The Detector Systems Technology
Gateway Centre

Oxford University Seminar

10 Feb 2010

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5. UK Astronomy Technology Centre, Edinburgh
Overview

• Introduction to the Campuses
• STFC – Gateways
• Detector Technology
  – History and future needs
• DSC Key Objectives and Drivers
• Organisation
• Estates Plans
• Project Examples
• Summary and Questions
Where it began

Science and Innovation Framework 2004 - 2014, Next Steps

Creating “Science and Innovation Campuses”

‘…In support of these objectives, the Government has decided that the Harwell site, which includes RAL, and the Daresbury site should become the Harwell and Daresbury Science and Innovation Campuses respectively. The Government will look to develop these campuses so as to ensure that the facilities located there are internationally competitive, support world-class science, and maximise opportunities for knowledge transfer.’
Campus Overview

**Harwell SIC**
- 734 acres
- 4,500 people and over 100 companies on site
- STFC Rutherford Appleton Laboratory
- Diamond Light Source
- Two Innovation Centres - START & Harwell Innovation Centre
- MRC, HPA, AEA Technology

**Daresbury SIC**
- 100 acres
- 77 Companies with over 900 employees
- Part of a wider “Daresbury Framework” completed in March 2008 of 614 acres
- Cockcroft Institute
- Daresbury Innovation Centre
- STFC Daresbury Laboratory
STFC Strategic Drivers

[Diagram showing four quadrants with the following text:

Attract new science programmes and large facilities

Maximise research collaborations

Maximise Economic Impact

Open up new funding opportunities for STFC

Maximise opportunities for Knowledge Exchange]
The STFC Campus Vision

To become world-leading centres for science and Innovation

1) STFC Expertise
   - Access the STFC’s advanced facilities and scientific expertise

2) Collaboration & Innovation
   - Promotion of Open Innovation and Collaboration

3) Training
   - Access a unique training ground with a highly qualified mix of professionals

4) Physical Environment
   - An amenity rich and collaborative environment

5) Competitive Critical Mass
   - High-tech industry, HEIs, other RCs, PSREs
The Vision

+ Prime location for the international R&D sector
  - home to some of the world’s most prestigious research facilities.

+ To support Government’s Science and Innovation Investment Framework
  - focus on science research, innovation and learning

+ Major contributor to the UK’s scientific and high-technology skills base

+ Create an interactive community of leading scientists and innovators
  - amenities and facilities to encourage collaboration

+ High quality sustainable environment
Founding Principles - joint venture structure

UKAEA  STFC

Public sector partnership

Goodman

HSIC partnership

Ownership, strategy and key decisions

Service contracts

Goodman

Implementation
Harwell Science and Innovation Campus

- UKAEA freehold ownership
- STFC freehold/leasehold
- HPA freehold ownership
- Land leased to NDA for 150 years. Land will be surrendered when cleaned-up
- Land to be leased to HSIC JV
- Land reserved for future major science facilities
- Land to be sold for residential development
We are establishing Gateway Centres to focus our technological capabilities and orient them towards a more outward facing collaborative role.

Linked to STFC strategic/EI drivers:
- Maximise research with HEIs, RCs, PSREs and industry
- Maximise opportunities for knowledge exchange through training, technology transfer and partnerships
- Open new funding opportunities for STFC
- Create an environment to attract new science programmes and facilities
# Access to STFC Expertise

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Gateway Centres

Based on our core technical competencies

*Detector Systems Centre* – advanced detector technology
*Space Centre* – a new space centre for the UK
*Hartree Centre* – a step-change in modelling capabilities
*Imaging Solutions Centre* – transforming “facilities access” into “solutions access”
*Joint Institute for Materials Design* – integrating materials innovation with advanced characterization
The STFC delivers world leading detector systems to large scale scientific facilities world-wide, but change is coming…

- The cost and complexity of this capability has increased dramatically
- The scientific landscape is rapidly evolving
- HSIC and DSIC offer enormous potential for future commercial activity

The Detector Systems Centre will exploit this opportunity

- Allows consistent approach to significant commercial interest
- Dual-site model (HSIC & DSIC)

Planned Centre areas of strength

- Training
- Interconnect Technology
- Microelectronics
- Systems Design
- Sensor Technology access

Status and Timetable

- £30m earmarked from LFCF
- Consultation and Science and Business cases
World-class expertise in Computational Science
- New kind of CSE institute for the UK, brings together academic, government and industry communities to focus on multi-disciplinary and multi-scale challenges
- The goal is a step-change in modelling capabilities for strategic themes including energy, life sciences, the environment and materials

Wide range of planned and potential activities
- Consultation with many research fields; Materials, Environmental Sciences, Engineering, Biological/Medical, Facilities (Jul–Sep 2008)
- Commercial, International, RCs and KE/Industrial consultation

Status and Timetable
- £50m earmarked from LFCF
- OGC Gateway Process and Public launch (Jan–Mar 2010)
Great opportunity to exploit world-leading science base with academia and research labs at/near HSIC

- Positions the UK academic and industrial interests to connect with global initiatives (exploration, climate change, security)
- Public engagement, encourage study of science/engineering
- Activities aligned with ESA and UK needs; no ESA centre in UK

Centre activities to include:

- Exploration: Planetary Protection, Novel Power Sources, Autonomous Robotics
- Climate Change: a focal point for Earth Observation (EO) data in climate/global change and use of data for sustainable management of the environment
- Integrated Applications: new applications through integrated use of space assets (EO, navigation, communication); tailored solutions

Ministerial Commitment for ESA programme currently sought
Our ability to image and understand our data has not kept up with our ability to generate it…

The Imaging Centre will enhance both the quality and quantity of our output

- Enhancing access to major facilities (Diamond, ISIS & Lasers) and support pre and post-experiment
- Multidisciplinary expertise to solve imaging problems, with the right hardware, software and data analysis tools
- Supporting development of new imaging technologies
- Possibility to support national centre for electron microscopy

Challenges

- To open up the subject across the disciplines
- From the living cell – to the turbine blade
- Imaging function and dynamics; tomography

Status and Timetable

- £24m earmarked from LFCF
- Consultation beginning now – Science and Business Cases (Feb–Apr 2010)
Joint Institute for Materials Design

**Significant investment in STFC facilities such as Diamond and ISIS, where ~40% of the research will be materials-related...**

Traditional facilities interactions have been characterised by
- A clear distinction between “facilities” and “users”,
- a “contact time” limited to the duration of the experiments and
- a “one size fit all” access mechanism.

**JIMD: maximise our investment in the facilities and enable the UK to address more adventurous large-scale challenges by**
- growth of samples and materials specifically designed for facility-based measurements
- design and operation of on-beam facilities to study materials in operating conditions (in operando), and
- design of hardware and software to enable accelerated materials discovery guided by photon or neutron beams

“Recommended for further funding” by DIUS (DBIS)
The Gateway Centres are based on STFC’s core capabilities which work together to underpin our delivery of facilities and science.

Gateway Centre Synergies

We expect these synergies to be enhanced by the Centres, and for this “team effort” to be made available to a wider community.
Facilities for the Future of Science

Large Facilities Approval Stages
- Selection of facilities for inclusion in the Large Facilities Roadmap
- Short-listing of facilities eligible for LFCF
- Prioritisation of facilities for LFCF
- Allocation of resource through the LFCF
- Preparation of the Science Case
- Preparation of the Business Case – OGC Gateway1
- Procurement Strategy – OGC Gateway2
- Consideration by DBIS of the Business Case and submission to Ministers for approval of the commitment of funds

http://www.rcuk.ac.uk/research/resinfra/lfroadmap.htm
A Focus for Engagement

Institutional UK

Global

Euro

UK

Innovation Campuses

RCUK

NERC
EPSRC
MRC
BBSRC
ESRC
AHRC
Technology Looking Back
Benefits

• How will other Research Council’s benefit from the new Centre?
  – The Centre will provide the Research Councils with a facility to develop emerging technologies and detector systems in a collaborative environment created to maximise the exchange of ideas, technologies and experience throughout the Research Councils research communities
  – Partner International Research Centres, industry and Campus SMEs in the development of new innovative systems and technologies
Large Hadron Collider

Atlas Silicon Tracker
Barrel Module Production at RAL

Better than 5 micron accuracy
1536 channels per module
720 modules
The Compact Muon Solenoid

Particle Physics: CMS

- ~210 m² of silicon, 10M channels
- 75000 FE chips, 40000 optical links

Radiation environment

~$10^{14}$ hadrons.cm$^{-2}$

Collaboration: STFC, Imperial College, CERN …
Technology Looking Forward?

Issues:
- ASIC development – 0.65nm?
- Hybridisation – industry?
- Test, Cooling, Materials, Powers....
LHC Experience

Increasing Design Complexity

![Graph showing increasing design complexity with bars representing prototype cycles and needs (ASICS).]
ITRS Roadmap
ESFRI Roadmap
Key Objectives

1) Substantially increase our UK capability to develop innovative detector systems.

2) Provide industry, the universities, and the science and technology research disciplines with improved access to world class detector systems and sensor technology.

3) Engage over 100 of STFC’s best scientists and engineers and key senior managers.

4) Become the UK focus for access to an extensive range of advanced detector technologies and training in their development and application.
5) Education, training and knowledge exchange activities will be provided at the Centre.

6) Facilitate the co-location of STFC, university and industry teams and with the Innovation Campuses to establish start up companies in close proximity to the Centre, and

7) Include a dedicated marketing team to ensure that the growth potential and economic impact of the Centre are maximised.
Campus Presence

- An ‘Open’ presence in Detector Systems Technology
- Backed up with E-Resources and Online Collaboration tools
- Looking at various siting options within the Labs and SICs
General Layout

Development Laboratories

Visitor and Networking

Design Teams and Management
Site Options – Where?
Delivering the Vision

- **Science and technology**
  - National Facilities
  - Engineering & Technology
  - Technology Gateway Centres
  - Co-location of HEIs, industry, etc

- **Innovation**
  - Funding opportunities
  - Investment networks
  - Innovation networks
  - Knowledge & Property Portfolio

Embedded critical mass of world leading science and technology programmes

Knowledge Exchange & Economic Impact
Research Complex at Harwell  2010
Research Complex at Harwell
Research Complex at Harwell

Research groups

- Oxford protein production facility
- Lasers for science
- CCP4 – software for crystallography
- So Iwata Group
- Simon Phillips Group
- Alex Cameron Group
- Marisa Martin-Fernandez Group
- Life sciences
- Physical sciences
- Engineering sciences
Centre Model

- Advisory Board
  - Technologies to support

- Projects in partnership with industry and HEIs
  - Examples such as Basic Technology and Instrumentation calls

- Summer schools and Topical Workshops
  - Matched to RC and Government Themes

- Doctoral training with HEIs
  - Doctoral Training Centres, CASE Students etc.

- Commercial engagement
  - KTPs and Knowledge Networks
Novel INMAPs Technology now Applied to PP Applications
Examples

- Examples of innovative Detector projects
- Examples of current projects
- Examples of Capabilities
Data Acquisition Delivery

• Collaboration with PPD Imperial College and CERN
• Massively Parallel Processing
  10 Tera–bits / sec (~2,000 CDROMs/sec)
• 15 Exa–Bytes of raw input per year!
Spacecraft return Sun panoramas

Here we see the entire Stereo panorama from the Sun to the Earth

Twin Nasa spacecraft have returned panoramic images that will help scientists to study solar explosions capable of causing havoc on Earth.

The Stereo orbiters, which are nearing their final positions, will study violent solar eruptions known as Coronal Mass Ejections (CMEs).

CMEs hurl energetic particles at Earth that can disrupt power grids and satellite communications.
CCDs Have Limitations

- Solar Orbiter Mission
- 40 solar radii close up and high latitude imaging and spectroscopy
- Extreme particle environments preclude the use of traditional CCD detectors

Solar Orbiter
A High Resolution Mission to The Sun and Inner Heliosphere
http://www.orbiter.rl.ac.uk

Back-illuminated Front-illuminated

RALs Forst 12M Sensor (with SSTD)

TSMC Wafer (with SSTD)

Light Source

P Epitaxial layer
P well
N well

P substrate
Nitride coated hi-resistivity silicon substrate
Space ESA Project:
Solar X-ray and Particle incidence spectrometer

**Features**
- Low noise FE
- Peakhold and comparators
- 12-bit SAR ADC
- RAD Hard design
- SEL and SEU tolerant
Monolithic CMOS imagers (MAPS) combine integrated circuit complexity with imaging pixels. This permits complex sensor functions to be integrated opening many novel application areas:

- Optical traps to capture, manipulate and measure forces on microscopic particles
  - living cells, plastic beads and oil droplets
- Goal:
  - six objects, position measurement and feedback control
Transmission Electron Microscopy

Improved radiation hardness allow direct sensing in applications where CCDs would not survive.

One of the first images of a virus (beginning 2007)

Commercial programme with MRC LMB Cambridge, European suppliers and UK Foundry...
Neural Imaging

- **Neuron APS**
  To study the spiking rate of a large number of neurons in parallel, each neuron being located with good spatial resolution across the surface of the visual cortex and with some depth discrimination.
Retinal Implant

- Artificial retina chip
  - to repair certain types of blindness is now a realistic prospect
- RAL and Glasgow Project
  - to develop a prototype retinal implant APS
- Study in-vivo measurements of retinal activity with APS technology
- First implementation of 'smart' neural encoding
  - With on chip neural network
I-Imas – Intelligent Medical Imaging

- Intelligent X-ray screening scans
- European collaboration
- Industrial and university partners

Example of mammography application
(image courtesy of Gary Royle - UCL)
MAPs and Basic Technology

Multidimensional Integrated Intelligent Imaging (MI-3)

- RC-UK Basic Technology programme
- £4.4m (6.5 mecu) budget over 4 years
- 11 partner consortium
  - University of Sheffield (Laboratory for Image and Video Engineering)
  - CCLRC (Microelectronics Design)
  - Brunel University (Centre for Electronic Imaging)
  - University of Glasgow (Particle Physics Experimental Group)
  - University of Liverpool (Liverpool Semiconductor Detector Centre and Laboratory for Environmental Gene Regulation)
  - University College London (Radiation Physics Group)
  - University of Surrey (Centre for Vision, Speech and Signal Processing)
  - University of York (Applied Electromagnetics and Electron Optics Group)
  - Institute of Cancer Research, Royal Marsden Hospital
  - MRC Laboratory of Molecular Biology, Cambridge
MI3 Sensor Developments

- In Pixel Intelligence: OPIC
To Electronics Research

Read-out ASIC at 4.2K

Nanostructure at <50mK

INITIALIZATION
A Return to Particle Physics?

- **MAPS for the Linear Collider**
  - Large “stitched” sensors, total area ~2000m²
  - 30 layers of silicon
  - Layered between sheets of tungsten
  - Detect and store “hits” caused by high energy particles as they pass through the metal
Sensor Device Modelling
(Link to Hartree)

XFEL example

$10^5$ 12KeV Photons

10 fs
One Future Challenge:

- FEL sources deliver bright short pulses of radiation

Scientists want to 'Film' fast materials process, e.g. the freezing of liquids in real time.
0.528m x 0.576m sensor surface
1,024 x 1,024 - 500um pixels
Nominal 300um between sensors
Target sensor operating temperature -20 °C
Total Power dissipation 3 to 5 kW
Divided into 16 supermodules
Supermodule has 16 sensors
Aluminised Rhocell window

Similar Issues:

ASIC development – 0.13 um?
Hybridisation, Test, Cooling, Materials, Radiation hardness, Power....
Future Imaging

**Spectral Range**
- Low energy HgCdTe
- High energy CdZnTe, Hgl

**Dynamic Range**
- Fast pulsed sources
- Combined count and integration

**Nano-Technology**
- Novel sensors
- Active surfaces

**Complexity**
- Pixel Density
- Novel functions: ADC, memories etc.

**Timing**
- Ultra-fast framing
- Deep in pixel storage

**Materials**
- Advanced interconnect
- Bio compatibility
- Scintillators
Centre Mission

a) Champion the UK development and delivery of world-leading instrumentation systems

b) Maximise the knowledge exchange of sensor technology with UK industry

c) Focus the engagement of the UK university and STFC research groups on a portfolio of sensor development programmes

d) Provide a centre for STFC and HEI collaborations, training, European and world-wide projects

e) Strengthen the contribution of UK industry in large science programmes world-wide and

f) Enable early adoption of new sensor technology in the UK
Business Objectives

• Deliver gearing of STFC investment in EI programmes
  - Tightly linked into STFC’s programmes
  - Undertake road mapping of technology for future programmes

• Provide an expert systems service for:
  - Students
  - Academic Users
  - Industrial Researchers, particularly Campus ones
  - STFC’s scientific programmes

• Complimentary to University Groups and industry
  - Not in ‘competition’
  - Linked to key technologies available in Uni Groups
STFC Project Team

- Marcus French – Team Lead
- Roger Eccleston – TBU Lead
- Steve Worm – Leads the Centres
- John McLean – Microelectronics (and the MSC)
- Barry Dobson – Science input
- Richard Farrow – KE lead, Technology Department
- Kate Ronyane – CLIK support
- Dave Bogg – Estates issues, DL
- Vraj Perera – Estates issues, RAL
- Linda Baines – Legal advice

An Advisory Board has also been formed...
Advisory Board

- Prof. Nigel Allinson Sheffield University
- Prof. Phil Allport Liverpool University
- Dr. Trevor Cross CTO e2v technologies
- Prof. Jim Dunlop Edinburgh University
- Dr. Heinz Graafsma DESY/XFEL
- Prof. Geoff Hall Imperial College
- Dr. Val Oshea Glasgow University
- Prof. Trevor Rayment Diamond Light Source
- Dr. Paul Sellin Surrey University
- Dr. Peter Sharp (chair) CERN/Imperial College
- Prof. Steve Watts Manchester University
Microelectronics Support Centre

Over 25 years of history supporting UK Academic Institutions with microelectronics design methodologies, tools and routes to implementation.
Microelectronics Strategic Partnerships
CMOS Imaging Strategic Partnerships

- University of Cambridge
- University of Oxford
- Imperial College London
- University of Birmingham
- University of Liverpool
- Brunel University
- UCL
- University of Glasgow
- MAX-PLANCK-GESSELLSCHAFT
- The Institute of Cancer Research
- Science & Technology Facilities Council (STFC)
- e2v
- INFN
- Aspect Systems
- Image Scan
- Applied Scintillation Technologies
- Austrian Microelectronics
- ACTA
- FAB
- Taiwan Semiconductor Manufacturing Company (TSMC)
- IBM
- Tower Semiconductor Ltd.
- 3DX-Ray
An open innovation Centre dedicated to the development of new innovative detector systems

Providing industry, the universities, and the science and technology research disciplines with improved access to world class detector systems and sensor technology

Engaging over 100 of STFC’s leading scientists and engineers in a new innovation environment

The UK focus for access to an extensive range of advanced detector technologies and training in their development and application
Education, training and knowledge exchange activities will be provided at the Centre.

Facilitate the co-location of STFC, university and industry teams and with the Innovation Campuses to establish start up companies in close proximity to the Centre, and

Include a dedicated marketing team to ensure that the growth potential and economic impact of the Centre are maximised.
Centre Strengths

- Microelectronics
- Interconnect Technology
- Training
- Systems Design

- >500 cards
- >20,000 BGAs
DSC Summary

- An open innovation environment in detector technology
- Linked to Government priorities:
  - Bioscience, Healthcare, Security etc
- Building headroom to maximise STFC economic impact
- Engaged with Campuses, Universities and Industry

This is evolving:

Input and Ideas welcome!

See [http://www.stfc.ac.uk/dsc](http://www.stfc.ac.uk/dsc)
Questions Please