fascination

June 2016

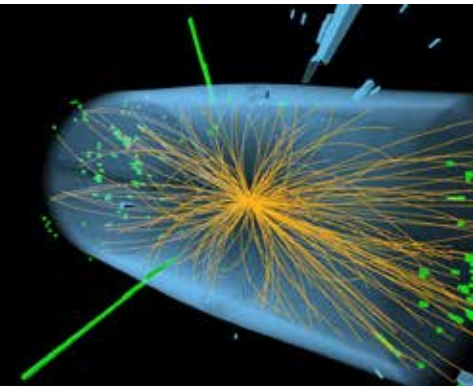
INSIDE Careers Special

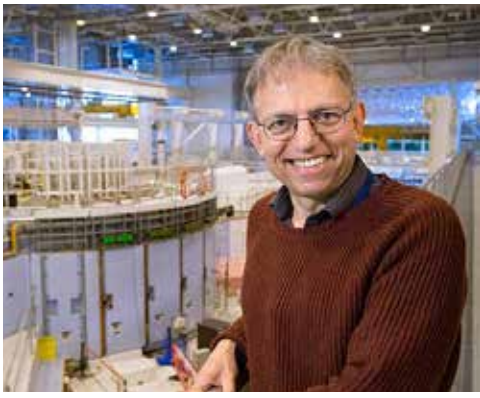
The greatest movie ever made: directed by astronomers, starring our Universe

Dark matter search enhanced by turbocharged 'brain'

Developing the UK's first cognitive hospital

Helping to protect more endangered species





Science & Technology Facilities Council

Welcome

Welcome to the summer 2016 edition of Fascination magazine.

IBM's Watson technology, a super-smart computer that can understand human feeling and language, is currently being trained to help children feel less anxious about, and more prepared for, their hospital appointments. Turn to page 16 to learn about how Watson technology will be applied to improve patient experience in the United Kingdom at Alder Hey Children's NHS Foundation Trust, Liverpool.

What's the greatest movie ever made? Star Wars? Pulp Fiction? Jurassic Park? Harry Potter? How about the movie about to be created starring our Universe? Turn to page 10 to discover more.

Despite global conservation efforts, many marine, fresh-water and land animals may become extinct in the next few decades. But thanks to a new freezing technique developed at STFC, we may be able to protect them (pg 12).

We hope you enjoy reading this edition. As always, we'd love to know what you think. Get in touch at fascination@stfc.ac.uk or contact us on Twitter @STFC_Matters

Best wishes,

The *Fascination* editorial team

About Us

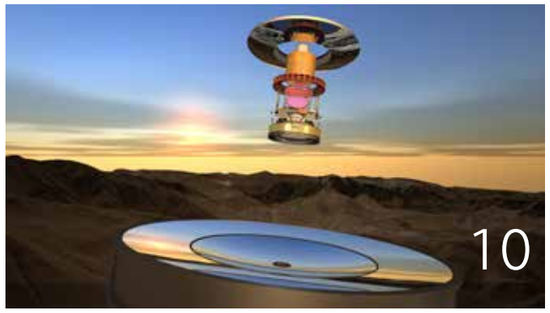
Our scientific research seeks to understand the Universe from the largest astronomical scales to the tiniest constituents of matter. Providing access to and managing a range of world-class research facilities, the Science and Technology Facilities Council delivers fundamental insight and scientific breakthroughs in areas ranging from particle and nuclear physics to space, laser and materials science. Through our UK operations and our involvement in major international collaborations, we generate outcomes that shape societies, strengthen economies, build industries, create jobs and transform lives.

Don't miss an issue

Fascination is STFC's quarterly in-house magazine. To receive an electronic version straight into your inbox for free, please visit: www.stfc.ac.uk/fascination and subscribe.

Cover image: This artist's conception shows the optical elements of LSST: 3 mirrors, and 3 lenses.
Credit: LSST

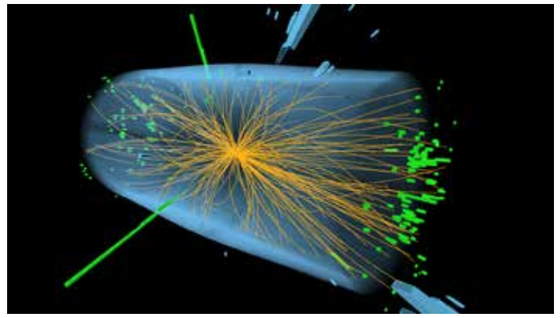
Contents



Contact us

Email: Fascination@stfc.ac.uk
Write: Fascination editor, Office B89, STFC, Daresbury Laboratory, Daresbury, Cheshire, WA4 4AD
Tweet: @STFC_Matters
facebook: Science-and-technology-facilities-council
LinkedIn: STFC

Dark matter search enhanced by the LHC's new turbocharged 'brain'



Event recorded with the CMS detector
Credit: CMS/CERN

The hunt for dark matter taking place at the Large Hadron Collider (LHC) at CERN has taken a great leap forward thanks to new detection technology developed by a team of scientists, engineers and researchers from the UK.

The system, installed on the CMS experiment, can be used anywhere in the world and the pioneering approach will enhance our understanding of the fundamental physics of the Universe.

It will also enhance our search for dark matter. Dark matter is the 'invisible' matter predicted to make up around 27 per cent of the Universe but it has yet to be directly detected.

The upgraded general purpose CMS detector for the LHC pulls together all the data produced in the microsecond after each particle collision. The detector studies the data needed for understanding a wide range of physics including the properties of the Higgs boson, searching for extra dimensions and for the particles that could make up dark matter.

Dr Jim Brooke from the University of Bristol believes the new system is much more flexible than the previous detector: "The system effectively receives a digital image of each collision from the detector. This upgrade is like switching to HD TV, the pictures are much higher resolution. We can also process an entire image in one chip; before we had to split them up and process each piece separately. With the old system, we mostly relied on identifying one or two high energy particles as a sign of interesting physics. Seeing the whole picture in high resolution means the electronics can begin to decide whether those particles come from a Higgs boson or new physics like dark matter production. It's a really flexible, powerful system, and we're only just starting to use its capabilities."

New chip design
Credit: CMS/CERN

Data from the CMS detector must be analysed in less than a millionth of a second to decide whether something interesting has happened and that the data should be kept for further analysis.

Professor David Newbold, Head of the Fundamental Physics Research Group at the University of Bristol and UK spokesperson for the CMS experiment at CERN said: "Although the CMS detector is huge, all of the collision data has to be immediately analysed by an electronic 'brain' the size of a microwave oven. The scientific results from the LHC depend crucially on selecting a tiny fraction of collisions for detailed analysis, and throwing away the rest. The new technology we are using in CMS is going to increase our chances of spotting dark matter and other new particles in the high energy collisions in 2016 - it's like turbocharging our detector". ■

Robo-crop could boost farm production

Robotic technology for Mars exploration could improve crop yields on Earth

STFC's RAL Space team is transforming a rover they originally designed and built to explore the surface of Mars into an agricultural monitoring device for testing the quality of soil and potentially reducing the environmental impact of farming.

The device consists of a mobile rover platform with a robotic arm carrying a soil-sensing Laser Induced Breakdown Spectroscopy instrument, to allow for soil measurements to be taken on the go. To build it, the team has to miniaturise an instrument that is normally the size of a large wardrobe to fit on a small mobile robot.

The device will be used on a research project by a team at the University of Strathclyde who, working with partners in the UK and China, will demonstrate the feasibility of the agricultural operation. The RAL Space team will design and build all aspects of the device, and will also provide equipment and logistics support for the field trial in China that will demonstrate the technology.

Aron Kisdi, a space systems engineer for RAL Space, said: "At STFC RAL Space we have taken our existing expertise in developing and building space technology for NASA, the European Space Agency and other major science organisations and we will be applying it to this Earth bound project. It is a brilliant example of just how versatile our space technology can be and demonstrates once again that the UK is a world leader in these pioneering technologies."

The project for the device, known as the AgriRover, is funded through the UK Space Agency's International Partnerships Space Programme (IPSP). ■

Finlay Harris (left) and Giacomo Corvi, students gaining research experience by working on the AgriRover project, with the AgriRover device.
Credit: University of Strathclyde

Frozen frog gives clues on fertility treatment and food storage techniques

A frog that survives being frozen for weeks in its natural habitat is helping scientists discover more about freezing techniques used in fertility processes, medicine and food storage.

In winter months, the Eastern Wood frog in North America survives being frozen to temperatures as low as -8°C for weeks. In spring, it thaws out and continues along its way perfectly healthily – completely restored to its former state. Called a psychrophile, an organism that can survive extremely cold temperatures, this unassuming animal has inspired a team of physicists at the University of Leeds to find out exactly how it survives. The team aims to mimic the frog's freezing process in order to improve the success rate of freeze storage techniques used in fertility treatments, drugs in the pharmaceutical industry and food storage in the future. In current methods, not all of the cells are recovered after freezing, meaning valuable samples could be lost.

Using an instrument called SANDALS at STFC's ISIS Neutron and Muon Source, researchers have re-created freezing conditions to see how glycerol, nature's answer to antifreeze, interacts with water to prevent harmful ice crystals from forming.

Through a combination of neutron experiments and computer simulations, the team has discovered how glycerol prevents ice crystals from forming in water as the solution is cooled to -35°C. They found that water molecules form clusters that are 'protected' by an extensive network of glycerol.

These results offer a platform for the future study of water at temperatures and pressures that were not previously possible.

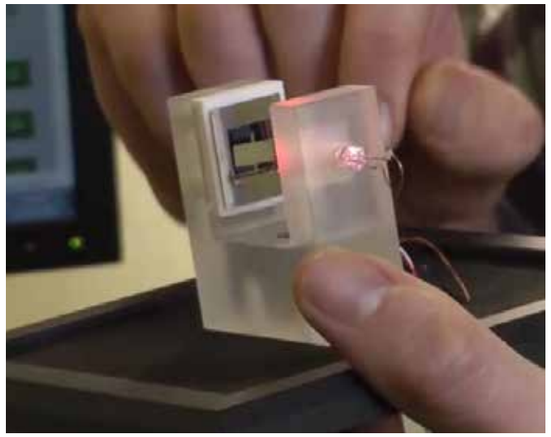
Dr Lorna Dougan, who leads the group at the University of Leeds said: "The experiments provide more insight into the fundamental properties of water. It's important because it raises questions about what cryoprotectants are doing in living organisms and could help us take steps to understanding how these organisms survive."

"If we understand what glycerol is doing we might be able to fine tune some of these cryoprotectants that are used to find more effective combinations."

Discover how similar research using SANDALS is helping protect endangered species, on pg 12. ■

Dr James Towey on the SANDALS instrument at ISIS. James completed the experiments during his PhD, supervised by Dr Lorna Dougan at the University of Leeds.
Credit:STFC

Smartphone technology adapted into super-sensitive gravity detector



Wee-g
Credit: Glasgow University

Smartphones already help us check our bank balance, find a restaurant and book a cab home.

Now part of the same technology is being adapted to build portable devices that could monitor volcanos.

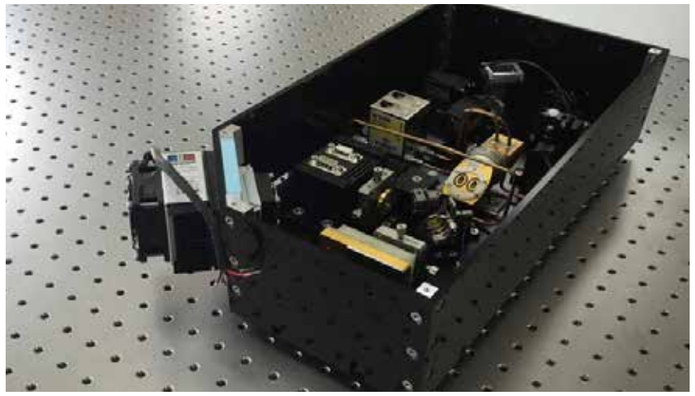
Scientists from Glasgow University, co-funded by STFC, have adapted a system often found in smartphones to create the Wee-g, a super-sensitive detector capable of measuring minute changes in gravity.

These affordable, portable gravimeters could have a wide range of applications, including volcano monitoring, environmental surveying, and oil exploration.

Gravimeters measure the gravitational field of the Earth. Although these devices have been available commercially for decades, and are often used in the oil and gas industry to discover fossil fuel deposits, widespread uptake has been limited due to their expense and large physical size.

The Wee-g uses the same cheap, mass-producible micro-electromechanical systems (MEMS) which are used in smartphones' internal accelerometers. While the MEMS technology in phones uses relatively stiff and insensitive springs to maintain the orientation of the screen relative to the Earth, Wee-g employs a silicon spring ten times thinner than a human hair. This allows Wee-g's 12mm-square sensor to detect very small changes in gravity and is so sensitive it can measure how the moon and the sun also exert a subtle effect on the Earth's crust, an effect known as the 'Earth tides'. The pull of the Sun and the Moon displace the crust, creating a very slight expansion and contraction of the planet of around 40cm. ■

Investment boost for diagnostic technology



The Laser Isotope Ratiometer beta prototype
Credit: Mohammed Belal, Director of MIRICO

A clever piece of laser kit that can test for disease and monitor carbon dioxide in an instant is about to hit the UK market.

The UK company behind the technology has taken an instrument originally developed to explore Mars and turned it into a product which can help monitor climate change, diagnose disease and detect counterfeit foods.

STFC spin-out company MIRICO, can now take its product to market after £1m investment from the Rainbow Seed Fund and Longwall Ventures.

The instrument works by using lasers to provide instant analysis of gases, targeting molecules with an immense degree of precision using very few components.

Its applications range from diagnosing medical conditions through testing human breath, verifying the origin and authenticity of food and wine and detecting carbon dioxide in the environment to help monitor climate change.

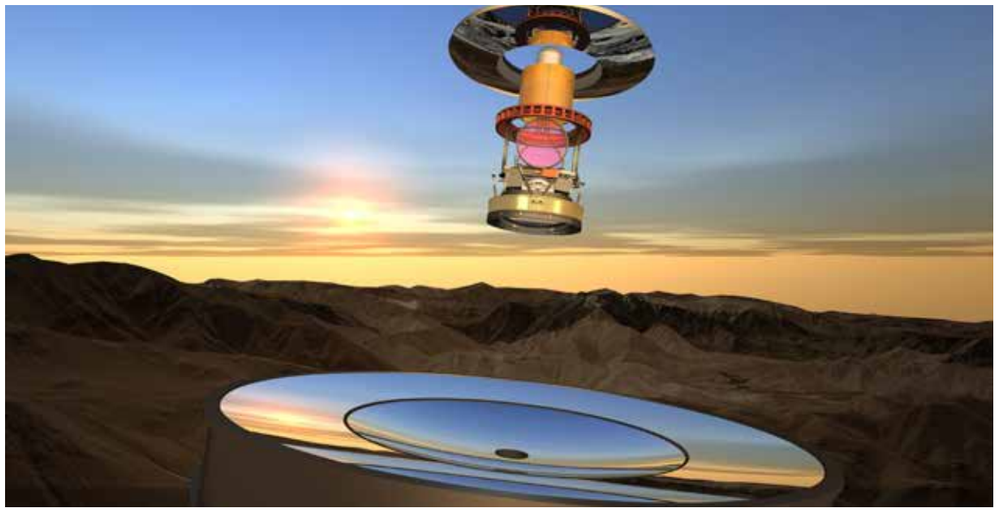
Because the technology was originally designed for use in space it is lightweight and yet robust, meaning that unlike previous equipment which is laboratory-based, it can be used by non-experts in hospitals, industrial factories and out in the field.

Dr Damien Weidmann, from STFC's RAL Space where the technology was designed, said: "We looked into technical solutions to make real time, highly sensitive isotopic analysers small enough and robust enough for space. Exploring potential business cases it became clear that many 'terrestrial' applications are also relevant."

In environmental monitoring, the instrument uses lasers to detect very low concentrations of greenhouse gases and stable isotope composition. It can also identify the authenticity of a food sample, simply by burning a small amount of it and monitoring the gases released.

On an oil rig, the technology could be used to analyse hydrocarbons from the gas they release and be used to map the type of rock below. This means that drilling for oil can be far more targeted, increasing the efficiency of the process. ■

The greatest movie ever made: directed by astronomers, starring our Universe



The optical elements of the LSST appear suspended over the coplanar primary/tertiary mirror. The secondary mirror, camera lenses and filters are also visible.
Credit: LSST

The world's first motion picture of our Universe, being dubbed the 'greatest movie ever made', is to be produced by international astronomers. The film, which could feature dangerous asteroids and uncover some of the mysteries of dark matter and dark energy, will be recorded on a giant digital camera comprising 3.2 billion pixels.

It hasn't been completed yet, but when it is, the Large Synoptic Survey Telescope (LSST) will be the world's largest digital camera. It will be able to take images of the sky that each cover over 40 times the area of the Moon, building up a survey of the entire visible sky in just three nights.

That means billions of galaxies, stars and solar system objects will be seen for the first time and monitored over ten years. UK astronomers will now play a key part after funding from STFC confirmed the UK's participation.

Steven Kahn, the LSST Director said: "I am delighted that STFC is supporting UK participation in LSST. It is great to see UK astronomers engaging in preparation for LSST, and we look forward to seeing our collaboration develop over the coming years. LSST will be one of the foremost astronomy projects in the next decades and the UK astronomical community will contribute strongly to its success. The telescope is being built in the Chilean Andes. Conditions there are some of the driest on Earth, making it the ideal position for observing.

When it starts operating, it will generate one of the largest scientific datasets in the world.

The LSST is a 'synoptic' survey because it will form an overall view of the Universe: billions of objects will be imaged in six colours, spanning a volume of the Universe that is larger than any previously explored.

"What is unique about LSST is that each of its images covers a large area of sky to a depth that captures faint objects, and that it takes these images really quickly", said The LSST:UK Project Scientist, Sarah Bridle from the University of Manchester. "That combination of area, depth and speed means that we can do lots of different science with the same dataset."

"LSST will build up a very detailed map of billions of galaxies, with approximate distances to each, from which we will learn about the mysterious dark energy that seems to be accelerating the expansion of the Universe. But, equally, it will look for changes in the sky from night to night; both moving objects, like asteroids, and new ones, like supernovae, that appear where nothing had been seen before. Covering each patch of sky over 800 times during its decade of operations, it will construct our first motion picture of the Universe".

The science themes of the LSST encompass astronomy, physics, chemistry, earth science, space science, mathematics, technology and computing, fostering interdisciplinary working.

As well as providing unprecedented scientific data, the development of LSST will help train future scientists and bring advances in computing.

"Extracting scientific knowledge from LSST will pose major challenges in the management and analysis of data. These 'big data' issues are seen across the commercial sector as well as in science, but astronomy provides the ideal testbed for addressing them, as our data is free from the ethical and commercial constraints found in other domains. Many from the generation of young researchers who develop their skills preparing for the LSST data deluge will end up applying their expertise in business or the public sector, so the impact of UK participation in LSST will be felt well beyond astrophysics", said the LSST:UK Project Leader, Bob Mann from the University of Edinburgh.

The benefits of the UK being a member of the LSST extend yet further. The LSST will provide unprecedented access to data, allowing for new kinds of citizen science and discovery. In recent years, the UK-based Zooniverse project has pioneered citizen science investigations of data in astronomy, enabling more than one million members of the public to, amongst other things, classify galaxies, discover planets and explore the outer solar system.

Zooniverse's Chris Lintott, member of the LSST Outreach Advisory Board, said: "We know that data from LSST will contain a vast wealth of exciting things; we're looking forward to making sure everyone, regardless of their background, can help us uncover what's hidden in there".

Discoveries made by the LSST will also be used to construct educational materials that will be freely available to schools and the public.

Andrew Norton from the Open University, the LSST:UK Education and Public Outreach Coordinator, said: "The LSST will allow us to see the night sky changing in front of our eyes and everyone can get involved to understand how the Universe works. The LSST will show us what a dynamic place the Universe is."

The telescope will take its first data in 2020 and its main sky survey will begin in 2022.

Like all good movie franchises, the LSST story will unfold in stages, from a preview in 2023 to a finale in 2033. Get your tickets now! ■

Helping to protect more endangered species

Target Station 1 Experimental Hall, where the SANDALS instrument is located
Credit: STFC

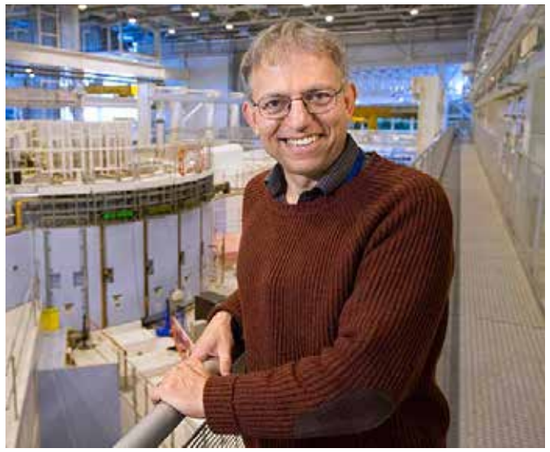
Despite global conservation efforts, many marine, fresh-water and land animals face the threat of extinction in the next few decades. But thanks to a new freezing technique developed at STFC, we may be able to protect them.

In an effort to protect endangered species, conservationists can freeze embryos in the early stage of their development and these can be stored for thousands of years - a technique known as cryopreservation. Some species' embryos, however, are more difficult to cryopreserve than others. For the process to be successful, it is essential that ice crystals do not form as they act as tiny knives, puncturing cell membranes and killing the embryo.

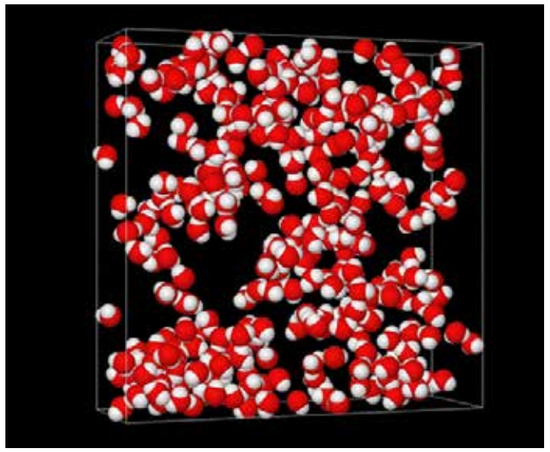
Now for the first time, the mechanism behind cryopreservation has been cracked at the molecular level. These results will make it possible to cryopreserve embryos of endangered species which are currently unachievable. In mammals the freezing of embryos is common place, whereas in some fish species it is more difficult; fish eggs have strong outer membranes that are impermeable to cryoprotectants - the chemicals used to preserve the embryo and protect it from ice crystals.

In neutron experiments at STFC's ISIS Neutron and Muon Source, scientists 'watched' the freezing process take place. The scientists were able to see what was happening to individual components in the mix of cryoprotectants and water and found that in mixtures with a particular concentration of cryoprotectants, the chemicals formed long chains and acted like a mesh or 'sponge' that locked the smaller water molecules in to pockets. In normal freezing, water molecules link up to form ice crystals, however the cryoprotectant mesh meant the water molecules were isolated in small clusters.

The study confirms observational experiments by scientists in the Czech Republic, who after several years of trial and error experiments, noticed that a particular mixture of cryoprotectants led to a perfectly preserved fish egg from a Common Carp.



Dr Alan Soper, ISIS Scientist and lead author on paper
Credit: STFC



A 1.5nm slab of the EPSR simulation box for samples 4–7 (23 vol.%PD, 17 vol.%methanol, 20 vol.%DMSO and 40 vol.%water), showing only the water molecules
Credit: Royal Society Open Science

Now the mechanism of cryopreservation has been found, these results can go towards a model for the cryopreservation of endangered species with more challenging embryos, such as some coral fishes.

Professor William Holt, former Head of Reproductive Biology at the Zoological Society of London (ZSL) said this work will contribute to conservation efforts:

"This represents a significant step in the development of a technique for fish oocyte cryopreservation. If eggs could be frozen and stored without losing viability, they would provide a valuable resource for conservation programmes. By providing genetic support to endangered populations, these techniques would help reduce the damaging effects of inbreeding, enhancing animal welfare."

The experiments took place on ISIS instrument, SANDALS. In the experiments, Dr Alan Soper and co-author Dr Oleg Kirichek took three different mixtures of cryoprotectants and quenched cooled, or rapidly cooled them in liquid nitrogen to -196 degrees celsius in seconds. They then performed neutron diffraction experiments to see the structure of each mixture after freezing.

As neutrons are very sensitive to hydrogen, a key element of water, scientists were able to 'see' at the molecular level what happened to the mixture after quench cooling.

Dr Soper, an ISIS scientist and world expert in the structure of water and water-based solutions who was co-author on the study said:

"Neutrons were crucial for this study because they instantly highlighted any ice that did develop in some samples, and also, by virtue of the ability to perform hydrogen/deuterium substitution on the water molecules, allowed us to access the water structure independently of the contributions from the other components in these solutions."

STFC supported the neutron scattering part of the research, both through funding beam time on ISIS and through the provision of samples. ■

Developing the UK's first cognitive hospital

Advance computing technology could soon provide a "digital concierge service" for hospital patients .For the first time, IBM's Watson technology will be applied to improve patient experience in the United Kingdom, at Alder Hey Children's NHS Foundation Trust, Liverpool.

Alder Hey in the Park

Credit:STFC

The ground-breaking collaborative programme between Alder Hey Children's NHS Foundation Trust and STFC's Hartree Centre, with support from IBM, will apply Watson - an innovation in computing technology – to create an interactive cognitive platform (like a digital app) that can:

- intelligently respond to patients' questions;
- allay patient fears by providing reassurance;
- understand sentiment, context and the meaning behind interactions;
- remind young patients and their parents about appointments and aftercare;
- identify clinical trends; and
- provide insightful feedback to clinicians about how patients are feeling before/during their treatment, so that they can respond accordingly.

The first stage of this multi-year project is underway, with an initial version of the platform expected to be ready for testing in the hospital around the end of the year. We believe that this cognitive platform can enhance patient care and potentially generate savings for both the hospital and the NHS as a whole.

What is Watson?

Watson is an innovative technology platform from IBM that signals a whole new era in computing. Watson analyses large amounts of unstructured data and, amazingly, is able to evaluate all possible meanings, understanding grammar, context and sentiment. When Watson is asked a question using natural language, it is able to use this understanding of the data it has to present intelligent, evidence-based answers. Watson continuously learns, gaining in value and knowledge over time, from previous interactions.

Training Watson for Alder Hey

To begin intelligently answering questions, Watson must first learn new subjects. So, for the next few months, Alder Hey's team of volunteers will be gathering questions from hundreds of patients and their parents on everything they might want to ask about, from parking, to what they would like to eat, to their favourite games and films, and what they want their bedroom to look like. This will also include their questions about clinical procedures, general anaesthetic, and surgery. A team of experts from the Hartree Cognitive team, made up of the Hartree Centre and IBM staff, will use this information to train Watson to anticipate and respond to questions from patients and families before they come into hospital.

Alder Hey Children's Hospital volunteer chatting to family
Credit: STFC

Alder Hey Children's Hospital volunteer chatting to family
Credit: STFC

A thinking, feeling hospital

Using the data it is given, Watson will be able to provide cognitive analytics that deliver insights enabling the hospital to - in essence - think, sense and feel what is happening within it. Patients and their families at Alder Hey will be able to access this platform pre-admission to hospital through a digital application on a tablet or smartphone, such as a mobile app. The app is being developed in parallel to the cognitive hospital, using funds raised by Alder Hey Children's Charity.

How will the cognitive platform be used?

There are many potential longer-term applications of the platform. It could be used to drive vital research projects by proactively matching suitable patients to clinical studies, monitoring admission patterns to help with bed planning or to help management of chronic illnesses through educational applications which could alert patients and their doctors when their symptoms reach the point at which they should seek medical help, or even automatically make an appointment for them.

We caught up with Iain Hennessey, paediatric surgeon and Director of Innovation at Alder Hey, to find out what he thinks of the project:

F: What does cognitive computing mean to healthcare from your perspective?

I: Here at Alder Hey, we're really excited about this partnership with the Hartree Centre. We've just moved into a state-of-the-art building and want to have state-of-the-art technology to go with that. We're looking at the technology we can use to improve patient care and we think that a cognitive platform is really where we should be going.

With cognitive computing, essentially you're trying to get a computer to act more like a human acts, so that it can look at data in an unstructured way. Computers at the moment work with numbers and tables, but struggle to interpret more unstructured things, like what people mean by what they say on social media; but there's so much richness to that type of data, and so much of it around. In fact, 90% of data is now in this unstructured format. We need to be able to look at that and use it to improve how we treat our patients. That's what cognitive computing means to healthcare; the ability to leverage the data which is out there but currently being wasted and not looked at by us.

F: How will having a cognitive platform improve the way children experience the hospital?

I: Our main aim at the moment is patient experience, which is very important, especially in a children's hospital. Children are naturally very afraid of hospitals; they are afraid of the unknown. What we want to do is to create an experience that starts in the home, in the patient's safe environment, where they start to learn about the hospital and learn about their condition. We need to be able to give them information in advance in a way that they understand and can interact with, so they can have an idea about what's going to happen to them when they arrive here. By doing that, we will reduce their anxiety levels and it will give us an opportunity to look at their anxiety levels by how they are interacting with it. It will give us a richness of insight, and allow us to tailor their experience to their needs. Familiarisation, for me, is a very important thing. It would also help with other things, like parents being stressed out because they don't know where to park. We should be able to give that information to them ahead of time in a more 'intelligent' reactive way. It's the little things we can improve to make people happier and less anxious. That makes their treatment easier and makes them get better faster.

For more information about Alder Hey, visit: www.alderhey.nhs.uk
For more information about IBM Watson, visit: ibm.com/watson
For more information about STFC's Hartree Centre, visit: www.stfc.ac.uk/hartree

F: How will this technology affect the hospital?

I: This hospital is brand new. It's just been born, and we're going to teach it how to look after children and how to improve their experience. This is a long project – we're going to grow it from the ground up and teach it what it is to be Alder Hey.

F: How does the cognitive experience differ to a website?

I: It's quite difficult to imagine, but having experimented with this, it's so much more relaxing to react with a cognitive platform than a website. Websites just throw information at you. Your eyes are searching everywhere, you've got to find menus and different layers. But with a cognitive platform, it's like having a concierge service. There's someone guiding you through, asking what you need to know and reacting to what you actually say. That's why I think cognitive platforms really are the way forward for how we give information to people. People like to be communicated with in a human way and this is what cognitive computing does – it mimics how humans react.

F: What do you think about the long-term possibilities for cognitive computing capabilities at Alder Hey?

I: I think we have to be realistic about what we can do as human beings. We need to be able to take that bottom 10% of what we do – the easy decisions that a computer could make for us – and free it up for what doctors are really good at, like problem solving and working with patients.

It's like what happened in the industrial revolution; it used to be that everyone used to make every single pin by hand, but that doesn't need a human brain or human skills. In the long term, I want to apply that same process of automation to some of the little things that happen in the hospital - like ordering a scan or informing someone about a cancelled appointment. These things can get missed, and can have enormous effect on patient experience. However, these are things which a cognitive platform really should be able to do. That's where I want to go with it. It's going to be an interesting journey.

Iain Hennessey
Credit: STFC

Science-and-technology-facilities-council

@STFC_Matters

SciTechUK

STFC

Science & Technology Facilities Council

Science and Technology Facilities Council
Polaris House, North Star House, Swindon
SN2 1SZ, United Kingdom