

Spin-off successes

European Space Agency
Agence spatiale européenne

***Preparing for
the FUTURE***



LE BOURGET SPECIAL 1999

contents

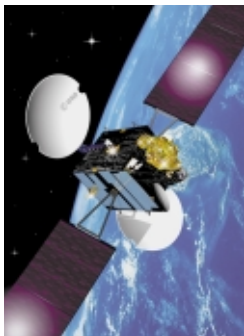
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ESA's role in technology transfer

From Antonio Rodotà, the Director General of the European Space Agency

Today, the achievements of space programmes have become so much a part of the economic, social and scientific scene that there is a tendency to undervalue their significance and the benefits associated with them. Through its technology transfer programme, the European Space Agency (ESA) has recognised the importance of helping other areas of industry to benefit from space research, and of easing the burden on public resources by adapting space technologies systems, and know-how to meet the needs of the wider population of Europe.

By moving technologies and know-how from the space sector to other sectors, companies can reduce the time scale and cost of developing new products. Technology transfer also reduces duplicated research and provides opportunities for professionals from a variety of industries to collaborate, increasing the overall effectiveness of Europe's scientific base. Finally, the exposure of European space technology to outside markets provides companies with a chance to inject their own expertise into the space industry.

A record of success

ESA has been measuring the success of its Technology Transfer Programme (TTP), now headed by Pierre Brissot from the ESA Technology Research Centre, ESTEC, in the Netherlands, since the early 1990s. At that time, a consortium of transfer agents from the ESA member states, the Spacelink Group (see page 34), was formed to support the activities of the programme. The success of the TTP, which has had the full support of Europe's space industry, can be summarised by the following achievements:

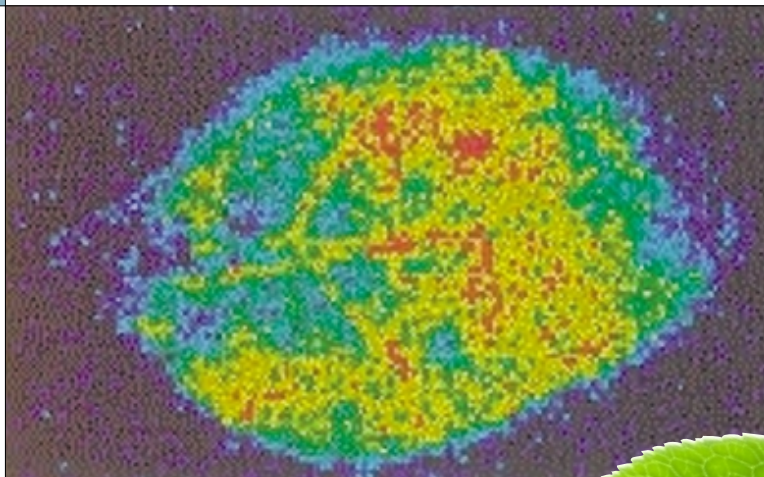
- More than 200 space companies have participated in the programme;
- 400 space technologies have been actively marketed;
- More than 70 transfers of technology have resulted between space and non-space industry, many transnational;
- The direct commercial benefit to European industry already runs into hundreds of millions of Euro.

This publication contains examples of a number of successful market applications of European space technologies. The companies involved in these transfers have seen significant financial and economic impacts to their businesses from these new developments. In many cases, the transfers themselves have contributed directly to the social and physical well-being of the people in Europe. The number of transfers in the medical sector is particularly rewarding. Because it can take up to five years from the introduction of the technology to the release of the product to the consumer, some of the innovations described offer a brief look into the future improvements to our lives that space research will bring.

I am very happy to present this compilation of *Spin-Off Successes* at Le Bourget '99, the biggest aeronautical and space event in the world. ESA is working hard to improve the image and awareness of the European space programme and this publication – a direct result of the technology transfer initiative – is only one of a number of tools that effectively illustrate how space can play an important role in society.

A. Rodotà

Technology used to detect and analyse faint objects in space has been adapted to observe chemical signalling from cells in plants and animals – including humans



Biomedical research is benefiting from advances in telescope technology

Making light of living cells



Researchers have for years been working towards the ultimate goal for astronomers – a telescope with optics so perfect that they catch, focus and analyse every photon of light available from even the most distant of heavenly bodies.

One of the most important technological developments in this area is the charge-coupled device (CCD). These silicon chips consist of light-sensitive pixels which convert impinging photons into electric charge. The accumulated charge is transferred out of the device, then measured and recorded, giving a measure of the number of photons that have hit. Data from an array of CCDs can then be converted into an image.

Ground-based and space telescopes now use CCDs, as do cameras and many other optical devices. Researchers at ESTEC are at the forefront of this technology, and their work is found in ground-based telescopes on La Palma in the Canary Islands, and in the Faint Object Camera in the Hubble space telescope – a European contribution to this successful project.

In an early success for ESA's Technology Transfer Programme, JRA Technology – the UK Spacelink partner – enabled the licensing of a vital element of the software controlling the CCDs to a UK company, Photek Ltd, which specialises in making cameras for biomedical applications. In 1993, Photek developed the technology further to detect bioluminescent and fluorescent materials incorporated into living cells. These markers allow researchers to follow and analyse the structure and internal workings of a cell (a greener alternative to radioactive tracing). Work was supported by the EU-EUREKA programme with partners HiLight OptoElectronics BV in Holland, IBH Consultants in Scotland, and the Rutherford Appleton Laboratory in the UK.

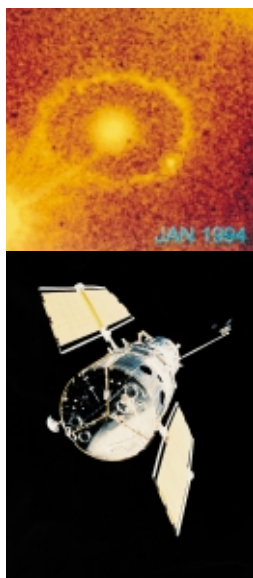
Seeing cell signals

One of the first beneficiaries of the new technology was Tony Campbell of the University of Wales College of Medicine. Campbell uses a bioluminescent protein extracted from glow worms to follow the behaviour of living cells. The protein molecules attach themselves to calcium ions, known to be involved in the internal cell-signalling process. Using the Photek detector it is possible to watch cells responding to stimuli in real time. Early experiments mapped the response of a seedling to being touched by an ice cube. Campbell believes this research offers important potential for the understanding and control of disease.

Technology, meanwhile, moves on. ESTEC researchers are now working on a technology based on a novel device called a superconducting tunnel junction (STJ). Exploiting a bizarre quantum phenomenon called the Josephson effect, an STJ not only detects photons but also distinguishes their wavelength, or colour. This spectral information is of great interest to astronomers.

The STJ could also be useful in medical research. Campbell and the Photek team are working on a device that detects colours to enable further research into genetically interesting areas such as the study of 'rainbow proteins' developed by Campbell. These bioluminescent proteins are genetically engineered to change colour when they bind with a particular chemical in the living cell. They have exciting applications in drug discovery and clinical diagnosis. For example, a potentially cancerous cell will change from red to green or from red to blue, and the next generation of photon-counting cameras will be able to record this, providing scientists with valuable data on the onset of disease. ■

The Hubble space telescope
Photon-counting technology developed by ESA is used in the Faint Object Camera – Europe's contribution to the Hubble space telescope – which identifies distant galaxies and supernovae



An analytical technique modified and improved for use in space has been transferred to industry via a company takeover

Separation technology brings companies together

High performance capillary electrophoresis (HPCE) is a powerful analytical method used extensively in hospitals, drug companies and the chemical industry. It is used to separate out individual compounds, for example proteins, from biological mixtures. Medical applications include the analysis of urine and blood samples for metabolic disorders, and the monitoring of concentrations of anticancer and anaesthetic drugs in the body. The technique involves passing the sample mixture down a capillary tube under the influence of an electrical field. Each kind of molecule moves at a different speed that depends on its electrical properties. Once the constituents of the mixture have been separated, they can then be identified chemically using standard spectroscopic and other techniques. HPCE requires only a small sample and, with minimum preparation, can analyse both high and low-molecular weight, charged and uncharged substances.

In the Netherlands, research on capillary electrophoresis has been centred at Eindhoven University, which several years ago started to investigate the possible application of HPCE in space laboratories. One important use of shuttle and space-station missions is to exploit microgravity conditions in various ways – for example, to prepare and analyse materials of biological significance. It is, for instance, extremely difficult to grow protein crystals on Earth that are large enough and perfect enough to analyse, partly because of the effects of gravity. Such materials are often limited in stability so it is necessary to analyse the structure quickly – in other words, in space.

An analytical system for space

It was with this aim that Eindhoven and an industrial consortium including the companies Comprimo BV and Lauerlabs BV began to develop a range of small, modular fully-automatic HPCE systems, some adapted for manual operation, for example, for monitoring the physiological changes in the body fluids of astronauts. These would initially be used on shuttle Spacelab missions and have the possibility for future use on the Columbus module for the International Space Station.

In 1994 Spacelink promoted the possible non-space use of these modular systems, at that time being produced by



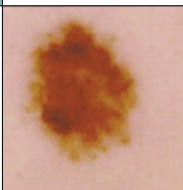
A modular high performance capillary electrophoresis unit

Lauerlabs BV, through the ESA technology catalogue. Helena Laboratories, a UK company making analytical instruments for the health and pharmaceutical industries, immediately spotted the synergy with its own range of products. The company also saw the possibility of improving its analytical support to clients by introducing portable automated machines. Helena quickly determined that the most effective way of achieving the necessary technology transfer would be to acquire Lauerlabs and this duly happened in January 1995, thus bringing the benefits of a valuable programme of space-focused research to the wider European pharmaceutical and clinical community. ■

High performance capillary electrophoresis units have been used by astronauts to complete microgravity research on Spacelab missions



The MELDOQ system helps doctors to diagnose skin melanomas



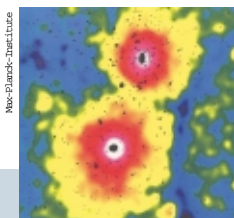
Cancer patients benefit from astrophysical research

A mathematical method used to analyse data from the X-ray satellite ROSAT is now offering a new way of detecting skin cancer in its early stages

An algorithm called the scaling index method (SIM) was developed at the Max Planck Institute for Extraterrestrial Physics (MPE) and extracts meaningful information from the sets of X-ray data gathered by the ROSAT satellite. This method detects very weak signals from the background of 'random noise', sources which might otherwise not have been noticed. SIM can also help to detect point-like and extended sources of X-rays and can characterise quantitatively fine structures in astrophysical sources, such as supernova remnants.

Researchers from MPE realised that SIM could be applied to other data sets where relevant information may be buried in background noise. The development team sought out partners at universities and institutes to exploit the algorithm's application potential. One group at the Institute for Medical Statistics and Epidemiology at the Technical University of Munich proposed several ideas, one of which became the project MELDOQ (melanoma recognition, documentation and quality assurance system) funded by the German space agency. Several other German institutes were involved as partners in this project, including the Dermatological Clinic in Regensburg, Fachhochschule München, and the Institute for Informatics at the Technical University in Munich.

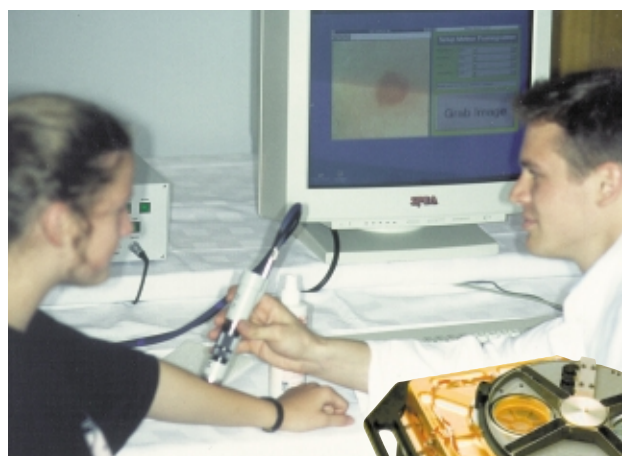
The cluster of galaxies A3528
An X-ray image from ROSAT of the largest confined objects in the Universe. The two colourful subclusters will merge in about 100 million years and contain information that tells scientists about the early Universe



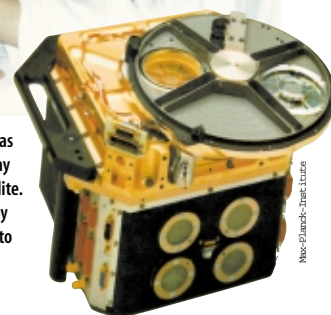
The ROSAT satellite

ROSAT is a joint German/US/UK mission to study sources of X-rays in the Universe, designed, built and operated by the German research institute DLR. The mission has just ended after operating successfully for eight years, detecting signals often from distant and weak X-ray sources. These data must be processed with the help of sophisticated methods to maximise the scientific results.

In fact, advanced data pre-processing and analysis techniques are some of the reasons for ROSAT's outstanding performance. During its eight years of scanning the Universe, data analysis capabilities have enabled ROSAT to detect more than 120 000 new X-ray sources. They have also enabled scientists to develop more precise descriptions and models of a wide spectrum of astrophysical objects – neutron stars, supernova remnants, protostars, galaxies, and even comets.



The scaling index method (SIM) was used to analyse data from the X-ray camera (right) on the ROSAT satellite. Patients undergoing dermatoscopy (above) benefit from SIM's ability to detect weak signals



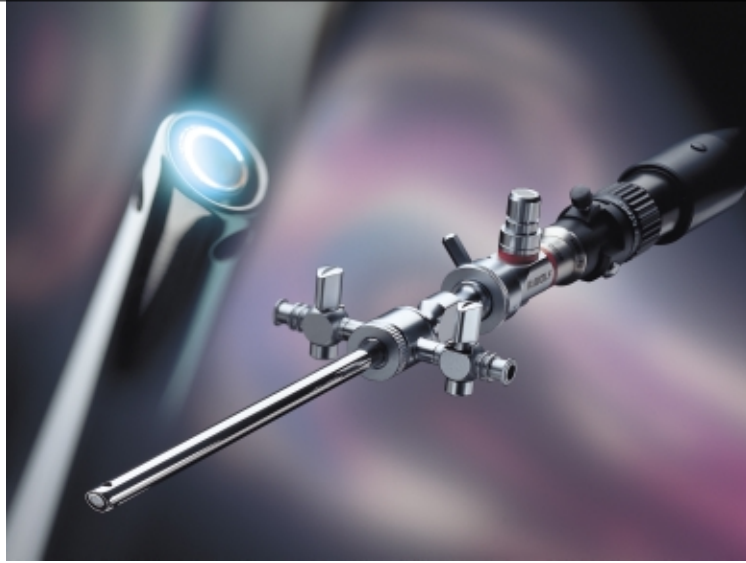
The MELDOQ system

MELDOQ is a computer-aided early recognition system of melanomas that uses digital image analysis. The system is based on dermatoscopy – a procedure that scans the skin's surface and magnifies it 10 times. Using SIM, the system can pick out finer differences in the colour of the tissue and quantify the distribution of structural components associated with the irregular cell growth of malignant melanomas. Complexity measures are employed to quantify the dermatoscopic ABCD-scores which describe different criteria of a melanoma – asymmetry, border, colour, and differential structures. The single letter scores are analysed and combined, turning the system into a dermatoscopic workplace which can powerfully assist the physician in the diagnosis of initial malignant melanomas.

MELDOQ provides an easy-to-follow system of classifying the results. It allows the doctor to make comparisons with reference cases, and supports them in reaching a reliable diagnosis. The system also has software models that teach medical students to diagnose skin cancer using this method. Furthermore, MELDOQ supports doctors, who may not be experts in dermatology, to make a diagnosis like an expert. This can lead to an earlier recognition of cancer, and usually a more accurate diagnosis. This year, the system will be tested on a PC platform in the Dermatological Clinic in Regensburg. ■

An oxide ceramic coating originally used to reduce light scattering in space cameras is now being used to coat endoscopes for medical and industrial use

Richard Wolf GmbH



An endoscope from the company Richard Wolf GmbH, with close-up detail of the optical system

Space coating

helps doctors see clearly

Scientists from two industrial-coating companies in Germany developed a coating process that minimises light scattering, and in 1993, they formed the company, PTS, in Jena. Their unique process generates layered, optically-perfect black surfaces without the use of varnish (varnish amplifies light-scattering effects). These surfaces are durable, sustain stable optical properties, and have uniform light-scattering characteristics. The coating, called Plasmocer, was originally developed for use in space cameras which have flown on both ESA and Russian satellites such as ASTRO 1-M, HRSC, SOHO, and SILEX.

Plasmocer-coated cameras in the SILEX project will allow ESA to test for the first time the transmission of data using light from a laser in space. The enhanced quality of the image from the coated cameras will enable optical communications between satellites in geostationary and low-Earth orbits, and a one-metre mirror telescope acting as a ground station. By overcoming the effects of light-scattering, ESA and other satellite controllers will be able to steer the beam of light more precisely than ever before, thus minimising energy losses. This should result in high rates of data transmission with low power consumption.

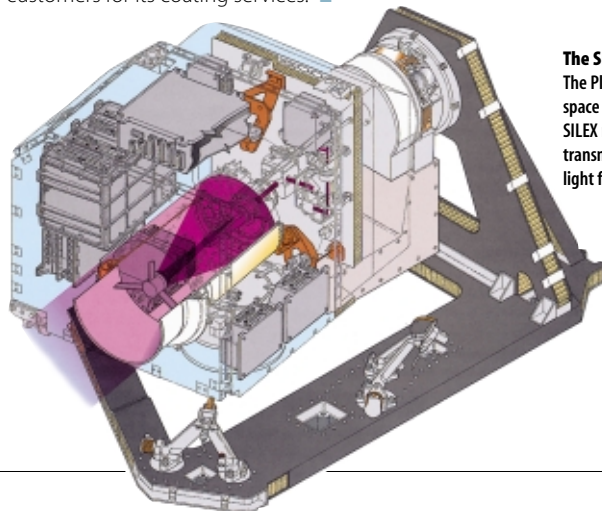
Moving from outer space to inner space

In 1994, PTS was introduced by MST – the German Spacelink partner – to Richard Wolf, the German manufacturer of medical and industrial endoscopes. Endoscopes are flexible tubes with a camera and a light source at one end, and are able to see inside a small, enclosed space. Typically, they use fibre-optic systems to transmit images back to a remote point.

In medical applications of endoscopes, the camera and fibre-optic cable are threaded through an opening in the human body so as to provide the physician with an image

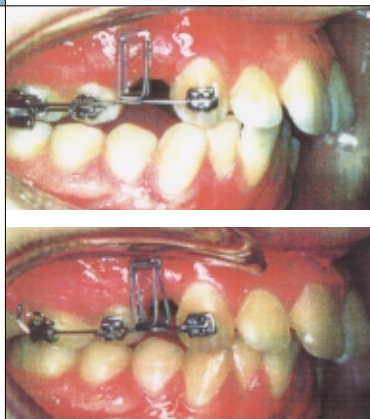
of internal organs such as the oesophagus, stomach, and colon. This procedure is commonly used to detect and diagnose afflictions such as tumours, ulcers, and dilated blood vessels. Additional instruments attached to the probe end of an endoscope enable the doctor to carry out diagnostics as well as perform small procedures such as biopsies – which, of course, require the most accurate image possible.

Richard Wolf was looking for a technology which would enable the company to obtain better images with its endoscopes by reducing image distortion. The Plasmocer coating seemed promising. In 1995 and 1996, PTS carried out test coatings on endoscope components. These tests showed that the coating enhanced the optical quality of the image by reducing light scattering by about 20 per cent. As a result, PTS received an order from Richard Wolf to coat 3000 endoscope parts. During the following three years, PTS expanded this market niche, acquiring three new customers for its coating services. ■



The SILEX camera
The Plasmocer-coated space camera flown on the SILEX mission tested the transmission of data using light from a laser in space

'Before' and 'after' photos show the impressive performance of the SMA spring in moving teeth together



A UK company has been developing medical devices, including a new orthodontic spring, from shape memory alloys used in space

Shape memory alloys (SMAs) are materials with a remarkable property: they 'remember' a shape given to them by a simple heat treatment. If the material is bent out of shape it goes back to the original form when a little heat is applied. Super-elasticity is another property of SMAs; at room temperature the material can be stretched or deformed and, like an elastic band, will return to its original shape.

These fascinating materials were originally discovered in the US and were first put to use in aerospace applications. In the 1990s, Brunel University's Institute of Bioengineering near London began to experiment with SMAs for use in the European space programme, particularly in plant and life-science research. Because astronauts are busy performing research projects in space, it is necessary to automate routine tasks where possible. In experiments, samples often need to be turned or cut regularly. One way of doing this is to make clutches or hinges from SMA that will turn a

sample when it reaches a certain temperature.

A researcher at Brunel, Tony Anson, recognised that SMAs, particularly nickel-titanium alloys, have applications in the medical sector which would compete with products that have high market values. In 1994, he created the company Anson Medical Ltd. to develop shape memory products for these new markets. The company has already seen success in developing staples made of SMA that pull together segments of broken bones when activated by body heat.

The SMA orthodontic spring

In 1996, Anson Medical began working with OrTech, a small dental engineering design consultancy in Norway, and the Danish Technological Institute in Denmark, to create an orthodontic spring that can control the displacement of teeth. Although orthodontic-wire treatments employing SMAs are already being produced and distributed in the UK, US, and Japan, the Anson Medical/OrTech spring is patented for new treatments including linear movement of teeth along the gums.

The way the orthodontic spring works is simple. It is attached to the teeth using conventional fixing brackets and is secured in place under tension. The tensile forces gently draw the teeth together, closing unwanted gaps. The extraordinary elastic property of the SMA is exploited – the device acts like a spring which can be stretched much more than an ordinary one. Because of this, the forces

Smart materials for smart mouths



applied to the teeth are constant, but gentle.

The spring provides a number of benefits over conventional devices to both the patient and the dentist. Not only is the rate of tooth movement about two and a half times higher than in standard treatments, but the movement of the teeth is more precise and patients feel less pain. Visits to the dentist are shorter and less frequent, so more patients can be treated. The saving in time for dentist and patient is increased further because the springs are pre-fabricated, requiring less preparation during fitting.

About one-quarter of all children will need orthodontic treatment during childhood, and ever more adults are seeking this kind of help for both medical and cosmetic reasons. Conservative estimates value the market for the orthodontic spring in the region of 5.8 mEuro per year. Anson Medical and OrTech anticipate the availability of the orthodontic spring on the market sometime during 2000 or 2001. ■

A technique for mapping the ozone layer is being developed for diagnosing budding cancer cells

Microwave spectroscopy was used to map the hole in the ozone layer (below) while the same technology may assist with the early diagnosis of cancer cells (left)

Microwave magic

Microwave radiometry is a well-established analytical technique. It is used to identify and measure materials which emit and absorb microwaves at certain wavelengths to give a characteristic spectrum. In the UK, microwave radiometry has been adapted by researchers at British Aerospace Space Systems (BAe, now Matra-Marconi Space, MMS) and the Rutherford Appleton Laboratory, RAL, (now part of the Central Laboratory for the Research Councils) to measure remotely atmospheric moisture and ozone.

Working with the UK Meteorological Office, BAe developed an instrument – the advanced microwave sounder unit (AMSU-B) – with on-board receivers dedicated to the frequencies associated with the microwave absorption spectrum of water and which measured the distribution of water vapour in the Earth's atmosphere. It was the forerunner of similar equipment that has since provided accurate data for weather-forecasters and climatologists.

In a different application, RAL in 1990 developed a unit which was tuned to the ozone absorption spectrum. When mounted on the American UARS satellite it provided the first maps of the changes to the size and thickness of the ozone layers above the geographic poles.

Non-invasive diagnosis of disease

Individual living cells have their own 'fingerprint' microwave emission and absorption spectra. It is thought that by detecting and evaluating changes in these spectra abnormalities can also be detected – providing an early indication of the onset of disease and its underlying causes.

MMS and a consortium of UK researchers have been awarded a grant from ESA to examine the possibilities for applying the microwave technology in this application. The results could lead to a non-invasive body scanner that can detect the microwave emissions associated with the 'switch-on' signals which trigger a chemical reaction within a cell leading to malignancy. Using such a body scanner at an early stage could lead to more options for treatment and better survival rates for patients. The non-invasive nature of the testing could also encourage more patients to undergo cancer screenings.

The underlying microwave technology provides a springboard for developing other measurement techniques

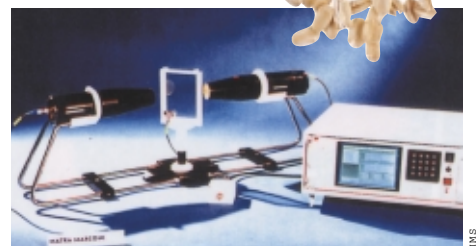
which can be used in other everyday applications – particularly those where accurate, real-time measurements are required.

- **MOISTURE DETECTION** in foodstuffs. MMS has developed a commercial device for measuring the moisture content in cereals, with a prototype undergoing continuous evaluation in a facility for producing dried animal feedstuffs in the UK. It is often important to know the precise level of moisture in food during processing as this has implications for freshness, quality and taste – and also economics. A large proportion of the cost of the production of raw grain cereals and other processed foods is in the transport and handling. Reducing the quantity of water in a process reduces overall weight of the product and the savings can be considerable.

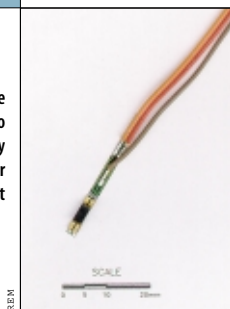
- **SECURITY SCANNERS** which can detect non-magnetic items. Current security systems at airports use magnetic detection to spot metallic objects as people pass through. A spectrometer would allow security staff to identify both metal and non-metal objects, such as drugs or firearms made of composite materials, located on or close to the body. Using either passive or active microwave systems to measure the changes in emissions from the scanned body, an image can be generated which reveals and identifies hidden foreign objects that would not have been detected with the currently used systems.

- **MEASUREMENT OF OIL AND WATER** in offshore oil pumping. It is important for the offshore industry not only to keep its costs down, but also to maximise the recovery of oil from subsurface reservoirs while maintaining environmental standards. The new microwave technology furnishes oil companies with a more accurate measurement of the mix of oil and water in the distribution pipeline. This allows them to adjust their recovery procedures in real time while making considerable savings in costs. ■

The MMS microwave moisture measuring device is used to measure the water content of cereals



A prototype of the miniature dosimeter to be used in laboratory trials for endovascular brachytherapy treatment



An Italian research institute has been using radiation sensors developed for ESA to monitor a medical technique that keeps unblocked arteries open

Space radiation monitors aid treatment of heart disease

Between 1975 and 1978 the company, Radiation Experiments and Monitors (REM) in Oxford in the UK, developed the radiation-sensitive field-effect transistor (RADFET) for ESA. The device acts as a radiation dosimeter, monitoring the cumulative or integrated dose of radiation on equipment in space. It has been used in unmanned programmes such as the Meteosat-3 meteorological satellite and the Hubble Space Telescope.

The simply-designed silicon chip carries a layer of 'thermal oxide' which has been sensitised to ionising radiation (gamma rays, hard and soft X-rays and high-energy particles). Radiation impinging on the sensor permanently changes the silica layer such that it acts as a record of the radiation received. The chip can then send

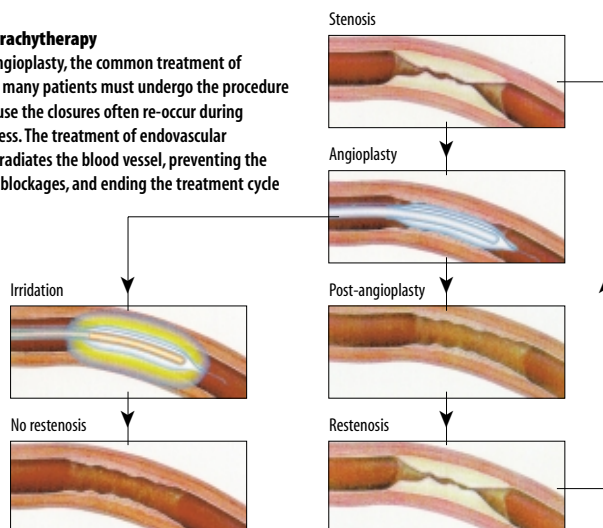
out a signal transmitting the radiation dose data in real time to a remote monitor.

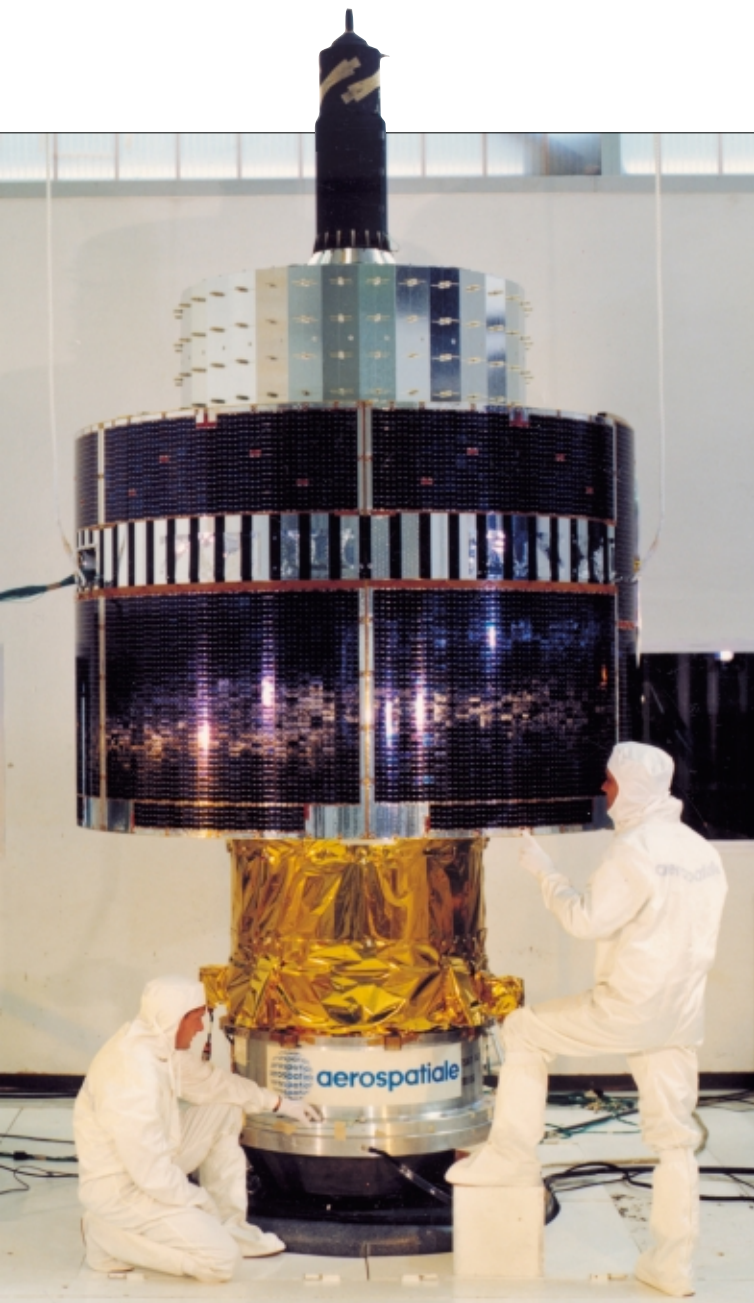
A key advantage to the RADFET is that, as a micro-electronic device, it can send its 'integrated dose' signal through a cable or radio link, and can thus be used remotely. It, therefore, has a potential use in terrestrial applications spanning sectors such as nuclear safety, civil defence, industrial processing, energy, environment, and medicine. The device has other advantages: it is cheap, costing less than 1 Euro before packaging, it is very small, only one square millimetre, and it can detect many types of radiation at a wide band of energy levels, from 0.1 rad to 100 megarad. Many thousands of RADFET chips can be made in a single production run costing around 17 000 Euro. Protective encapsulation is done using mass-production methods that were perfected in the semiconductor industry.

On the medical front, in a government-funded project, Harvard Medical School in the US used the dosimeter to test its suitability for *in-vivo* radiation monitoring during the treatment of cancer. The sensor was cut to size and inserted through a needle into tumours in mice. Although these tests were limited in scope, the results encouraged REM to pursue further medical applications, particularly where radiation needs to be carefully mapped over a small area. In 1997, D'Appolonia – the Italian Spacelink partner – contacted the highly regarded Italian institute for cancer research, Istituto Scientifico Tumori (IST), as a potential development partner for REM. Luciano Andreucci, Director of Biophysics at IST, recognised the possibility of miniaturising the dosimeter and identified a new medical application of the RADFET in a treatment called endovascular brachytherapy.

Endovascular brachytherapy

With coronary angioplasty, the common treatment of blocked arteries, many patients must undergo the procedure repeatedly because the closures often re-occur during the healing process. The treatment of endovascular brachytherapy irradiates the blood vessel, preventing the re-occurrence of blockages, and ending the treatment cycle





Space radiation

Naturally occurring radiation in space (from the Sun and cosmic rays) is an environmental problem that spacecraft designers and mission managers must take into account in relation to the life span of equipment flown in space. Radiation such as high-energy electrons and protons – commonly found in the belt-shaped regions around Earth and Jupiter – causes physical damage to the molecular structure of materials, particularly those used in optical and electronic components. Particles of radiation can dislodge electrons from the material's atoms or even their nuclei. This degrades the efficiency of solar panels, sets up anomalous currents which can cause the unexpected resetting of spacecraft computers (single-event upsets), or can lead to the catastrophic failure of digital circuits.

Solutions to the problem of space radiation include shielding spacecraft from the radiation and monitoring it. Unfortunately, shielding is an inefficient technique which often adds extra weight to the spacecraft, increasing the cost of the launch and limiting the amount of equipment that can be carried by the vehicle. Radiation-tolerant parts are also very expensive. Monitoring the radiation during development can help determine how long systems will last under the level of exposure experienced during the mission. It also reveals opportunities for saving weight by shifting radiation-sensitive equipment away from high concentrations of radiation or for applying economical 'spot shields' on sensitive areas only.

RADFET was used to monitor space radiation encountered by ESA's Meteosat-3 satellite

procedure – many traditional devices are too expensive, cannot provide real-time measurements, and are not small enough to fit in a catheter or be used in the body. Until now, the experimenters have been forced to rely on artificial models for their calculations.

The solution, being developed by REM and IST, is to mount a RADFET sensor in the catheter in order to monitor the locations where a radiation dose may be delivered. The aim is to send the signal giving the accumulating radiation level to instruments that the medical team can monitor during treatment. Because the RADFET is so cheap when produced in bulk – less than 1 per cent of the total cost of treatment – it can be thrown away after each procedure.

Rewards from RADFET

Animal trials on endovascular brachytherapy are now well advanced and human trials are just beginning. However, it will probably be several years before the RADFET dosimeter is routinely incorporated in the procedure. Andreucci is currently involved in the development of an endovascular brachytherapy treatment unit, and is collaborating with various companies on the engineering side.

It is estimated that, globally, around one million patients a year will be candidates for endovascular brachytherapy. With a new sensor being used for each intervention, the potential world market for the RADFET dosimeter in this application is in the area of 30 MEuro per year. ■

Eliminating arterial blockages

When doctors find plaques and accumulations of cholesterol on the interior walls of arteries (arteriosclerosis), they often treat patients with coronary angioplasty. A balloon catheter is inserted into the artery to open the insides of the blood vessels so as to prevent coronary events such as heart attacks. In about 45 per cent of patients, arterial blockages or closures re-occur during the healing process (restenosis), and the patient must undergo the procedure again.

Recently, research has shown that irradiation can prevent arteries from becoming blocked again. This involves inserting a catheter into the blood vessel, which is then exposed to gamma-ray (typically from the radioisotope iridium-192) or beta-ray (typically from phosphorus-32) radiation. This treatment is called endovascular brachytherapy.

In order to control the degree of irradiation so as to prevent damaging the surrounding tissues while optimising the treatment, the amount of radiation in each layer of the tissue needs to be monitored precisely. However, no suitable dosimeters were available for this

Virtual reality software was used to visualise the ERS-2 satellite (inset). It was also used to animate the motion of Hurricane Andrew (right)

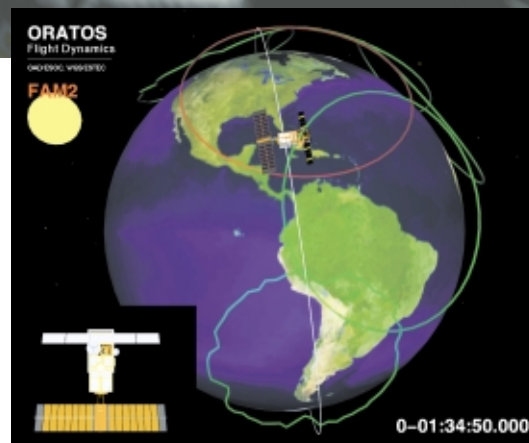
A virtual spin-off

An ESTEC engineer with expertise in computer simulations of spacecraft operations has established a spin-off company to offer the same technology to other industries

For the 10 years until 1996 Frank Bagiana was working in ESA's ESTEC laboratories in the Netherlands on research into software for 3-D visualisation and simulation. His aim was to develop tools that could support activities such as training astronauts, remotely controlled tasks (including medical operations) requiring video links, and simulating future satellite missions.

In this last application the software was used to visualise in real time the deployment of the antennas and solar panels of the ERS-2 satellite after it was launched. It was also used to visualise (in 3-D) and animate the motion of Hurricane Andrew over a period of four days in 1994 using infrared and water-vapour data received from the meteorological satellite Meteosat orbiting high over the Caribbean. The animated sequence has provided meteorologists with a unique insight into how the hurricane formed and behaved.

When in 1996, however, ESA was required to rationalise areas of ESTEC research, Bagiana identified the possibility of offering his expertise more broadly to European industry by establishing a spin-off company. With funding from the ESA Social Plan – established to support such initiatives – and permission from ESA to use the software tools he had



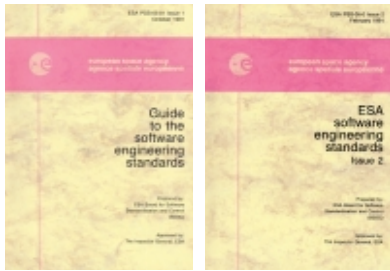
Ariane-5 launches are visualised in real-time using VR techniques



helped develop, Bagiana established Silicon Worlds as a spin-off company in Paris. Its aim was to provide expertise in virtual reality and other services across a whole spectrum of markets from the automobile industry to the media.

Today, three years on, Silicon Worlds employs 10 people and has a turnover of one MEuro. The software has been further developed and sold as a product to Arianespace for use in the real-time visualisation of Ariane-5 launches – from lift-off to payload separation. The graphical visualisation of the ill-fated Ariane-501 flight was recorded and presented to the committee investigating the accident.

More significantly, with French and German partners the company is now contributing to a 6.3 MEuro EU-ESPRIT programme aimed at producing a commercial PC-based tool (called the 'distributed instrumentation simulation tool') for the broader industrial market. Silicon World's role is to provide the 3-D visualisation element of the simulation. One of the applications for the developed tool is the visualisation of vibration and acoustic data obtained when testing car-body panels. ■



ESA's software standards control the production, integration and testing of software. They are a benchmark for the space sector and have been published in a generalised format for use in other industries

ESA's software standards employed world-wide

Developing software, particularly for large, multi-faceted space projects, is a complex business. Commonality of specification, design, validation, test and documentation, together with rigorous attention to configuration control, is essential if critical and potentially expensive failures are to be avoided. ESA was one of the first organisations to see the benefit of producing comprehensive software standards. Projects such as Ariane and the ERS satellite have immense software requirements with interfaces spanning many spacecraft systems and companies throughout Europe. In environments such as this, an enforceable model of software development is essential to guarantee the success of a project.

A similar situation exists in many non-space sectors that depend on computers and high technology. As computer and communications technologies become ever more sophisticated, the global marketplace becomes smaller. Companies and employees from different regions collaborate on projects which are eventually integrated and implemented at a central point. These organisations need to be certain that their software complies with universal rules.

Standards for all

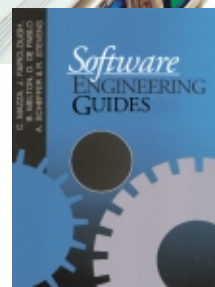
ESA first developed and published a set of software engineering standards in 1984. These quickly became the norm for all ESA programmes with a software content and have been regularly updated. These regulations soon became adopted by many space companies – even for their non-space related programmes – and the seeds of technology transfer in this area were sown.

As space contractors began applying the guidelines to their non-space projects, word spread of their benefits, and demand grew for the publication among non-space companies. In 1994 Prentice-Hall publishers began printing and distributing both the *Software Engineering Standards*

and *Software Engineering Guides* to meet this world-wide demand.

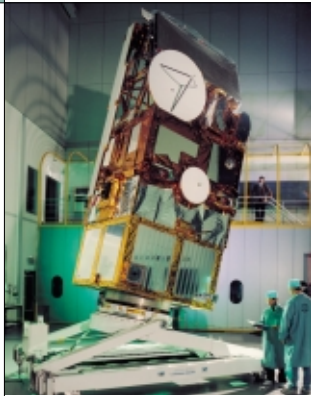
In the past four years, Prentice-Hall has sold more than 8000 copies of the guides to companies from countries all over Europe as well as other parts of the world including the US and Australia. Users include organisations such as the Defence Evaluation and Research Agency in the UK who have benefited from the logical systematic approach to complex projects. ESA can justly claim to have had a significant influence on the development of effective software standardisation in Europe. ■

ESA projects have immense software requirements that need to comply with universal rules



Prentice-Hall has sold more than 8000 copies of the new guides to industry

The ERS-1 satellite uses radar interferometry to image the Earth



A software package designed to create interferometric data from radar satellites is being used to detect changes to the Earth's surface

Satellite software aids earthquake research

Today, the Earth's surface can be mapped using satellite radar imaging. Even small changes on the Earth's surface can be monitored over a period of time. This is done via a technique called interferometry, whereby two radar signals acquired from approximately the same geographic position but at different times are combined and thus compared. If the signals are identical then the wave-form of the combined signal will remain the same. If there has been any change at ground level then the waveforms will be slightly different and will 'interfere' when combined (in the same way that some waves are partially cancelled and some are re-enforced when they interact). By analysing this interference pattern on a computer it is possible to identify any changes in

topography and to map small displacements.

Interferometric measurements have traditionally been carried out using simultaneous measurements from two or more instruments situated in different locations. However, a single satellite can 'interfere with itself' if its measurements are taken and properly recorded at consecutive passes over the same place. This technique was developed in the 1980s when software became available that could compute the radar data digitally and in a reproducible fashion.

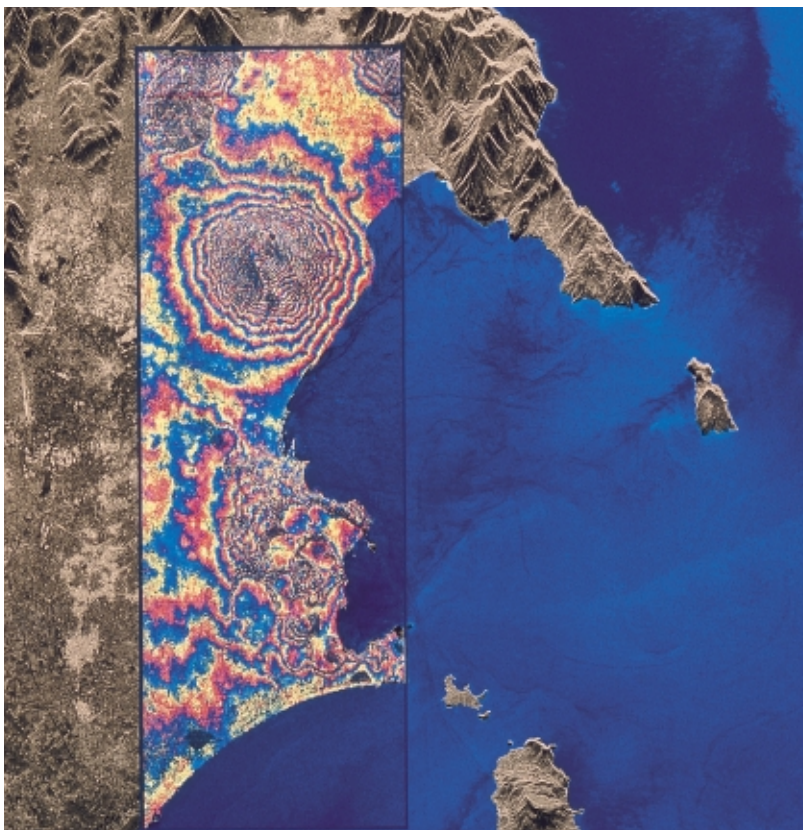
Using its expertise in this area, the French national space agency, Centre National D'Etudes Spatiales (CNES), developed a software package, Diapason, for radar satellites such as ESA's ERS-1, which images the Earth to monitor environmental changes. Not only does the software provide efficient and almost automatic computing capabilities, but it is also simple to use. Diapason can detect changes in sections of the Earth's surface one kilometre across to within a few millimetres in some cases. In particular, very small surface displacements can be noted, which is useful in identifying changes that precede volcano eruptions or, possibly, earthquakes.

Terrestrial applications of Earth imaging

Recognising that Diapason is user-friendly – it does not require a specialised knowledge of radar – CNES began to think about selling the package outside the space industry. In particular, the organisation targeted large laboratories and geophysicists as potential customers. These users typically buy radar data from governments that operate radar satellites. They then must find a way to generate useful results.

CNES developed a training programme which encouraged scientists to learn how to use Diapason, focusing on the fact that the software automatically does the work of translating the radar data into information the scientist can easily understand and use. These efforts resulted in the adoption of the software in laboratories across Europe and in the US, primarily for non-commercial application in the early detection of earthquakes and other tectonic movements. CNES has also been approached by two French companies who wish to license Diapason for commercial use. ■

A radar image that detected small geographical displacements caused by a volcano



Testing and verifying the design of systems for the control and implementation of vital, often safety-critical processes – be it in spacecraft, weapons or chemical or other industrial processes – has always been the subject of the utmost rigour. Increasingly over recent years, software has played an ever more important part in the make-up of control systems. Software systems are inherently more difficult to verify than hardware, and, as the complexity of the software itself increases, improved techniques need to be developed to prove the integrity of the control process and the safety and reliability of the system being controlled.

A spacecraft contains perhaps one of the highest concentrations of safety and mission-critical systems, all increasingly dependent on software for control. To meet the challenges of software verification in such applications Logikkonsult NP of Sweden has developed NP-Tools based on a new method for system analysis and validation.

NP-Tools employs a new, patented method of so-called formal verification. Formal methods allow a software developer to prove mathematically the properties and veracity of software controlling large, complex systems. The key is a powerful analytical approach called propositional logic, which is capable of modelling, for subsequent verification, any software system in which the variables are finite and definable.

In NP-Tools, the methodology has been implemented in hardware and software, using a graphical workstation interface that can rapidly analyse complicated systems. Typical aspects such as fault tolerance, system safety and reliability, and robustness to faulty data inputs can be checked – thus reducing testing and certification time, and increasing confidence in the system.

NP-Tools is used widely for verifying spacecraft systems and many recent programmes have benefited from it.



Applications

Since its availability has been more widely advertised through ESA's TEST catalogue, NP-Tools has now been successfully applied in other safety-critical applications. Two examples are given below.

● Nuclear power plant certification

In a Swedish nuclear power plant, the emergency cooling system has one particular subsystem controlling the flushing of water intake grids to remove debris. Precise control of grid flushing – thus the supply of cooling water to the reactor – is critical, and the Swedish certification authorities chose to perform a rigorous analysis using NP-Tools to verify the system.

● Railway signalling

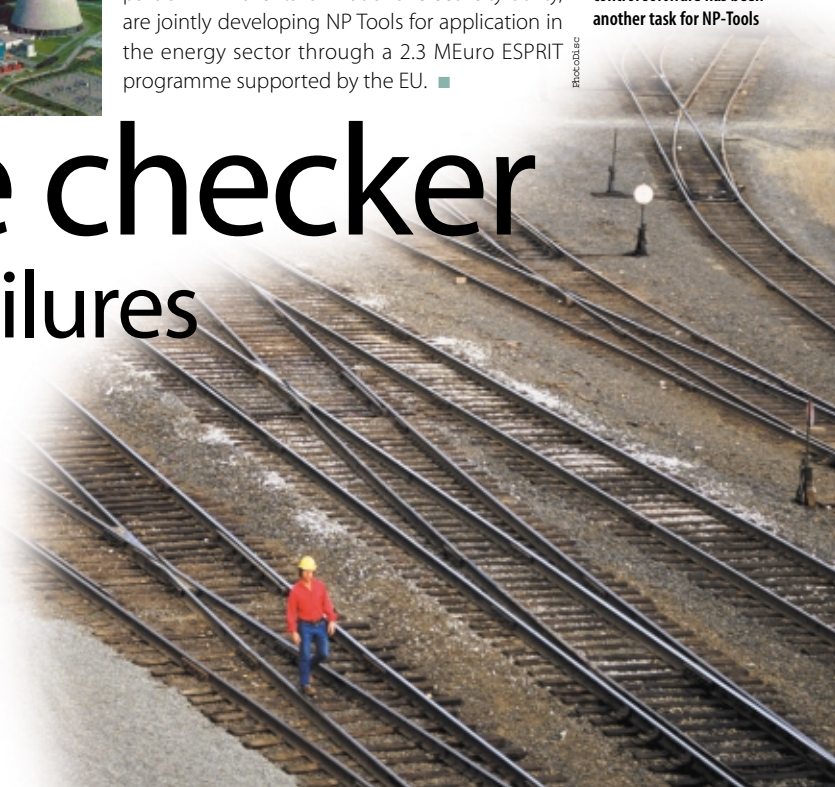
The use of software to control and coordinate railway signalling provides a understandable example of everyday safety-critical usage. In order to verify the safety of its signalling software, ABB Signal in Sweden developed a customised version of NP-Tools and no software-induced failures have occurred in its signalling systems since its introduction.

The potential spread of applications has been widened by exposure of the tools in the ESA TEST catalogue. CISE, who specialise in the design and manufacture of energy control systems, evaluated the tools for application in the energy sector under the auspices of the EACRO (now EARTO) programme supporting the ESA TT initiative coordinated by Bertin in France. Both Logikkonsult and CISE, now part of ENEL the Italian national electricity utility, are jointly developing NP Tools for application in the energy sector through a 2.3 MEuro ESPRIT programme supported by the EU. ■



NP-Tools is used to confirm the integrity of safety-critical systems on spacecraft (above). Software control systems in nuclear power plants have been checked using NP-Tools (left)

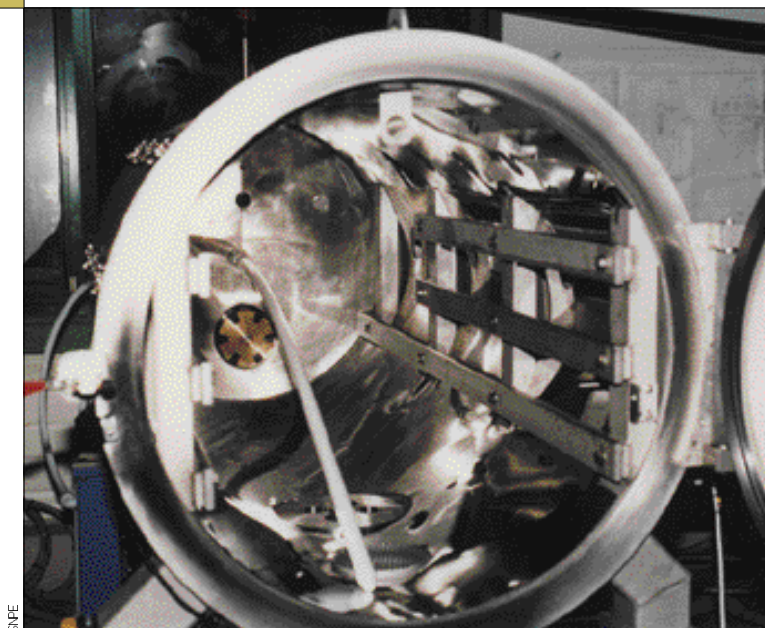
Checking railway signalling control software has been another task for NP-Tools



Software checker reduces failures

A new tool for verifying software controlling safety and mission-critical systems in spacecraft has found equally vital uses in nuclear plants and in railway scheduling

The plasma-processing machine at SNPE's St-Médard facility (right) is being used by a German manufacturer to bond seals to valve bodies (below)



A French company that has been using cold plasma technology to bond materials to the inside of the casings of rocket motors has opened its facilities to other industrial users

Cold plasmas heat up new markets

Since the early 1990s, SNPE Propulsion in St-Médard, France has been exploring how to exploit cold plasma technology (see below) to replace a purely chemical method used to coat the inside of rocket motors with a protective thermal layer – a process that normally requires long and careful preparation. In 1993, SNPE developed a prototype plasma-processing machine which was tested to ensure that this new technology could effectively replace the old process. Because the tests were

so successful, SNPE set up an industrial-scale facility for space-propulsion applications.

However, this did not utilise the full capacity of the facility, so SNPE teamed up with the University of Bordeaux, and received EU funding to search for users in other sectors. This partnership guarantees research work subcontracted from the University and provides the company with additional academic expertise.

Filling capacity

In 1995 and 1996 the partnership launched a promotional campaign which targeted small local businesses, attracting seven customers and two new financing partners. The facility now regularly carries out prototype work or surface treatments of small production runs for these companies.

SNPE has also expanded the scope of its business for large customers from the aerospace sector to terrestrial markets. SNPE will complete a validation study for a major French manufacturer of domestic appliances, which is considering setting up its own facility to test the use of plasma surface treatments on its products. These include bonding polypropylene covers or handles to glass and preparing products for painting or marking. The facility has also attracted the business of a German manufacturer of industrial pipework, who needs a better way of bonding seals to valve bodies.

Following through its leadership in the application of cold plasma technology in France, SNPE will work on a European funded project to generate a set of guidelines for future users of cold plasma technology, with a focus on use by small businesses. ■

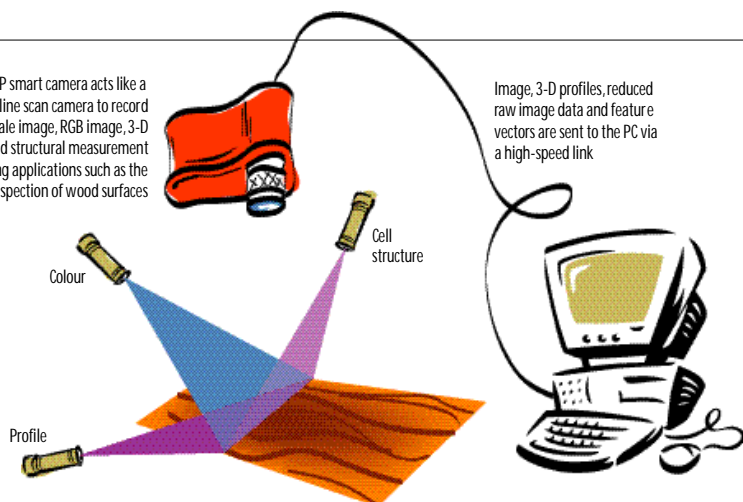
The science of cold plasma technology

A plasma, which is an ionised gas containing charged particles – electrons and ions – and also neutral atoms and molecules, offers a unique medium for initiating interactions at surfaces. These include chemical reactions, melting, and evaporation. Technological plasmas have a broad range of applications from welding to depositing super-hard coatings.

The simplest way to produce a plasma is by passing an electric current through a gas. The plasma's properties, and thus its uses, depend on how it is made. In low-pressure cold plasmas, made by radiofrequency-driven discharges, the electrons are at a very high temperature (100 000°C) but the ions and neutral particles, and any nearby surfaces, remain at only just above room temperature. The energetic electrons in the cold plasma can be used to ionise or break up molecules of a gas present, causing it to react chemically with the surface. In this way it is possible to deposit a thin coating such as an adhesive or paint layer on a material. Because the temperature of the surface hardly rises, the bulk of the material remains unaffected.

Advantages of this kind of cold plasma treatment are that it is non-polluting, it can be automated, it requires few consumables, and is very fast (treatment cycles range from 15 to 30 minutes). Not only does it provide major cost savings, but it can increase the bonding efficiency of technically useful materials like silicone.

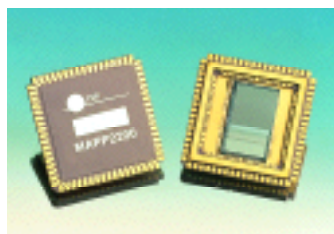
The MAPP smart camera acts like a multiple line scan camera to record grey scale image, RGB image, 3-D profiles and structural measurement during applications such as the inspection of wood surfaces



A Swedish company has been selling a chip used to position satellites to manufacturers who need a precise way of visually inspecting finished products

Vision chip

The smart optical sensing system designed by Integrated Vision Products (IVP) of Sweden is unique in that it is a complete image-handling system on a single chip. Its circuits include optical sensors, analogue-to-digital converters, memory, and a processor for handling image information. Because the chip itself is no larger than a fingernail and can be fitted to a miniature camera, it is particularly useful in space where equipment has to be as light and compact as possible.



Although IVP originally developed the system for terrestrial applications, CelsiusTech Electronics of Sweden and ESA soon found uses for it in ESA's communications satellite programmes. The imaging system enables satellites to position themselves with respect to the Earth. The optical sensor 'watches' the surface of the Earth, and compares the images with those programmed into the chip. Constant comparisons between the two image sets enable the system to keep the satellite and its antenna correctly positioned.

Following its success in the space industry, IVP has continued to pursue terrestrial applications for its smart optical sensing system. The architecture of the chip offers many advantages: it is flexible and the configuration of the vision system can be made quite simple; operations on the image can be performed directly on the chip – including digitisation, filtering, edge detection, thresholding, and thinning; finally the parallel architecture of the chip means that data can be processed much faster than in traditional optical systems.

Smart cameras

One important application of this smart optical chip is in 'smart cameras' which blend images from multiple sensors in real time. The chip's small size and its speed of image processing (up to 4000 images per second) mean that the system can be used in up to 90 per cent of all industrial applications involving image-processing.

The system is currently being used to detect superficial defects in ceramic tiles, textile products, wood-ply products

and preserved fruits more quickly and effectively than by traditional means. For

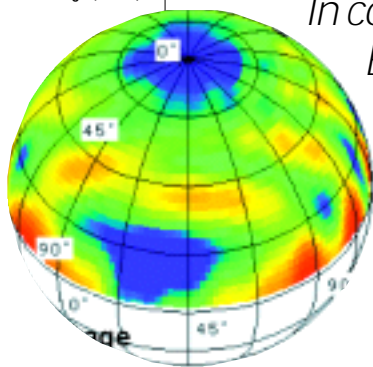
example, grey scale images, RGB (red-green-blue) images and 3-D profiles of a wood surface can be recorded at the same time by equipping the vision system with a multiple laser source and RGB filters.

In the transport industry the system is being used to develop real-time, 3-D profiles of rails for high-speed trains in order to identify conditions on the track that are potentially dangerous. IVP's system is also being used for the 3-D modelling of human feet (and other parts of the body) for orthopaedic purposes, such as designing made-to-measure shoes. ■

IVP's imaging chips (left) enable satellites to position themselves with respect to the Earth. The smart camera system (below) can detect defects in food products

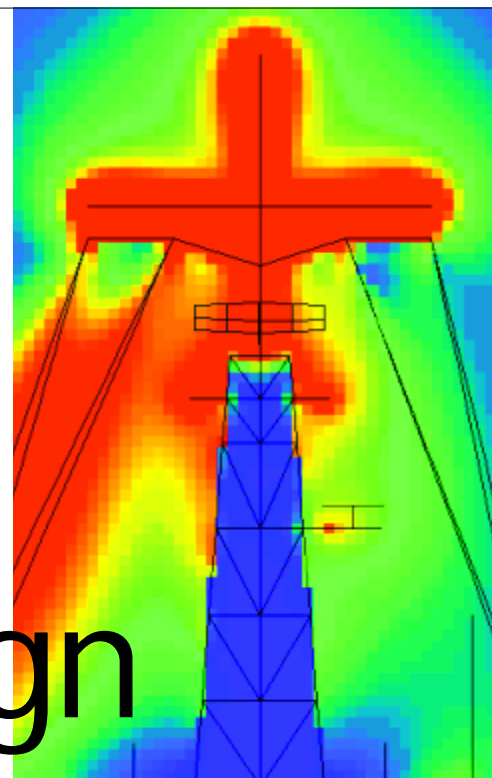


Ship antenna modelling
showing radiation coverage
and hazard analysis (right)
Satellite antenna
modelling showing world
coverage (below)



Positioning antennas on spacecraft and checking their performance is tricky.

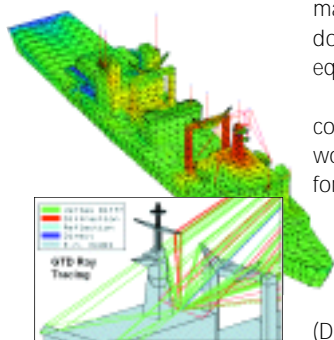
In collaboration with a European team of antenna designers, ESA has produced a set of computer tools to simplify the task



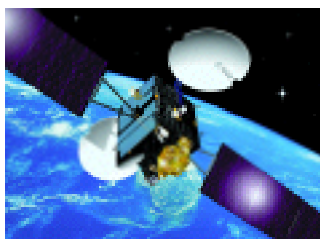
Antenna design made easier

Factors to be considered during design or positioning of antennas – whether mounted on spacecraft or elsewhere – include performance, footprint, masking, radiation safety and electromagnetic interference. That is to say: antenna designers need to ensure that the communications or sensor emissions are powerful enough, that they have the necessary area of coverage, are not masked by adjacent structures, do not endanger life and do not interfere with other systems or electronic equipment – in short quite a complex set of constraints.

Since the early 1980s, the naval division of an Italian company, Ingegneria Dei Sistemi SpA (IDS) of Pisa, has been working on the problem, developing computer methods for assessing these factors. In 1993, the company started a collaborative programme with ESA to design an integrated set of software tools to help design spacecraft antennas. Also involved in the development team were Thomson CSF/RCM (France), TICRA (Denmark), EPFL – LEMA (Switzerland) and CIRMA (Italy).



Ship antenna modelling



The ADF system is used in the design and positioning of satellite antennas

The result was the antenna design framework (ADF) software system which provides all the functions required to model antennas in isolation or on a spacecraft. ADF employs software tools that work in a distributed graphical environment, and which can provide a detailed assessment of all the issues confronting a designer. The tools model the electromagnetic output of the antenna using 3-D visualisation to show the area covered by the antenna's range, the intensity of the emissions, as well as interactions with nearby electronic systems or structures, and any resultant hazards or malfunctions.

ADF also provides designers with additional features to log design histories and optimisations as required – a great improvement on current, non-integrated procedures. The capabilities of ADF may be further extended in future simply by adding relevant proprietary or commercial tools.

Naval spin-back

ADF was promoted widely for non-space use by Spacelink in the TEST catalogue. Having contributed early expertise and experience developed with support from the Italian Navy, IDS has been able to spin-back to the naval community the advances made in the ESA antenna design framework programme.

The company is developing in parallel a ship electromagnetic (EM) design framework which performs the same function for ship-based antenna designs. An early commercial benefit to IDS of this spin-back was the award of a major UK Ministry of Defence contract for evaluating the design and positioning of antennas for a naval vessel. It is anticipated that this tool may therefore play an important role in designing and implementing the new generation of joint European surface ships now being studied, as well as helping spacecraft designers address their tasks in a more structured manner. ■

A coating used to minimise friction on the bearings of the Space Shuttle fuel pumps is also increasing the throughput and quality of plastic sheeting

Diamond-like coatings for clearer plastics



Diamond-like coatings can be used on rotating worms in calendars such as this to produce clearer plastic

When two components in a system rub together, they create friction, which can wear out components and heat up the system. A German company, MAT in Dresden, developed a special diamond-like coating for treating bearings in the fuel pumps of the Space Shuttle. This coating is a carbon-based material with a molecular structure resembling that of a diamond. The advantages of the coating are its resistance to wear and scratching, its chemical stability, and the fact that it minimises friction in mechanical systems.

As part of its work in ESA's technology transfer programme, MST – the German Spacelink partner – regularly organises technology transfer forums for space and non-space companies. In 1996, MST was approached at one of these forums by the world market leader in plastic film and packaging, the German company Kalle Pentaplast, which was having manufacturing problems. Residues were being deposited on its plastic sheets during production as a result of friction. Recognising a terrestrial application for the friction-reducing diamond coating, MST was able to mediate a transfer between MAT and Kalle Pentaplast.

Plastic foils are produced using a large rolling mill, called a calendar. The main parts of the calendar include the extruder, which mixes the polymer, and a series of rolls which transform the plastic material into sheets, or foils. Within the extruder, the granules of plastic are heated so that they melt and congeal into a continuous material. A key component of the extruder is a rotating worm, which mixes the material during this process.

Before the coating process was used, the surface

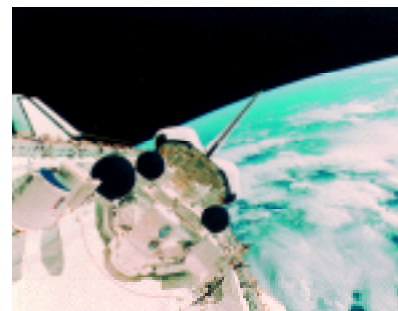
roughness of the rotating worm caused the plastic to stick to it during mixing. The plastic stuck to the hot worm would then carbonise and crumble into the plastic mixture, forming black particles in the finished foils. Kalle Pentaplast attempted to reduce sticking by coating the rotating worm with a variety of materials such as titanium ceramics that had been coated with Teflon, but none was effective enough to reduce the particle deposits to an acceptable level. Complaints from customers about the 'dirty' plastic increased costs to Kalle Pentaplast, particularly when orders needed to be remade to meet customer specifications.

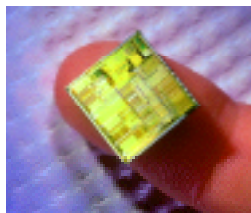
Diamond-like results

Coating the rotating worm with the diamond film resulted in a significant decrease in residues. These improvements provided the company with an annual saving of 85 kEuro per calendar. Considering that Kalle Pentaplast operates 36 calendars, this cost saving could add up to more than 3 MEuro a year.

Another bonus to the company is that the decrease in friction between the coated rotating worm and the plastic material increases the throughput of plastic in the extruder because there is now less drag in the system. Each calendar can produce about 10 to 15 per cent more product than before. Once all the calendars undergo the coating process, Kalle Pentaplast can look forward to additional production potential amounting to 126 MEuro per year. ■

Bearings in the fuel pumps of the Space Shuttle are treated with a diamond-like coating to reduce friction





Flexure structure technology has assisted the miniaturisation of many electronic devices

A new technology for the accurate positioning of lasers in space is now being used to make the next generation of microchips

Putting lasers in their place

Conventional mechanical positioning systems used on spacecraft suffer from errors that are hard to remove, such as those associated with friction, backlash due to the tolerances generated when several components are joined together, and wear. These errors limit the accuracy of these systems to below that required to point laser emitters and optical sensors across the expanses of space.

One way of achieving more precise mechanical positioning, with variations of less than a micrometre, is to replace conventional kinematic elements, which often comprise a number of linked components, with frictionless, bendable homogeneous structures that offer translational and rotational movements in all directions based on purely elastic links for guidance and transmission. That is to say the structures have the minimum number of connected separate parts (flexure structure technology, FST). A variety of bendable structures can be accurately designed and

optimised on a computer. They are then re-shaped (mainly in aluminium or beryllium-copper alloy), to the precise shape by a number of methods including wire electric-discharge machining.

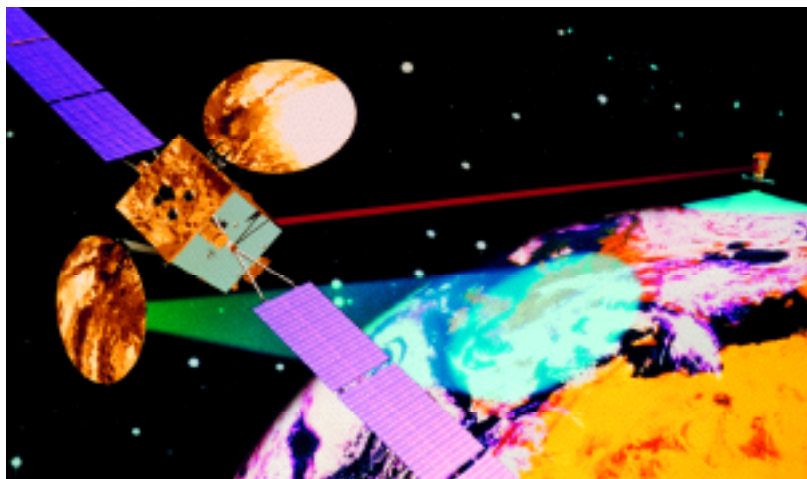
This technology can be applied in a wide range of communication and scientific observation satellites, enabling precise positioning of laser communication transmitters and receivers, remote sensing instruments and Sun and star-trackers. A Swiss company CSEM, pioneers in the development and application of the technology, have applied FST to the optical data relay payload aboard Artemis, which when launched in 2000, will make a major contribution to the introduction of global optical data communications. Artemis is being specifically designed to explore the transmission of data between satellites in a revolutionary new way – using laser beams.

More recently, the same technology has been applied terrestrially in the electronics industry where lasers have many uses. One example is the transfer of text using optical character recognition by a scanner into a computer, requiring very accurate laser optics. In 1995 CSEM received a contract from a manufacturer of optical scanning equipment, Lumonics in Canada, to develop a laser system embodying the flexure structure technology.

A prototype has been delivered to Lumonics' subsidiary company in the UK and production levels of several hundred units a year are anticipated.

Another application is in the production of ever-smaller electronic components for the latest generation of miniature mobile phones, CCD cameras and other chip-based products. Lasers are used in the process that creates the tiny circuits on a microchip. The laser beams have to be positioned very accurately within 10 nanometres (billionths of a metre). ■

Flexure structure technology was used to design antenna pointing systems for the Artemis data relay satellite



Spacecraft propulsion units need accurate, fast-acting actuation systems to control rocket thrust during launch. In the early 1990s PHASE SpA in Italy undertook a study for ESA to develop high-power electrical linear actuators for this task. Prototype devices have been produced weighing less than 7 kilograms but capable of exerting forces of 26 000 kilonewtons to a positional accuracy of 20 micrometres over short distances. The actuators are powered by an integral brushless (13 kilowatt) servomotor and controlled by three-phase drive electronics operating at a frequency exceeding 60 hertz. They provide a performance-for-weight that cannot be equalled by equivalent hydraulic or pneumatic systems.

In 1994 the impressive specification of the linear motor was spotted by D'Appolonia – the Italian Spacelink partner – which promoted the technology in ESA's TEST 3 catalogue. At about this time, the British Hydrodynamics Research Group (BHR) in the UK needed to improve the performance of industrial tools that exploit high-pressure jets of water as a cutting mechanism.

Cutting-edge technology

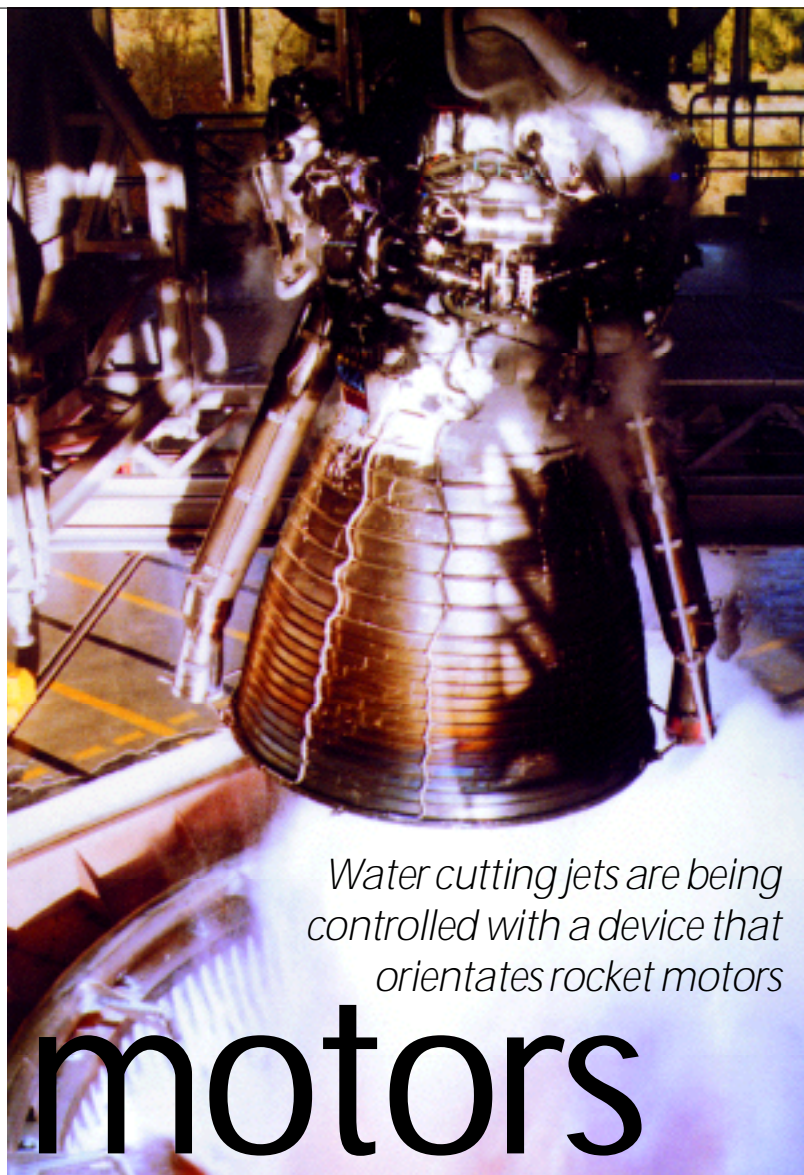
Cutting with high-pressure jets is effective for a wide range of materials including aluminium, stainless steel and metal matrix composites, an advantage over competing technologies such as laser and wire electro-discharge machining. Fine jets of water travelling at supersonic speeds, laden with abrasive particles, can cut, profile, shape, gouge, clean and descale if applied correctly. Unlike many other techniques, water cutting is a cold process – it does not produce any heat in the region of the cut, and leaves

Space smooth the cut

the surrounding material undamaged.

The existing generation of water cutters suffers from one drawback – they can leave 'chatter-marks' in the cut material. These surface marks result from small variations in water pressure which alters the angular spread of the jet. Currently the very high water pressures needed are achieved and maintained by 'intensifiers' – pairs of large, pneumatically-controlled pistons operating sequentially. BHR was aware that the control provided by the intensifiers did not give a smooth enough flow. The company immediately spotted the potential in the PHASE motor for controlling the water pressure more accurately and in a finer jet.

BHR addressed the cost of developing this application



Water cutting jets are being controlled with a device that orientates rocket motors

with the help of European partners and EU funding. In 1996, five organisations formed a consortium with PHASE and a BHR subsidiary, Diajet: a manufacturer of high pressure equipment, Bohler Hochdrucktechnik GmbH (Austria); two cutting jet service providers, Masijet Oy (Finland) and TIRAC (Ireland); the University of Hannover in Germany, an expert in this area; and Bombardier Aerospace's Shorts unit in Northern Ireland which is evaluating the technology for use in precision forming of composite structures for the aerospace industry.

The EU Brite-Euram programme provided support of 2.6 MEcu, and the technology-development phase is nearing a successful conclusion. The improved precision in materials processing achieved with this technology transfer should result in a significant increase in European competitiveness in this large and expanding global market.

Should, as is anticipated, Bombardier Aerospace find a use for the improved technology for the cutting and forming of advanced aircraft structures, then the PHASE linear motor will be an example of a technology spinning out of one area of the aerospace sector, only to return as a key component in another. ■

The linear motors were designed to control rocket directional thrust during launch

Linear actuators are used to control high-pressure water in cutting devices such as this





A small German company has used its expertise in spacecraft aerodynamics to help develop a new food packaging machine



Aerodynamic research is completed in wind tunnels such as this

Landing a potato crisp

Hypersonic Technology (HTG), in Grottening, Germany specialises in solving aerodynamic flow problems for space projects such as ESA's ELITE initiative, which examines the flight characteristics of Europe's launchers. By observing how model spacecraft behave in wind tunnels, HTG can calculate the effects of very fast air flow on the motion, temperature and physical properties of space vehicles. These experiments help designers to decide on the best materials for building spacecraft, and also to determine the angle and speed at which a vehicle can re-enter the Earth's atmosphere and land safely.

The aerodynamics of food

In 1998, MST – the German Spacelink partner – was challenged by an inquiry from a German packaging machine manufacturer, ROVEMA. The company wanted to develop a machine that could fill packages with lightweight food products, such as potato crisps, quickly and without breaking them. As the leader in the sector of packaging machines, ROVEMA is a group of companies with subsidiaries in Austria, Spain, Italy, the Netherlands, UK and USA. Although the company produces a range of packaging machines, it must introduce new machines to its product line every two-to-three years in order to stay competitive. The constant search for ways to improve the performance of the machines led ROVEMA to explore space technologies and know-how.

After some consideration of the request, MST recognised that the scientific problem of

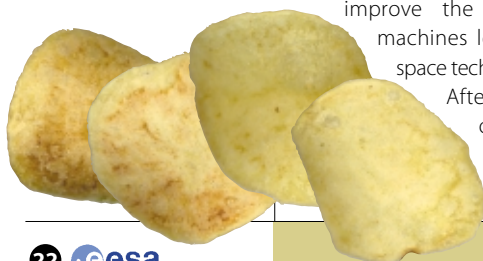
dropping a potato crisp into a bag without breaking it is conceptually similar to landing a spacecraft safely. Both problems must take into account the optimum speed for a safe descent, and also consider how the flow of air affects the temperature, structure, speed and direction of the falling object. Familiar with HTG's expertise in solving this type of problem, MST introduced the company to ROVEMA as a partner in product design and development.

Using the modelling, calculation methods and measurement know-how developed through work on ESA projects, HTG was able to develop a bagging system for ROVEMA which could be integrated into a new packaging machine. This device can package foods 30 to 50 per cent faster than standard equipment. The company also worked with ROVEMA to test the machine in use, adjusting the system until it reached the best balance of speed compared with breakage.

ROVEMA has tested a prototype model and anticipates that this new packaging machine will be mass-produced in 1999. The machine received its first public viewing at the major international packaging trade-fair, INTERPACK, in Dusseldorf, Germany in May, 1999. ROVEMA is anticipating an annual turnover of about 30 MEuro from this innovative machine. ■



Landing a spacecraft on Earth or the ESA Huygens probe on Saturn's moon Titan, as seen here, is just like dropping a crisp into a bag



Green car power

from space research

Fuel cell technology developed by European space researchers has been adapted for use in the cars of tomorrow



The Mercedes N-car will use a fuel cell as its power source

The limitations of solid and liquid hydrocarbon fuels are well known. They rely on the Earth's diminishing supplies of fossil fuels and are inefficient, producing carbon dioxide and other emissions harmful to the environment. Hydrogen, however, is a highly efficient fuel which when reacted with oxygen can produce large amounts of energy and no harmful emissions (the waste product is water).

For spacecraft designers in particular, hydrogen has one big attraction: it is light, and the power-for-weight potential of hydrogen-based propulsion is enormous. Major drawbacks are that hydrogen does not occur in any great quantity in nature, and it is highly volatile and explosive – as operators of early hydrogen-filled airships discovered! Nevertheless researchers have developed one particularly successful way of exploiting hydrogen to generate power, and that is in a so-called fuel cell.

How a fuel cell works

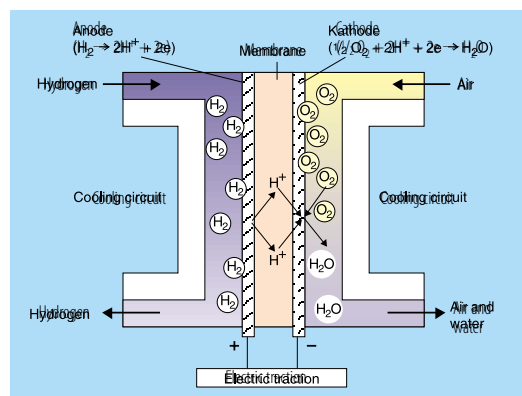
A fuel cell is similar to a battery in that it produces an external electrical current through the electrochemical reaction of certain materials at electrodes within the cell. However, while a battery relies on a finite source of chemicals, a fuel cell receives a continuous supply. The simplest kind of fuel cell uses hydrogen and oxygen from the air as fuel which are each fed to separate electrodes coated with a platinum catalyst. At the hydrogen electrode, the hydrogen molecules split into hydrogen ions (protons) and electrons (which produce the energy for propulsion). The protons then pass through an ion-exchange membrane which allows them to travel between electrodes while keeping the gases apart. When they reach the oxygen electrode the protons combine with oxygen to form water.

Fuel cells generate energy efficiently, at relatively low

temperatures with low noise and vibration, and no noxious emissions. They have few moving parts and are highly reliable.

The German aerospace company Dornier (now part of DaimlerChrysler) has been working for some time towards producing a safe, reliable hydrogen fuel cell for use in spacecraft, specifically for the Spacelab and (now cancelled) Hermes programmes.

When Dornier became part of DaimlerChrysler in 1996, its know-how in fuel cells technology became readily available to the automotive divisions of this large multinational company. In particular Mercedes-Benz used this know-how to develop fuel cells of its own. The first Mercedes using fuel cell power will be the N-car which should be on the streets in four or five years from now. The N-car (new electric car) will be a version of the current A-class and will use liquid hydrogen stored in a thermos-like cylinder. The electricity generated will drive an electric motor which will provide the final power to turn the wheels. The N-car will have a 40 per cent increase in range over a battery powered car, it will reach 90 mph and carry a family of five and their luggage nearly 280 miles. ■



A hydrogen fuel cell
The simplest kind of fuel cell uses hydrogen and oxygen from the air as fuel which are each fed to separate electrodes coated with a platinum catalyst

A UK company has exploited imaging technologies from ESA satellites in designing a camera that can take pictures through oil

Satellite technology sees down-hole

Proneta is a company that was founded in 1997 in the UK by John Hother to design electronic systems and sensors, and to provide consultancy services in engineering management and marketing. Hother's team of professional engineers, physicists, and project managers specialise in bringing best-practice techniques from one industry to another – in particular, taking advantage of their expertise in the fields of electronics, avionics, radar, real-time computing and networks, and aeronautics.

In 1997, Hother contributed to an ESA-supported seminar for the aerospace and offshore oil industries. A challenge was posed to him from the offshore sector: find a way to see through the oil inside a well. Conventional video cameras are regularly used to diagnose problems in drilling, completion, and workovers. However, these cameras cannot see through the oil, so can be used only after all the oil has been flushed out first with a continuous supply of brine. The cost of the flushing is huge, and the delays caused by bringing the pump and filter equipment to the rig mean that very often the use of a 'down-hole' camera is rejected.

Proneta decided to explore how this problem might be solved, and secured part-sponsorship from the European Commission for the initial research. A team of supporting organisations was set up: Conoco provided a set of oil



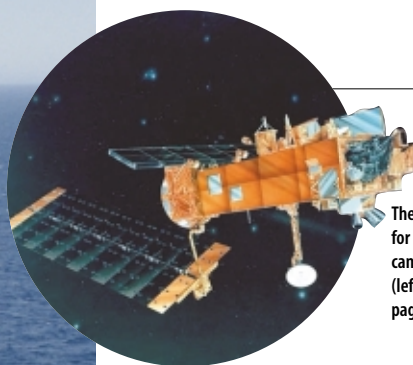
samples for use in the experiments and University College, London ran tests on the oil for Proneta in areas where the company did not have the necessary equipment.

Applying Earth-imaging in the oil industry

Through the exploratory tests, researchers at Proneta identified special characteristics of the oil. With its experience in the space industry – particularly in designing electro-optic instruments – the team knew that sensors that could penetrate oil had already been developed for use on meteorological satellites such as ESA's ENVISAT and ERS missions. These satellites monitor the environment, climate, and changes in sea-level.

Based on the satellite-imaging technology and the results of the oil tests, Proneta determined that not only could its camera achieve useful images through the oil, but that the equipment could also be engineered to withstand the severe environment and the tight constraint on size and bandwidth. Proneta filed patents for the new technology – but also needed to demonstrate to the oil companies that it really would work beyond paper calculations or computer modelling.

With part-sponsorship from ESA, Proneta built a test-rig in their laboratory to produce pictures to show to oil companies and other prospective sponsors. The test-rig is



The imaging technology for Proneta's camera came from the Envisat (left) and ERS-2 (opposite page) satellites

Offshore oil wells, such as this one, will use the new 'down-hole' camera to diagnose problems during production

working successfully, producing useable images.

The next phase for Proneta will be to construct a full-scale demonstrator, in which the camera will be shown working with real targets. A vertical tank 30 centimetres across and 3 metres high will be built and filled with crude oil. Inside the tank will be pieces of standard casing and tubulars (the targets) and the camera will be lowered inside. This set-up will allow Proneta to develop the correct optical configuration, and will be suitable for showing to prospective sponsors for the following phase. This will be the development of a trials unit that can produce images down an operating oil well.

During the engineering development, Proneta will be teaming up with a company that already builds conventional down-hole video cameras, and possibly a major oil and gas service company. The resulting unit will then go on trial in real wells during workover periods. Major oil companies have already offered the use of their wells, and Proneta is now actively seeking funding for the demonstrator phase. ■

ESA's Harsh Environments Initiative

Through the Technology Transfer Programme, ESA has recognised the need to support industries in their efforts in finding new business solutions through the use of space technologies and know-how. A recent focus has been on companies operating in harsh environments, in particular the offshore gas and oil industry, whose operational and technology needs closely shadow those of the space industry. In July 1997, ESA committed 1.8 MEuro over two years in developing the 'Harsh Environments Initiative' (HEI) with the organisation C-CORE in Canada.

The HEI provides an opportunity for members of the space industry to learn about current and future challenges in the oil, mining, tunnelling, and forestry sectors. With the assistance of C-CORE, ESA has sponsored a series of workshops, with contributors from companies that work in harsh environments discussing specific technology challenges they will need to solve in order to remain competitive. A workshop held in January 1999 brought together attendees from space and non-space companies across Europe, Canada, and the US, and highlighted technology needs – ranging from better simulation of systems, increased use of remote and tele-operations, and improved capabilities in locating equipment and products in unknown and unfriendly environments.

ESA hopes that the harsh environment companies will make use of remote sensing, virtual reality, data handling, materials, and robotics technologies and know-how developed through the European space programme and its missions. To support potential transfers, ESA has made available small grants to be used for completing feasibility studies for the new technology solution.

For more information about the HEI, contact Bob Robinson C-CORE, Memorial University of Newfoundland.

e-mail: hei@morgan.ucs.mun.ca

For a booklet describing technology needs of the offshore industry, contact JRA Technology.

email: mail@jratech.co.uk

Every four seconds, somewhere in the world, aircraft such as this Airbus land using carbon brakes



A French aerospace company has been developing high-tech carbon composites for braking systems suitable for cars and planes

Making a better brake

Composite materials composed of a carbon matrix reinforced by long carbon fibres can withstand extreme temperatures, and are very resistant to wear. Brakes made from such composites are more reliable, reduce vehicle vibration, and cause less pollution than traditional brakes.

Société Européenne de Propulsion (SEP), now a division of Snecma and the creator of the motor for the Ariane rocket, began developing these new high-tech materials for use in the nozzles of solid rocket motors in 1969. The company

created a new company to produce carbon disks for aeronautics and automotive transport, acquiring in 1992 the company Carbone Industrie based in Lyon, France, which has expertise in carbon composites. More than 90 per cent of Messier-Bugatti Carbone Industrie division's business has been in the aerospace sector. Together, SEP and Messier-Bugatti have developed a novel carbon composite braking system called Sepcarb, which is very cheap to make.

Sepcarb brakes are currently used in aeroplanes – particularly Airbus, Boeing, Rafale, Falcon and the Mirage fighter. Because traditional brakes can not provide the same mechanical performance with the light weight of carbon composites, more than 80 per cent of Formula 1 and GT cars have Sepcarb brakes and Carbone Industrie is the leading supplier of this type of brake in race cars.

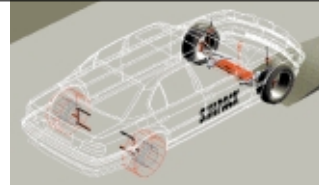
Moving into new markets

The Snecma Group is hoping to expand the market for their carbon composite brakes, and are looking at luxury and sports car manufacturers, such as Mercedes and Porsche, as new customers. ■

Luxury and sports cars such as this Porsche are target markets for carbon composite brakes. Porsche has recently fitted another of its models, the RUF-CTR2, with carbon brakes from Carbone Industrie a division of Messier-Bugatti



Car manufacturers are using the same software to simulate vehicle dynamics as ESA used to design the International Space Station module, Columbus



Car manufacturers such as BMW and Rover are using SIMPACK to develop virtual models of automobiles

Space station modelling in your car

It is important in space projects such as the construction of the International Space Station (ISS) for the builders to understand – before the system is actually assembled – how the individual components will be put together and how they will interact with each other. Movements and vibrations, both from within and among the separate modules, can undermine the stability of the structure over the long term, and it is prohibitively expensive to fix problems after components have been launched and assembled. Prevention also ensures a more habitable and productive environment for the astronauts whose lives will eventually be sustained on the ISS.

The SIMPACK software was a joint development project initiated in 1987 by the German research institute DLR and the German company MAN. It was used during the development of ESA's Columbus module. The computer program simulates mechanical systems with more than one moving part such as the large structures and platforms used in Columbus and ISS, as well as smaller mechanical parts and systems.

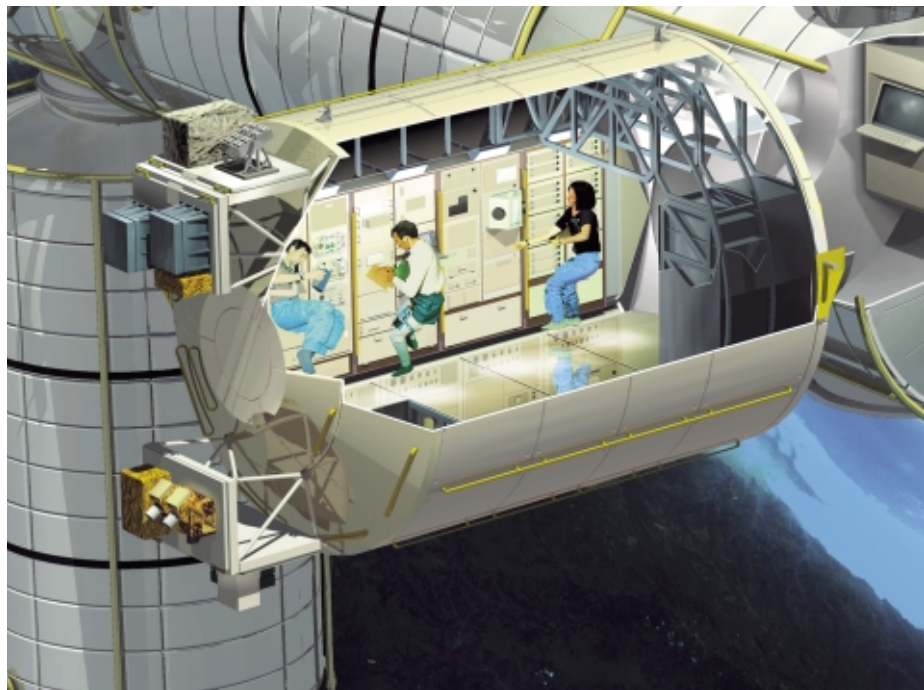
By simulating the overall system, ESA used SIMPACK to analyse large and small motions such as the modes of vibration in the ISS structure, allowing designers to correct for these displacements in the final design of the Columbus module. A main advantage of using the software is that it can assess the behaviour of the system throughout all stages of its design and before a physical prototype is created. This reduces the time and cost for companies developing new products.

Spinning-out a technology and a company

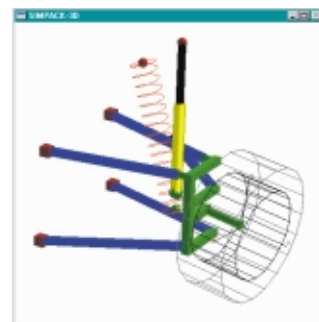
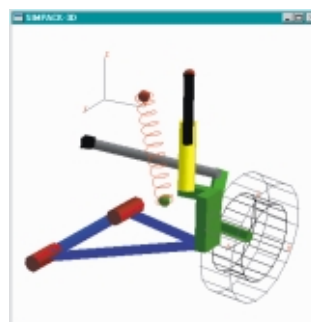
In 1993, DLR spun-out a company, Ingenieurbüro für neue Technologien (Intec), to promote SIMPACK to markets outside the space domain. Potential customers include any sectors where product safety and reliability depend on small and large moving parts. These include road and rail transport, robotics, biomechanics, and printing and packaging machinery.

Through its promotion activities, including exhibiting the software at technology fairs, SIMPACK has attracted attention from manufacturers and suppliers of cars and heavy goods vehicles, such as BMW, DaimlerChrysler, Rover, MAN, Iveco, Bosch, and Wabco. These companies now use SIMPACK to develop virtual prototypes of entire vehicles on the computer, which aids and hastens the development of new designs.

Between 1996 and 1999, Intec completed more than 100 commercial licences of the software. The overall simulation market is expected to grow annually by 25 per cent, which could translate into an annual growth rate of 40 per cent for the company. ■



SIMPACK software was used in the design of ESA's Columbus module, part of the International Space Station



Close-up views of the SIMPACK modelling of tyre systems

Space robot technology

adopted by car manufacturers

A system that ensures predictable motion in space robots is now being used by car makers in their automated production lines

Robotic devices used in space undergo thorough testing to guarantee their performance during a mission. The robots are first programmed off-line with positioning data. A software model of the robot and its working environment is then developed and finally calibrated. During this latter phase, the robot is tested against the software model to find errors in performance, so that the programmed data can be corrected.

ESA contracted the Belgian company, Krypton Electronic Engineering, to work in collaboration with another Belgian company and a Swiss company to study ways of making robot calibration more precise. Measurement systems and test procedures had to be developed to quantify the performance of a robot and generate improvements through calibration. The goal was to eliminate all differences between 'perfect' robots in a 'perfect' CAD-modelling world and real robots on the work floor. Accurate measurements and an adequate modelling of the robot behaviour are required to compensate for all major differences. This ensures that robot tasks planned on Earth can be performed in space with limited human interaction.

The system these companies developed, Rodym, employs multiple cameras which measure the movement

of infrared LED markers attached to the robot. The system provides three-dimensional coordinates (on the x, y, and z axes) for the robot as it moves. These real-time measurements are very accurate, and can account for random errors, predictable errors (for example due to temperature fluctuations), and systematic errors. A specially developed mathematical model is used to adjust the programming of the robot to compensate for the differences between the real data and the assumptions made when the robot was initially programmed. This last step ensures that the robot consistently reaches its correct position and orientation during the mission.

Krypton also developed a hand-held probe that can be used in conjunction with the Rodym system to calibrate the positioning of tools manipulated by robot arms. Using a similar camera/LED system, it is possible to evaluate and correct the positioning of the point of the tool that is interacting with other objects in the working environment.

Bringing precision to production

Robots that have been calibrated with the Rodym positioning and compensation system perform 10 times better than others. Vehicle manufacturers have shown a

strong interest in adopting this technology for use on robots in production lines. More accurate performance of robots could lead to higher production rates and better quality control. Most recently, BMW decided to make Rodym a standard part of their production systems. This year, Krypton is anticipating sales of 2.5 MEuro for applications of Rodym in this sector. ■



Production lines that employ robots, such as those used in automobile manufacture, are a promising target market for the Rodym system

Under contract from the Canadian Space Agency (CSA), the Canadian company, Kinetic Sciences Inc. (KSI), developed a proximity sensor that can provide both image features and range data very near to the surface of the sensor. Because the sensor works without using conventional lenses, it reduces the potential for distorting the image.

The concept for this technology originated during research on tactile and proximity sensors funded by CSA for use on Canada's contribution to the International Space Station, the mobile servicing station (MSS). This facility exploits robot technology to assemble, transport, and maintain payloads in orbit. A key component of the MSS is a two-armed robot that has the tactile capability to handle servicing and repair tasks that are usually performed by

Space robot sensor stymies computer hackers

astronauts on space walks. While discussing the requirements for sensors on the MSS, and in particular for this robot, the project team realised that no array sensors (a series of sensors that work together) existed that could be used in very close proximity to the fingertips of the robot.

An important need in many robotics systems is to obtain proximity measurements – which establish how close one object is to another – of the features of an object as it is approached at a close range by the finger tips or robot 'grippers'. In this situation normal visual sensing tends to be obscured, and can prevent the robot from properly grasping objects or completing tasks. What was required and developed by KSI was a 'near-touch proximity sensor' that could provide detailed information on the distance and orientation of one object with respect to another for objects between 1 centimetre and 1 millimetre away from the finger tip of the robot.

From robot fingertips to human fingerprints

KSI turned the proximity sensor into a product known as Vision Skin TM, a human fingerprint biometric sensor (a fingerprint reader) that has enormous market potential in police and security applications. In May 1997 the company signed a license covering Asia (excluding Japan) for the commercialisation of fingerprint identification devices in this part of the world. Under this license, KSI received 365 kEcu in development funding and will receive royalties on future sales.

KSI is currently looking for venture capital investment to launch the sales of the fingerprint imager in North America. Besides the police and crime-fighting sectors, the computer industry is also being targeted as a major market. Instead of using a password to access a computer, it would be possible to scan a fingerprint over a reader, making the machine far more secure and more difficult for hackers to access. ■



A sensor that was developed to help robots determine the proximity of an object is now being used to read fingerprints

Fingerprint reader
Sensor technology developed for the mobile servicing station is now being used to identify fingerprints for security applications, particularly to replace computer passwords





The Spanish company that co-designed the European space suit is using its knowledge to develop air-conditioned protective suits for use on Earth

Space suit technology On Earth

The company, Zodiac, has been working under an EU-Eureka project with another small Spanish company, a small Belgian company, and a Belgian university. Together, they have been using their expertise in space suit design, space electronics, and human heat transfer to develop a protective suit that will allow its wearer to stay cool. Much of the know-how being used in this project has come from work done for ESA in developing a space suit to be used by European astronauts.

The protective suit is a modular system, with the base of the system being an undergarment that can be worn on its own or with full protective gear. The undergarment takes advantage of the body's natural cooling mechanism – the evaporation of sweat from the skin – by using a system which blows cooled air over the wearer's skin. The system in the undergarment is light and is based on Peletier elements, which are components that have no moving parts. The system is powered by rechargeable battery packs, which provides the wearer with a great deal of autonomy in movement. Zodiac and its partners are investigating new



The European space suit

Work done on the European space suit enabled Zodiac to design a protective suit for use on Earth. The 'air conditioned' undergarment can be worn under bullet-proof vests to keep policemen cool

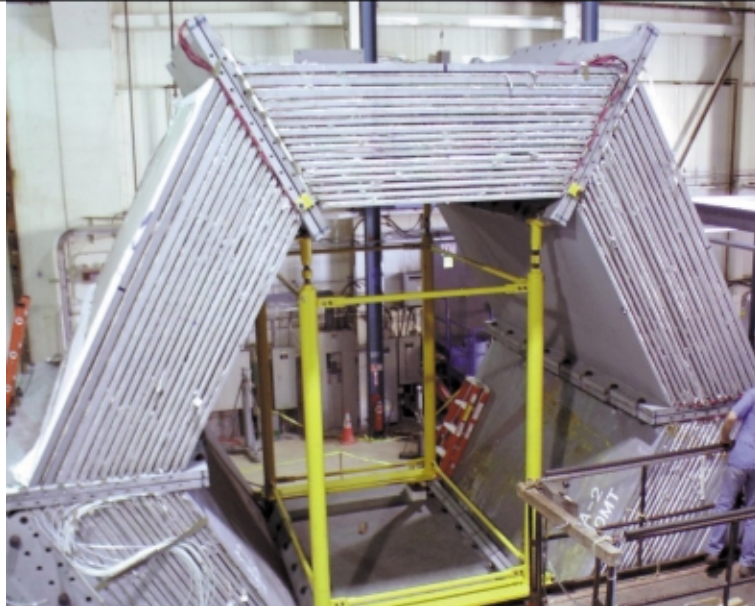
sources of power, such as solar panels.

The undergarment on its own is suitable for use in applications where the wearer may not be working in hazardous conditions, but may be exposed to high temperatures. Bakers and motorbike riders could benefit from wearing the undergarment, and the London Police Department is assessing its use under bullet-proof vests worn by policemen.

For workers who must be protected from hazards in their working environment, such as firemen, removers of toxic and biological wastes, and fumigation specialists, the research partners have developed an advanced model of the protective suit. This garment would enclose the entire body, with cooling being based on one of two systems. The first would circulate air inside of the suit, with the air being cooled by a heat exchanger within the cooling system. The second would pump liquid refrigerant through tubes in the suit, and would also use a small airflow. Zodiac has also designed breathing systems which can either use air from outside or be a self-contained unit within the suit. All systems would again be powered by battery packs, eliminating the need for an external power source and an umbilical cord which would limit mobility. ■



City of London Police



RADFET chips monitor the radiation encountered by equipment in the BaBar experimental facilities

SLAC

Radiation chip can keep public safe

The RADFET dosimeter, as described in the article 'Space radiation monitors aid treatment of heart disease' has clear benefits to the medical sector in its minute size and cheapness. Other advantages that have emerged from its use in space, and which can be transferred to terrestrial applications, include the chip's low power needs and convenient data transmission.

Applications that exploit the combined benefits of RADFET could include distributing thousands of dosimeters across the countryside in the event of a nuclear explosion or disaster. Civil defence or disaster management agencies could then monitor the residual levels of radiation, and update the public on the safety of the affected area.

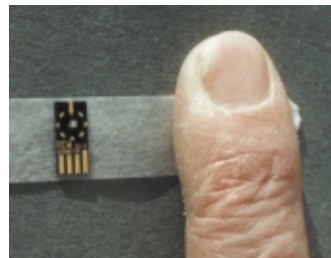
In industrial use, RADFETs can provide a timely warning of an impending radiation leak to companies that use radioactive materials in routine work. It is also possible to use the dosimeter to certify food products which have been sterilised via irradiation.

The device has also found a role in 'big bang' research at the American particle physics facility, the Stanford Linear Accelerator Center (SLAC) in California. A new experiment is starting up there called BaBar which collides electrons and positrons (positive electrons) in order to make subatomic particles called B-mesons. The particles are detected by arrays of so-called scintillation crystals arranged in a barrel-shaped detector.

The experimental environment, however, is similar to that in space, in that there is radiation present (from the particle collisions) which cannot be avoided and the highly

The space radiation dosimeter that has been finding new medical applications can also be used to check radiation levels in sensitive environments

The RADFET chip
With the chip's minute size, low power needs, and convenient data transmission, arrays of RADFETs provide a reliable and inexpensive solution to radiation monitoring on Earth



RBM

sophisticated instruments must operate for many years. The crystal detectors are particularly sensitive to radiation. Brunel University near London, which is participating in the experiment, has received funding from the UK Particle Physics and Astronomy Research Council to install an array of 130 RADFETs in the underground experiment hall to detect radiation problems and give warning of potential damage to instruments. ■

transferable

A flameproof textile developed for the Ariane rockets is being used in terrestrial applications where fire prevention and protection against heat transfer are required



Rocket textile prevents flame and heat damage in industry

Société Ariegeoise de Bonneterie (SAB) is a family-owned textile company in Montferrier, France. Founded in 1941, the company's main products have traditionally been for consumer use such as undergarments. However, in 1990, Aerospatiale, industrial architect of the Ariane series of rockets and Société Européenne de Propulsion (SEP), which produces the Ariane motors, contacted SAB because they were having difficulty in developing flameproof materials for use in rockets.

Applying its 40-plus years of experience and expertise in textile knitting and coating, SAB was able to provide Aerospatiale and SEP with a unique textile, Flamebreak, that can not only stop a fire from advancing and consuming materials, but can also reduce the flow of heat from the fire through the textile. These qualities are important to rocket manufacturers because they need to capture and sustain the energy in the rocket's flame while preventing nearby equipment from burning or melting.

The main fibre components of the textile are polyacrylonitrile oxide (preox) and Kevlar. Using a special knitting technique, SAB has created a fabric structure which acts as an optical filter, blocking up to 90 per cent of infrared radiation at temperatures ranging from 200 to 1150°C, leaving the fire-protected side of the textile at a temperature of around 100°C. By inserting an air space between sheets of Flamebreak, almost all heat transport is eliminated.

Flamebreak was modified slightly for use by Arianespace in the Ariane rockets. SAB used its know-how in textile

coating to impregnate sheets of Flamebreak with a special silicon product produced by Aerospatiale. Four of these sheets were then laminated in layers five millimetres thick. This textile is used in the Ariane-4 rockets to protect electric cabling from the flame of the rocket motor. Flamebreak is employed in the rocket motor 'Vulcain' developed by SEP for Ariane-5, and protects SEP's test facilities in France.

From sky to Skydome

Terrestrial applications for Flamebreak have been widespread, particularly as there are few competitors in the flameproof textile sector that can provide a material of similar quality. Studies carried out at the Centre d'Etudes de Cadarache (CEA) in France are a good illustration of the textile's use. The centre has been examining how a nuclear reactor core behaves when its cooling system fails – as happened in the 1980s at Chernobyl. The Flamebreak textile protects employees from heat and dripping metal during high temperature experiments (2100 to 2500°C), and transparent screens made from Flamebreak allow researchers to observe their tests on-site.

Companies in the metal and glass-working industries, such as Pechiney SA and St. Gobain SA in France, have also used Flamebreak to shield employees from the heat emitted during production. Flamebreak has been incorporated into upholstered seats in public buildings and vehicles. A recent example of the textile's use is in covering

The Skydome in Toronto, Canada (below) used Flamebreak as a flameproof cover on the seats inside (above right)



textiles

Spacelink partners introduced a French textile manufacturer to a consortium of companies who needed a theft-proof textile for road and rail transport across Europe

Anti-vandalism textile



Following the success of flameproof textiles developed for use on the Ariane rockets, the French company Société Ariégeoise de Bonneterie (SAB) modified its knitting technique to create a textile from steel wire which is extremely difficult to cut because of the way it is woven. Although this textile was not originally used for space applications, it attracted the attention of Novespace – the French Spacelink partner – which had spotted an article about the textile in a newspaper. As part of its ESA-sponsored work, the Spacelink group routinely surveys non-space companies for potential technology needs, and publishes a booklet which is circulated among the Spacelink partners and European space companies. Shortly before the newspaper article appeared, Créaction – the Belgian Spacelink partner – had published and circulated to the Spacelink partners a technology need for a textile that could deter vandals.

At the beginning of 1996, two small companies – a French manufacturer of rail/road haulage containers and trailers and a Belgian manufacturer of plastics and composites – set up a collaboration with a large Belgian rail/road haulier to develop a new system of lateral panels for containers. Overall, combined rail and road transport over long distances has been increasing. However, the tarpaulin-covered containers often travel unaccompanied from the dispatcher to the customer and are left standing for periods of time in loading or storage depots. Thus, the incidence of vandalism and assault has also been increasing (see Box), particularly by thieves who use knives to rip open the tarpaulin to gain access to the cargo.

Screening out vandals

Créaction was contacted by the consortium when they proposed a technical feasibility and market study as Phase 1 of a 600 kEcu EU-CRAFT project. The results of Phase 1

indicated that the consortium should focus on the development of a fabric that was flexible and light, while also being suitable for a vandal-proof sliding screen, rather than a more traditional, rigid, plywood-type panel. The consortium searched for partners who could provide expertise in specialty textiles, coating sliding screens, and manufacturing fastening systems and sliding screens. Along with another French and a Dutch company, SAB was introduced to the consortium by the Spacelink partners.

During Phase 2 of the CRAFT project, the six members of the new consortium will work toward developing sliding screens for transport containers. Not only must the new screens adhere to standard criteria of the tarpaulins currently used, such as using the same fasteners, having the same weight (900 to 950 grams per square metre), ensuring the same ease of use, and offering the same decorative and cleaning conditions, but they also must be able to withstand an attempted theft involving a cutting device and prevent the load from spilling.

The European market for containers and hauliers is estimated at 120 000 units a year, with a price for each unit of tarpaulin of between 850 to 900 Euro. The sliding screen consortium is looking forward to penetrating this 100 MEuro market late in 2000. ■

Textile expertise

A French manufacturer developed the Flamebreak textile that protects wiring and equipment in the Ariane rockets and the Vulcain rocket motors from heat damage. The same company is also developing a vandal-proof screen for lorries

Lorries such as this, with tarpaulin-covered sides, will encounter fewer events of vandalism once the slash-proof screens are installed



Cargo theft in Europe

Illegal access to hauled cargo in Europe is a serious and costly issue. The 1998 data show the number of thefts from tarpaulin-covered lorries reported per year is 1200 in France, 1700 in Belgium, and 3000 in the UK. Estimates also indicate that the 15 000 lorries that park in depots in Luxembourg are slashed open twice a year.

Insurers of these containers and cargos can each expect annual claims from these attacks and thefts to be in the region of 85 MEuro.



Pierre Brisson
Head of ESA TTP

Since its inception in 1991, ESA's Technology Transfer Programme has been supported by the Spacelink group of companies. This consortium identifies space technologies with a potential for broader commercial exploitation and aids their transfer to companies outside the space industry

Spacelink Group activities for the ESA technology transfer

Spacelink, the technology transfer network set up by ESA, is based on core organisations located in Germany, France, the United Kingdom, and Italy. These companies operate nationally, and manage a network of partner correspondents in every ESA member state including Canada. Each partner supports Spacelink and ESA in promoting technology transfer activities within its own country, and makes use of national and local business support organisations to achieve a broadly-based but targeted marketing approach to non-space industries.

Technology transfer process

In order to identify technologies appropriate for transfer from the space programme, Spacelink assists companies which are developing new space technology to carry out technology audits. The technologies chosen are assessed for novelty, intellectual property protection, maturity, applicability, and potential market size.

A main tool employed by Spacelink to attract transfer partners is the catalogue of Transferable European Space Technologies (TEST), of which seven editions have been

published. TEST is produced in five European languages and is distributed more than 40 000 European companies outside the aerospace industry.

Spacelink will work with companies through the completion of the transfer – arranging meetings, providing support and advice, and often assisting in identifying and securing sources of development funding. When specialist information is needed in order to adapt technologies for particular applications, Spacelink provides the company with a connection to the European Association of Research and Technology Organisations.

Identifying market needs

To gain a better understanding of the advanced technology needs of non-space companies, Spacelink routinely completes surveys of these companies, and presents the results to space researchers throughout Europe in order to further stimulate beneficial cross-sector cooperation and interaction.

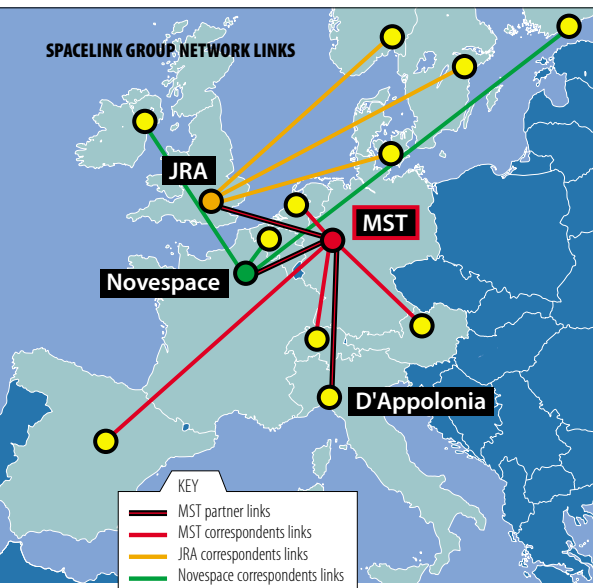
The activities of Spacelink have resulted in more than 70 transfers of space technologies, many across international borders and often involving collaborations of several European nations. Another 20 transfers are in progress. In addition, the numerous space and non-space company contacts that have been generated from Spacelink initiatives have led to many successful collaborations involving technologies and know-how outside space research. It is almost impossible to quantify the widespread benefits to both European industry and the wider community as a result of these collaborations. The increase in commercial activity already runs into several hundreds of MEuro. The impact on the everyday lives of European citizens has also been considerable and reflects great credit on the ESA/Spacelink team. ■

The TEST catalogues are used to promote space technologies and attract non-space transfer partners



Pierre Brisson
Pierre Brisson

SPACELINK GROUP NETWORK LINKS



For more information on the ESA technology transfer catalogue, visit the ESA Publications web site: <http://esapub.esrin.it>

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