of multi-scale modelling (Cementitious Materials)
- Lack of understanding of concrete behaviour at higher temperatures ($>70^{\circ}$)
- Lack of real material samples

Opportunities

- Use expertise in graphite for AGR's for GEN IV
- Transfer of expertise to future reactor types
- Development of new methods to product long timescale behaviour
- Harvesting materials from decommissioning program
- Match UK expertise to produce multi – scale modelling

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Multi – scale modelling (length and time)
- Access to irradiation facilities for testing and analysis
- Linking above
- Building on fundamental understanding of material
- Treat the stochastic nature

Post it – Mechanisms of Non metals structural integrity likely to be similar to metals – cross fertilization is required. Problems of scale also similar (David Smith Bristol)

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Linking expertise in different areas to create critical mass

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Lead Contact/s: Barry Marsden (Manchester) Ray Chegwin (NPL)

Sub theme name:
The Fuel Cycle

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately. Includes – fuel management* – characterisation – in reactor performance – spent fuel management*
**includes cladding / UO₂/furniture for Fabrication/Assembly*

Strengths

- Long history of fuel cycle and fuel cycle development
- Fuel modelling (world wide reputation)
- Fuel manufacturing facilities for present fuel designs
- Spent reprocessing. Industrial scale and underpinning

Weaknesses

- Not carrying out a programme of development future types. For existing/future reactor types
 - UK limited experience on open cycle & long term storage of spent fuel (some experience with wet storage(Sellafield) dry magnox (Wylfa)
 - Current models empirically based with limited underpinning physical basis
- Post – it Fuel behaviour in Disposal conditions? FRL*

Opportunities

- Note fuel is the fundamental part of a reactor system, for existing, forthcoming future NPP's
 - Ongoing need to understand in core performance and spent fuel longevity
 - Developing the microstructure requirements and processes
 - Building on UK strengths to develop international expertise in fuel L cycle technology
- Post - it More re-use of PU waste in-process*

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Research council underpinning research that develops clarity to discover fundamental processes that underpin. For existing and advanced reactor and fuel cycles
 - fuel manufacture
 - In Core
 - Spent fuel behaviour in the long term
- Conducting research in;
 - radiation damage effects
 - Fission product behaviour in chemical thermal gradients
 - cladding behaviour
 - micro structure evolution
- Both modelling and experimental capability req'd working together

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- UK needs to rebuild strategic capability
- Require knowledge of other parts of the reactor system (Integration)

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

- Holistic endeavour that spans the entirety of the fuel cycle
- Crucial to economics of nuclear power in the UK
- Central to maintaining the UK as a world player

Lead Contact/s: Robin Grimes / Tim Abram / JE

Sub theme name:
Training

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*

Strengths

- NSAN and cogent
 - Growth in UK Universities
 - Universities adapted to part time MSC's
 - Workforce analysis exists
- Post – it Lots of RDA funding available*

Weaknesses (Immediate)

- Funding – masters level
- Coordination
- Both nuclear and non nuclear skills
- Limited capacity
- Demonstration of progress
- Eligibility of people for use in UK industry
- Access to active facilities

Opportunities

- Large market for nuclear skills (1000's)
- Upskilling re-skilling from other hazard industries
- Large market for numerate (scientists/modellers)

Post – its Require discipline training for multidisciplinary challenges and team formation.

Problems in sectors engineering of silo mentality thro' too early specialisation. Should encourage broad based post graduate training up to say charter level. Then specialise. Will require close (closer?) links academia v industry. JE

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Funding Master – URGENT
- Fund ENGD and PhD **Nuclear ENGD Fission DTC just been funded (5 years)** *Post – it Yes but insufficient*
- Building a research community for safety case development
- Fund targeted advanced fellowships
- Secondments for academics
- “Sign posting” – new build / GDF
- Coordinate masters / PLD / ENGD
- Provide access to active facilities

Post – its 1. Need to work with NSA – nuclear. 2. Simulation technology can improve and speed up training and education process Graham Wren

Undergrad sponsorship – get them early

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Do not do training in responsive mode (Very high)

Post – its Need MSc students support – joint EPSRC/STFC committee P Regans Surrey. RC split STFC/EPSRC need stewardship. With regard to EPSRC coordination, it was not possible in this time frame to coordinate the skills provision to match the existing workplace analysis. If EPSRC can coordinate this to ensure UK MSc course provision meets these needs

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Lead Contact/s:

Sub theme name:
Waste

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Managing radioactive waste safely

Strengths

- Research base in waste
- Large community of researchers outside 'nuclear' that could apply their skills

Post-it Link to NDA Agenda

Weaknesses

- Research base patchy and disjointed repetition of research since original work 'in confidence'
- Lack of access to active facilities no clear strategy for some wastes no peer-review of strategy limited coherent research community for disposal and safety case no transmutation research

See below for post – it's

Opportunities

- Declassification of previous 'in confidence' research
- One body to co-ordinate UK waste strategy
- Build on DIAMOND/carbon capture consortium
- International skills (Can we import researchers)
- Waste volume reduction
- Decay storage (short-lived wastes)
- Start long-term experiments now (>30 years to waste emplacement) *See below for Post – it's*

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Need a disposal workshop like this urgently (everything from post interim-storage awards)
- Participants from oil and gas, geophysics, rock mechanics carbon capture, microbiology, hydrogeology
- Need research to address some key issues (e.g. co-location of wastes, retrievability, new build wastes etc) characterisation of waste forms, site characterisation
- Fundamental (as opposed to 'needs driven') research (for all of the above)
- Underground research laboratory (geology specific)
- Long term aspiration for independent research access from the academic community

*Post – its Waste ≠ disposal - research into **transmutation***

Structural integrity of waste containment "systems" is NOT being addressed within academic community
David Smith (Bristol)

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Scale of need is too high for this to be sufficient

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Substantial long-term funding commitments are needed - rolling programme over decades →

Weaknesses Post – it's Lack of openness of eg Hanford

Common view that 'its all been done', but much older work of questionable quality

Low expertise in structural integrity of metallic containment

Opportunities Post – its Predict long term stability >1000 years

Or ground source heat via heat pump borehole systems

Use waste- heat to make hydrogen locally via steam turbines - store He - fuel cells

UK knows much less about HLW and spent fuel disposal than about ILW or LLW

Lead Contact/s: **Becky Lunn (Strathclyde) | Richardson (Leeds)**

Sub theme name:
[(Corrosion Chem)] Reactor and Corrosion Chem

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*

Strengths

- Gas cooled reactor chem.
- PWR autoclave work (available but limited)
- Imaging autoclave
- Industry – Academia interaction
- Wythenshaw boiler rig crevice characterisation

Weaknesses

- Aging Expertise base
- High temp, pressure CO2 Chem
- Radiation chemistry
- Radiation materials testing
- PWR autoclave capacity
- Corrosion product transport and deposition
- Corrosion mechanisms

Opportunities

- Wythenshaw boiler rig – University expansion of programme
- In – situ radiation exposed studies
- Sensors for extreme environments

Post – it Materials for long term packaging of nuclear waste fuel is increasingly important as the dates for design of the GNF become increasingly uncertain. Certain parts of the steel/fabrication section actively supporting sector players. But should be underpinned by academia

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Access to facilities - funding academics to work on (and extend) Industry facilities
- Support cross- disciplinary chem - materials – theory programs
- Infrastructure for irradiation studies and rigs (Work)
- Underground performance of materials for waste disposal
- Plant - life extension
- New materials and chemistry for next gen (Extreme cond. Performance and adaptive)

Post – it Corrosion of waste forms during storage and geological disposal over millennia WEL

Post – it Microbially accelerated corrosion?

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- To big, to complex, to expensive. Needs teams.
- Strategic area.
- Specialist facilities

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Needs to be advisory body (with teeth) to identify areas that call out for attention and identify the key teams that need support (Stewardship)

Lead Contact/s: Pimblott (Manchester)

Sub theme name:
Control and Instrumentation

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Control, sensing, monitoring and analysis

Strengths

- Ex-situ sensing and analysis software for control and protection (also analysis of)
 - Chemical/physical transducer design
 - Instrument design and build
 - In-process tomography
- Post –it Control system design*

Weaknesses

- Facilities for testing
 - In-situ monitoring
 - Open problems re: software validation
 - Radiation robustness,
 - Operation in harsh conditions
 - Radio chemical analysis
 - Industrial conservatism to innovation
- Post – it Vendors are non-UK*

Opportunities

- Assurance of programmable systems
- Sensors for harsh environments
- Remote sensing, in-situ monitoring
- Digital data acquisition for fast radiometrics
- Multi – parameter measurement; integrated systems

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Build on existing strengths to address opportunities
- Link to active facilities (NNL etc)
- Establishing validation and design scheme for safety critical software/hardware
- Sensors/systems for harsh environments

Post – its Co-ordination with international approaches

Validation of sensors /instruments using NPL facilities e.g. Neutrons, radioactive etc

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- No current motivation (Needs KT from non-nuclear sectors) to get together
- Driven by the needs of industry/vendors
- Multidisciplinary mix of skills needed

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Lead Contact/s: John May, Malcolm Joyce, Andrew Mount, Colin Boxall, William Heath, NPL (Ray Chegwin)

Sub theme name:
Environmental issues and Policy *Post it - Energy*

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Governance, Stakeholder and regulatory Convergence

Strengths

- Nuclear has a predictable (but high) cost base.
- Context is volatile electricity and carbon process
- A proven Technology

Weaknesses

- Poor understanding of investment in capital costs
- Targets hit or liberalized markets are both possible?
- Waste remains an unresolved issue

See post-its below

Opportunities

- More publicly acceptable systems
- Low cost, quick to build systems – small scale and flexible
- New dynamic regulatory environment
- Robustly proliferation resistant Technologies for export

Post its – UK PU Legacy What is the policy UJN

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Link with ESRC, NERC and STFC and MRC
- Better joined up nuclear research policy with and within the EU. Euratom, DG Research DG Tren
- Issues of Government and Governance
- How to archive long term sustainable fuel cycles which are proliferation resistant
- Nuclear when renewables and smart meters change base load - Grid design and Operation

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- Joined up RCUK aspects – cross cutting

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

- Now BIS and DECC work together?
- Link to NDA Agenda

Weaknesses - Post its Waste unresolved – perception or fact? – If perception in what group(s)? FRL
Should endeavour to understand the BPEO for open cycle v recycle nuclear fuel management. Required to underpin important and urgent management/strategy decisions. JE

Lead Contact/s: WJ Nuttall, R Cywinski, Stephen Turnock, Joe Howe

Sub theme name:
Facilities

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*

Strengths

- Basic materials characterisation γ & n sources
- Materials stimulants' facilities
- Large scale structural testing synchrotron access

Post – its Neutron diffraction SANS & INS on active samples Neutron radiography/tomography ILL and ISIS

Weaknesses

- Active materials characterisation
- Heavy Ion irradiation (coming DCF)
- Trained personal
- Access to high active facilities with infrastructure
- Active work at synchrotrons
- Thermal hydraulic test rigs

Post – its Large nuclear component flawed specimens available for inspection qualification SERCO, Risley

Opportunities

 Test and training reactor

- Equipment for high active facilities
- Underground lab and characterisation facility
- ADSR test facility
- Academic facilities for fabrication
- Academic access to active facilities and relevant sites
- Leverage with Euratom and NSF *Post – it Engagement with facilities management discipline*

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Equipment and access to active facilities – NNL, AWE
- Interactions with Euratom and NSF
- Support research programmes to use facilities (costly) (Nuclear waste, active graphite)
- Coordination and user support of existing and coming irradiation facilities – NPL, DCF, AWE (i.e. focusing resources to help business cases – stewardship role)
- Advanced test reactor – contribution to research programs

Post – its AWE facilities are 'single mission' and pretty stretched. Also security issues over access. [Not an AWE view!](#) [MarkPollington](#) PWR water chemistry testing facilities SERCO, Risley

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- Strategic need and UK capability (independent)
- Large cost, multi university needed

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

- Coordination and interaction with NNL, NPL and AWE (BAE Systems?) EURATOM, NSF, DOE

Lead Contact/s: Fairhall (NNL) Pimblott (DCF) R Cywinski W Nuttall R Chegwin (NPL)

Sub theme name:
Future Reactor Systems

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*

Strengths

- Wave of interest from students
- Niche small PWR expertise – transferable
- New joined up thinking in Universities

Weaknesses

- Long fallow period since last addressed
- Low investment
- Reluctance to fund – just in case
 - long way off

*Post –its UK GEN IV participation still possible via Euratom WJN
UK withdrawal from GEN IV programme WEL*

Opportunities

- Generate potential for UK leadership in advanced technologies
- Sustainability
- Public-private partnerships
- Exploitation of new fuel systems e.g. Thorium

*Post-its Nuclear process heat applications (CF PBMR New strategy) WJN
Leverage from European and US programmes*

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Infrastructure reqs e.g. accelerator lab for ADSR
- Integrated cross discipline studies
- International/European collaboration

*Post – it's Skill building on UK gas reactor experience and UK F.R. programme PFR.D.F.R.
ADS related (STFC) research at G&I/FAIR facility – cross – sections (P.Regan Surrey)*

Huge UK experience AGR high temperature materials and operation has direct relevance to new design of high temperature reactors David Smith (Bristol)

Couple to Hydrogen production? High temp reactors integrate nuclear and H energy sectors

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

- Too large
- Too far out for industry
- Capability building

Post – it High – T reactions for H2 production

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Only opportunity to gain major role Internationally

Post – its Fair project at Darmstadt? Formal UK Membership Paddy Regan (Surrey)

Lead Contact/s: Aidan Goldsmith, Bob Cywinski, Bill Nutall, Matt Eaton, Simon Walker, Tim Abram

Sub theme name:
Homeland Security

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Proliferation Resistance, Security, Safeguards

Strengths

- Fundamental understanding of neutron and gamma ray spectrometry
- UK Universities
- Links to AWE, NPL

Post – It Use NPL Networks e.g. neutron users group ('small neutron community')

Weaknesses

Requires Cross Council collaboration
Lack of facilities
Small neutron community

Opportunities

- Nuclear data for homeland security applications
- Disarmament centre
- Improving public perceptions of "Nuclear"
- Thorium cycle
- Activities and passive detection systems
- Studies in advanced fuels
- Neutron science

Post – it Transmutation of non-waste of fissile materials reduces security issues and increases Public Acceptance Requires funding into accelerator and laser methods
Graham Wren

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Active and passive detection system HEU detection
- Accelerator driven systems and high T breeders
- Lasers for transmutation (of Pu)
- Fission fragment cross section
- Proliferation proof fuel forms

Post – its Validation/instrument development @NPL

Portable rapid response decontamination

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Interdisciplinary/Research Council (Falling between stools)

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Joint research – energy, nuclear?

Lead Contact/s: Mark Pollington, Malcolm Joyce, Paddy Regan, Andy Boston

**Sub theme name:
Instrumentation 2A***

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*
Development of versatile high-resolution gamma –ray spectrometry for nuclear fuel/waste assay and remote sampling technologies and strategies

Strengths

- UK research leadership in this area (e.g. Agata and rising gamma-ray array development)
- Autonomous system design and robotics has UK leadership

Weaknesses

Fundamental research in this area is funded by STFC (rolling and project grants) needs some cross-council leadership

Opportunities

- Market and interest in 39PU / 235 U + minor actinides assay – stockpile stewardship
 - Decommissioning and decontamination radioactive waste characterisation and classification as low/medium level waste
 - Cost of decom. Process – characterisation and evaluation of radioactive waste / storage facilities
 - Opportunities in autonomous robotic systems to assay waste in – situ
- Post-it Also assess material changes in storage – to indicate change to package state*

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- 235 U/239 Pu assay – Modelling and development of specific detector set ups for low-background measurement – integration of detector technology Geant MC modelling; and nuclear decay data evaluation
- RC should try to “Bridge the gap” between early fundamental technology and deployable application in final working environment
- Assay of Fission waste products with links to decay heat measurements and long term safety case

Post-it Leverage existing/future Govt – research @ NPLfunded

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

Research is “Classic” interdisciplinary research

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Barrier is much of the expertise/interest is in STFC funded areas/groups

Lead Contact/s: Stephen Turnock, Andy Boston, Paddy Regan, Industry? AWE plc; Sellafield Ltd?; BAE Systems; Arriva Ray Chegwin (NPL)

Sub theme name:
Life Cycle Analysis and Sustainability

The Landscape: *This section concentrates on the wider landscape*

Description: *Summarise cards or subsection of cards you are focusing on. You may simply feel the cards cover everything adequately.*

1. Uranium supply/conservation 2. Risk Management and uncertainty

Strengths

- Industrial collaboration
- Research and KT Reputation
- International links and networks

Weaknesses

Lacking defined community

*Post it (across weakness and opportunities)
Do current techniques identify a broad enough risk register? – safety – economic (or do they focus on certain technical areas) New systems techniques - Leveson*

Opportunities

- Interdisciplinary
- Engagement with new build and build in sustainability
- Promote and deal with uncertainty
- (RE) Engage stakeholders
- Link to Government and sustainable procurement Agenda

Research Councils: *This section particularly concentrates on the research councils and what activities they should concentrate on.*

Where should the research councils now focus? *How do we take forward opportunities, build on strengths and address weaknesses? What topics should we be considering or funding?*

- Defining links across Councils
- Defining Application to End Users
- Getting “Match” £ from End Users

Post it - This theme needs integration of issues of resilience, systems failure, social impacts and gaps between scientific and public assessment.

Why isn't this responsive mode? *What added value is this going to provide above and beyond a standard responsive mode proposal? Why is this best developed through a managed activity?*

All research needs to be linked to Stakeholders consortium programme

Post it – This theme also needs to consider wider aspects of nuclear industry raw materials usage (beyond U) and socio economic issues (cross RC) and must engage strongly with the public (public understanding of science grants?)

Other Comments? *Any other comments? Barriers that need to be addressed, partners that need to be included, international activities we should align with?*

Recognise split in 1 above. Develop understanding of International governments / UK PLC

Lead Contact/s: Howe, Uclan, D. Vazquez, Brass Cardiff, L Macaskie Univ Birmingham

Annex 4: Group discussions on how to take the output forward.

Table 1

- £5m is not sufficient to deliver everything – should review how to increase this or how to go about obtaining funding from other sources.
- A rolling programme with a varying portfolio depending on priorities change might be appropriate.
- Group debated training requirements – MScs vs EngDs – they didn't come to a consensus other than that training was important.

Table 2

- A possible mechanism would be to highlight specific goals (both fundamental and those for Industry to tackle) and invite contributions.
- A generalist panel should assess this made up of people who could take a UK strategic view. This might include representatives from the research councils, industry and the learned societies.
- Either a nuclear energy centre along the lines of the ETI, or broadening the remit of the ETI to include nuclear would be desirable.
- The UK needs the capability to do experiments with radioactive material.

Table 3

- The Eols submitted to attend this workshop should be made available as a source of information of the skills set within the UK. People could use this to help build consortia.
- The Research Councils could run a call with a general remit, aiming to fund a number of consortia covering different areas.
- The process should include an Eol or outline stage; international panel members/reviewers should be used.
- There should be industry representation, but the outcome should not be dominated by industry.

Table 4

- Engage with industry for consortium development – ask them which academic areas they would like to engage with (develops buy in to these areas).
- Creates added value for the industrial community.
- Funding should be separate from the contract PhDs type of work but shouldn't exclude these students from being involved.

Table 5

- Important to maximise the value of the £5m available.
- Prioritise down to 5 key areas using input from industry and develop co-funded programmes with industry in these areas (EngD).
- Strategic underpinning research tying in the use of the UK national facilities. RCNDE model – industry pays in as well as EPSRC core funding.
- There might be benefits to going through EU/RAEng/RS schemes.

Table 6

- There is a need for engagement with end users (industry, regulators, government etc) but end users shouldn't dictate the content of the programme.
- There is an opportunity to use facilities that exist and are coming on line. Secondment to these facilities could be included in funded projects. This implies funding at PDRA level for ~ 4 years.
- Should try and leverage additional funding.
- Need to prioritise - £5m not sufficient to cover everything.

Table 7

- £5m not enough.
- Don't include "needs based" research as there are other routes to getting this funded. EPSRC should focus on fundamental research.
- Engage with stakeholders and leverage funding.
- The majority of funding should go to PhDs, to get the "biggest bang for the buck".
- Build on current centres of expertise.
- Access to facilities is important – engage with NNL, DECC.

Key messages

- Leveraging of funds
- Possibility of establishing a body/panel to help co-ordinate research
- Need a strategic view of UK and use this to inform research.
- Access to facilities key.
- Need to balance engagement with end-users and need to ensure fundamental research.