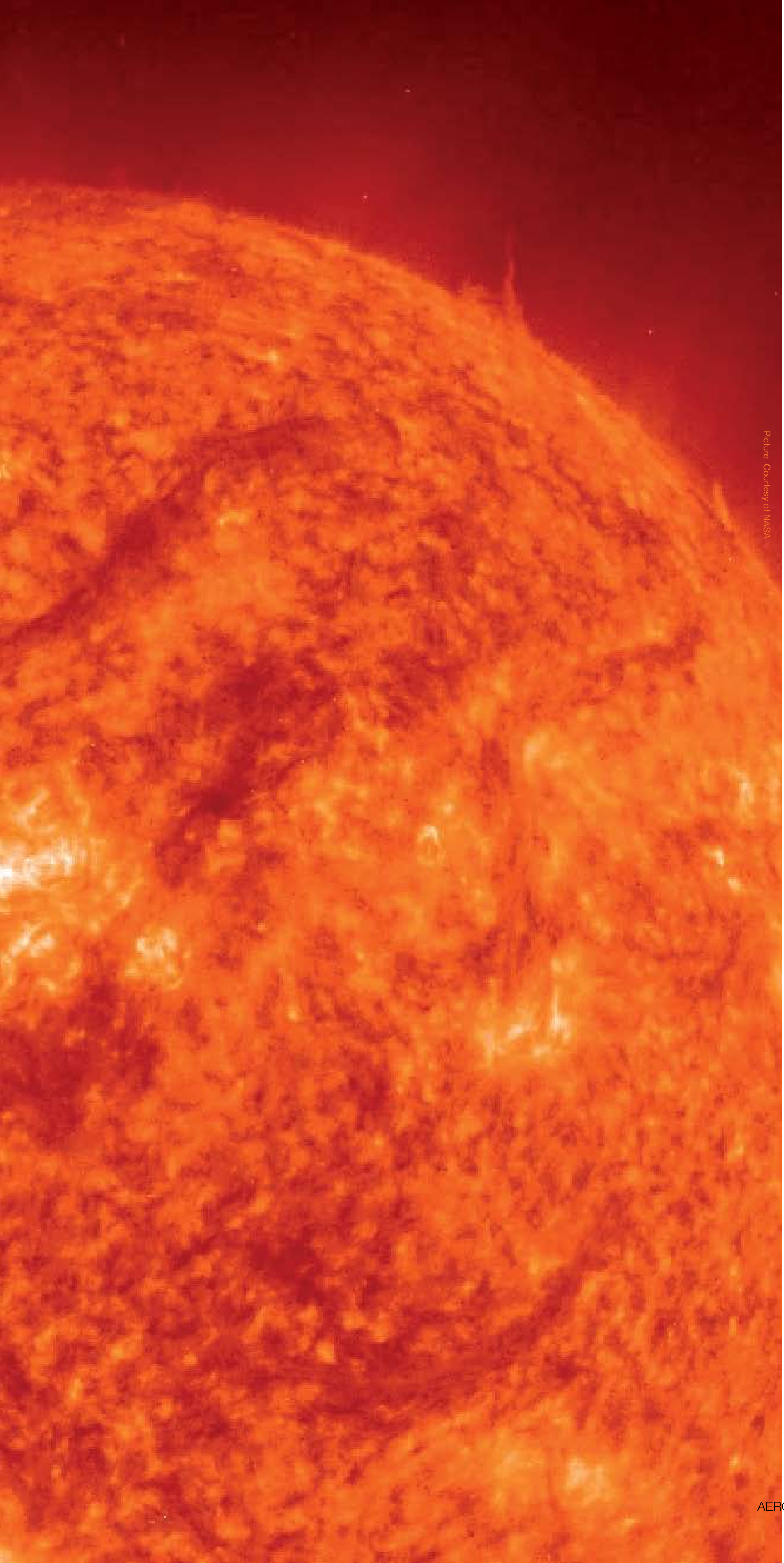
Cosmic flare-up

How neutron scientists in the UK are helping to ensure the safety of future aerospace technology against cosmic and solar radiation



Dr Martyn Bull

Work carried out at the leading ISIS neutron source addresses both the quality of microelectronic components inside the cockpit as well as the stresses exerted on the very structure of the aircraft. British neutron scientists are tackling the challenge of cosmic radiation and its damaging effect on sensitive microchips in the aviation industry. Accelerated testing at the renowned ISIS neutron source in Oxfordshire replicates the effect of thousands of hours of flying time in just a few minutes.

Solar wind, a flow of fast-moving charged particles from the sun, showers cosmic ray bursts onto the earth. These cosmic neutrons collide with microchips and upset or damage microelectronic devices. These episodes, known as 'Single Event Effects' (SEEs), can affect circuitry on the ground, but the problem is 300 times greater at high altitude. This makes it of particular concern to both the civil and military aerospace industry.

A microchip in an aircraft can be struck by a neutron every few seconds. When a neutron hits silicon, a nuclear reaction occurs causing an electrical charge shower that can interfere with the normal operation of electronic equipment.

Dr Chris Frost, project leader of chip irradiation research at ISIS, explains the phenomenon: "An SEE occurs when a high energy particle in the atmosphere strikes sensitive regions of an electronic device, disrupting its correct operation. This can lead to temporary loss of RAM memory or even permanent burnout of equipment functionality."

Although SEEs have long been recognised as an issue, the problem is being compounded by the drive for greater RAM density in computers. Smaller electronic circuitry is more vulnerable to this buffeting from neutrons.

During the 1970s and 1980s companies such as Boeing would fill an aircraft with electronic components and attempt to test the affect of SEEs on these systems once the plane had returned to

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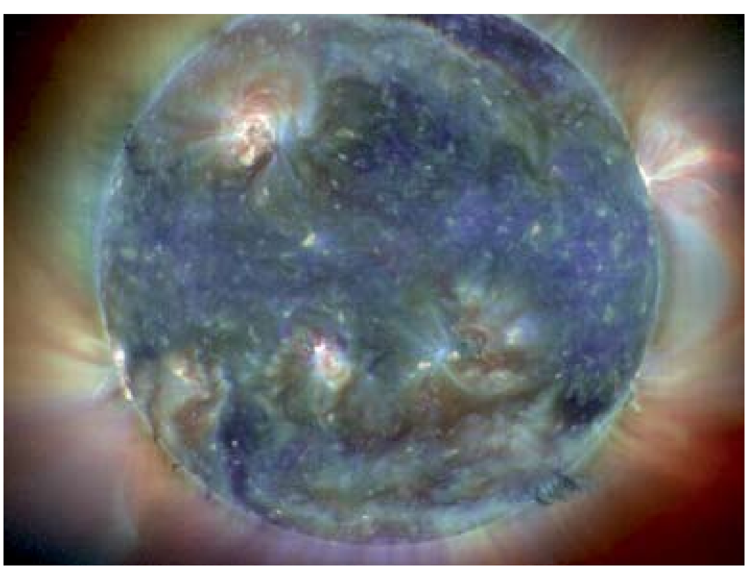
the ground. This was an extremely costly and inefficient way of experimentation. A far better way of tackling the issue is to test the quality and susceptibility of components under accelerated conditions. The ISIS neutron source, a leading facility for research in the physical and life sciences, can replicate the experience of four and a half years of flying time in just one hour of experimental time in the neutron beam.

Frost explained that by exposing components to neutrons produced at ISIS, the industry can learn lessons about the best way forward. "At ISIS we have the ability to produce intense beams of neutrons with similar energy ranges to those occurring naturally. This enables accelerated reliability testing of microelectronic elements used in the aerospace industry. Once manufacturers understand where the biggest susceptibility problems lie, they can begin to redesign circuitry on a more robust basis."

In 2003 a consortium of aerospace companies backed by the then DTI came together to start looking at the problem. MBDA, a leading aerospace systems company, heads the team known as SPAESRANE (Solutions for the Preservation of Aerospace Electronic Systems Reliability in the Atmospheric Neutron Environment). Other players in the group include BAE Systems, Smiths Aerospace and Goodrich Engine Control Systems.

Andrew Chugg, senior technical expert at MBDA, sees it as one of the major issues facing the industry: "SEEs are now recognised as the dominant reliability issue for avionics in the coming decade. Naturally occurring neutrons in the atmosphere are the most intractable source of SEE in electronic components, because they are too penetrating to be shielded."

Chip irradiation testing first began at ISIS in July 2006. A 20-year collaboration between ISIS and the Italian universities of Milan, Padua and Rome led to international electronics company ST Microelectronics being introduced to the ISIS source. Carla Andreani, Professor of condensed matter at the University of Rome, Tor Vergata, begins the story, "I was collaborating with ISIS on a project developing the VESUVIO spectroscopy instrument when a colleague put me in touch with ST Microelectronics which was looking to access the Los Alamos neutron source in the USA. I proposed doing a feasibility study at



Dr Chris Frost with an irradiated microchip (above). The Sun with solar flare and radiation highlighted (left)

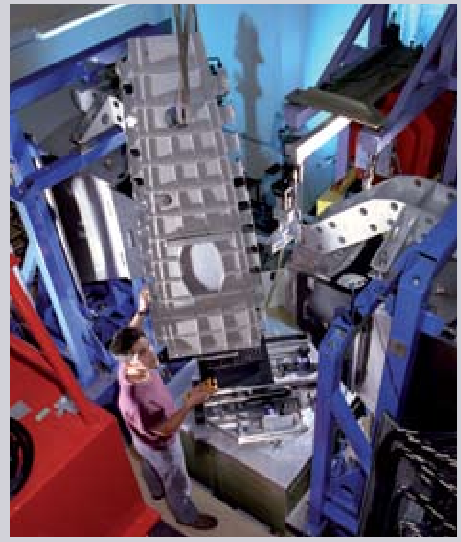
STRESSED OUT

Neutron science can also be valuable in testing the stresses and strains on the fabric of the aircraft itself. The structural integrity of an aircraft component is defined by its mechanical properties and residual stresses apparent in the component. It is therefore important to characterise the residual stresses generated during manufacture and establish the effectiveness of stress relief treatment before a component can be put into production.

Neutron stress measurement is a non-destructive technique that measures stress fields deep within engineering components and structures. It has become an important tool within engineering, leading to improved manufacturing processes to reduce stress and distortion as well as to the definition of more precise component life prediction procedures for safety-critical structures. Civil aircraft design regulations demand damage tolerance (essentially resistance to crack growth) in safety-critical parts.

Engineers at ISIS have developed techniques allowing the non-destructive evaluation of the residual stress field in the full range of specimens needed to provide the design data required for welded aircraft structures. This work is part of an EPSRC program also involving AirbusUK, Cranfield University and the Open University.

Reliable residual stress data is of optimum use only if it is used to influence both process design and subsequent damage-tolerance data collection and use. Traditional methods of stress measurement, using small, laboratory-sized representative samples, are no longer adequate for large fabricated components. This means there can be a size effect whereby the fatigue crack growth rates measured in small (100-300mm) laboratory specimens are no longer representative of those seen in larger welded structures.



Now residual stress fields are measured non-destructively in components as large as wing skin-stringer fatigue test panels. That representative aerospace structures can be routinely measured on the Engin-X neutron instrument at ISIS represents a

ISIS instead." A team of ISIS, the three Italian universities, along with ST Microelectronics carried out chip irradiation testing on field-programmable gate arrays (FPGA's) which form the basis of many microelectronic devices. FPGA's are semiconductor devices containing programmable logic components called 'logic blocks', and programmable interconnects. The tests revealed some important data for statistical analysis of the soft errors in FPGA's and RAM. From this point on ISIS knew they were able to be a major player in the chip testing field. It was after these initial tests that the SPAESRANE team came to ISIS and began their initial program of testing.

Although the current 'Vesuvio' instrument has been converted to carry out this work, future plans at ISIS are more ambitious still. A £140 million new 'target station' or neutron source is currently in the final stages of completion alongside the original building. The plan, subject to funding from the Science and Technology Facilities Council, is for the ISIS Second Target Station to include a dedicated and full time instrument to test the effects of SEEs and chip irradiation. The new instrument, which has already been designed, would be capable of recreating the experience of 100 years of flying time in just one hour. With the possibility of flooding a room with enough neutrons to test several chips simultaneously, it would be capable of testing complete systems in a working environment in an incredibly short space of time.

Chugg at MBDA welcomes the prospect, "ISIS is one of few facilities in the world capable of producing enough very high energy neutrons to perform such accelerated testing. The proposed instrument at the Second Target Station would result in the creation of the best SEE screening facility in the world."

Results from this testing will allow manufacturers to mitigate against the problem and build triple redundancy into their electronic components. This increased confidence in the quality of electronic systems will help to make both civil and military aircraft safer. It will also be beneficial to the electronics industry in general and help to safeguard future generations of mainframes, pacemakers, defibrillators, ABS systems and many other components in our everyday lives.

Richard Stockdill of ST Microelectronics also recognises the importance of a dedicated European site, "The development of a European facility for the testing of neutron-induced effects in semiconductor devices at the nanometric scale is being followed by STMicroelectronics with a great deal of interest.

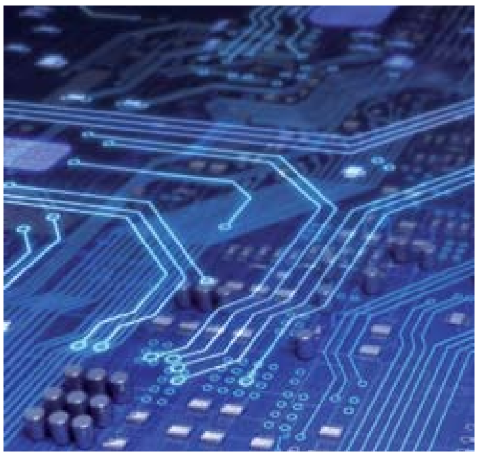
"The potential danger of this phenomenon should not be underestimated in the development of silicon chips in the future. Therefore it is very important to exploit the capability of monitoring it as the industry moves to finer process geometries. For this reason we are improving our collaboration with the Italian universities experienced in this field and also the Italian Research Council-CNR, which made it possible for ST to carry out its own measurement program at the ISIS neutron source." ∎

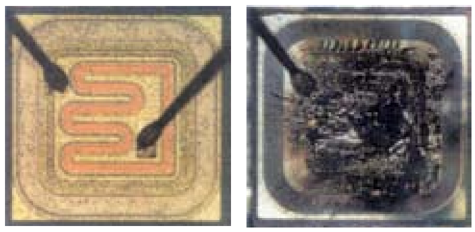
Dr Martyn Bull is a neutron scientist and head of communications at ISIS

SECOND STOP

The Second Target Station Project will keep the UK at the forefront of neutron research. It will enable scientists to continue to make breakthroughs in materials research for the next generation of super-fast computers, data storage, sensors, pharmaceutical and medical applications, materials processing, catalysis, biotechnology and clean energy technology.

ISIS is the major facility at the Rutherford Appleton Laboratory, and has been operating for over twenty years. ISIS is a world leading centre for research in physical and life sciences.





Transistor before damage and after (above). Cosmic neutrons can easily affect onboard micro-systems

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