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> CARS & TRUCKS

Technology Transfer Programme







What do cars, trucks and satellites have in common? This brochure will help you find out, and tell you just how the European space industry is having an increasing impact on the automotive industry in general.

Several of the technologies used in the design and manufacture of modern cars and trucks come from materials and systems that were developed for applications in space. I hope this brochure will give you an insight into how advanced European space technologies are being applied to vehicles, not only to improve their cost and performance but also their comfort and safety.

Many innovative non-space products and services that will benefit society are now being introduced as a result of technological spin-offs from the space industry, and it is worth remembering that car manufacturing is not the only sector to take advantage of the new technologies developed by European space companies.

I hope this brochure will enable you to discover the new and unexpected ways in which space activities improve our daily lives. Pioneers in cars were also pioneers in aeroplanes, thus it is not surprising that car design and manufacture have always benefited from the aerospace industry.

If you take the time to check out what in your car is coming from space technology, you would probably be very surprised! Many of the improvements in safety, security, power, and communication are coming from space spin-offs. But as one of our major concerns has become the protection of the Earth's environment, so a new kind of energy found in space is beginning to power our cars. Cleaner fuels and solar cells will power the cars of tomorrow - thanks to space spin-offs!





Pierre Brisson Head of the Technology Transfer and Promotion Office





SCREENING OUT VANDALS

Theft from lorries and haulage containers is a growing problem throughout Europe and those with sides made of fabric are particularly vulnerable to attack. Cargo containers spend a lot of time unattended in loading or storage depots and their tarpaulin covers, while light and convenient to use, offer little protection against the knives of vandals and thieves.

By 1996, so serious had this problem become that three companies, a French manufacturer of haulage containers, a Belgian plastics and composites company and a large Belgian rail/road haulier joined forces with CRIF, a Belgian collective industrial research centre, to develop a new protection system for containers.

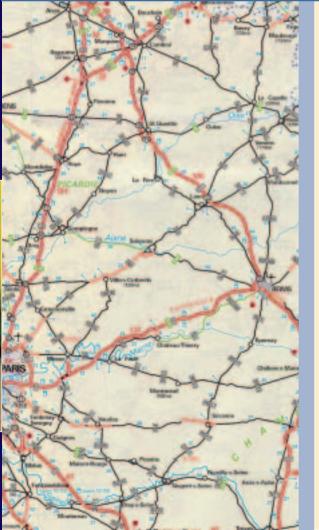
The work was supported under the EU's CRAFT scheme and initial studies pointed towards the development of a better material for fabric screens, which would retain the advantages of lightness, flexibility and ease of cleaning, while offering great strength and resistance to attack. But where might one find such a material?

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THE FRENCH CONNECTION

As part of its work, ESA's Technology Transfer Network (TTN) surveys nonspace companies to see what kind of technology they might need. It was through this mechanism that the Belgian TTN partner Creaction circulated the requirement for a vandal-resistant textile. By good fortune, a French company Societé Ariegeoise de Bonneterie, following the success of its flame-proof textiles used on Ariane rockets, had modified its knitting technique to create a flexible fabric from steel wire which was extremely difficult to cut and wellsuited to the application. A newspaper article about this new material was spotted by Novespace, the French TTN partner at the time, and so the connection was made.

Parcouri, a consortium of eight European companies that includes a Dutch multinational producer of vehicle covers and a French SME specialising in coach building and kit fixing systems is now developing a vandal resistant alternative to the standard tarpaulins presently in use. Within an existing global market of 120,000 units a year, current predictions for the new material show a healthy potential market opening of 7000 units annually.





CARBON BRAKES

Above left: The energetic pyrotechnic charge produced by SNPE Propulsion. Above right: An airbag gas generator. Composite materials made of a carbon matrix reinforced by long carbon fibres can withstand high temperatures and are very resistant to wear. These materials were originally developed for use in the extreme conditions found in the nozzles of the European Ariane rocket motors. The developers realised that brakes made from such composites were more reliable, reduced vibration, and caused less pollution than traditional braking systems fitted to planes and road vehicles. Messier-Bugatti, based in France, produced a novel carbon braking system called



Sepcarb[®] for use on aircraft such as the Airbus and now supplies one-third of the world market for carbon composite brakes for commercial planes with more than 100 seats (over 145 airlines have now chosen Sepcarb[®] carbon brakes for over 1600 aircraft). Similar systems have also been employed on Formula 1 racing cars, road vehicles and passenger trains.

FASTER INFLATING AIRBAG

Another important safety feature - the airbag - has contributed a great deal to safer car travel in recent years, saving many lives and helping to prevent serious injury in collisions. Today, the device is considered to be one of the most important safety devices since the seat belt was first introduced in the 1960s. When an airbag inflates, there is essentially a controlled

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explosion occurring inside your car! The typical standard device is housed in the centre of the steering wheel along with the inflator. An igniter activates compressed gas capsules and these fill the bag with an inert gas when an impact of above a certain force is sensed. The whole inflation process occurs within a split second and the bag is completely deployed in less than a second - enough time to restrain the occupant.

As most new cars employ such safety devices, the market for the pyrotechnic charges is huge. The French company SNPE Propulsion is using its knowledge in the field of solid propulsion for ballistic missiles and space launchers to design and develop the pyrotechnic charges used in airbag gas generators and seat-belt tighteners. SNPE Propulsion estimates that its products are used in one out of every four safety devices fitted on new cars each year.

PRESSURE-SENSITIVE PADS FOR SEATS AND BUMPERS

To help in the construction and maintenance of the International Space Station, the Canadian Space Agency has been coordinating the development of the 'Special Purpose Dextrous Manipulator' (SPDM) - a two-handed robot which is essentially an extension of the astronauts' own limbs. Until recently, these augmented limbs lacked one critical feature - a sense of touch. Without a sense of touch, machines can easily accidentally knock over or bump into other objects. In space, obviously, this can have drastic consequences. Although automated vision systems have been under intensive development for several years, tactile sensing technologies are rare and relatively primitive.

Recognising this challenge, Canadian company Canpolar East developed KINOTEX - a novel sensor that emulates human touch and can be applied like a skin or sleeve to cover entire robotic limbs. Described as a 'deformable integrating cavity', the sensor consists of a sheet or block of polymer foam with a opto-electronic transducer embedded in it. When the foam is deformed its optical properties are altered, generating a proportional signal in the transducer. Normally arranged in arrays, these sensors can detect and interpret contact at many points over the surface of the machine. Because they use





light to detect change, KINOTEX sensors can be very small and are immune to interference from sources such as electromagnetic radiation. They are also very responsive, sensing minute amounts of pressure and reacting extremely quickly to change.

Many industries are implementing KINOTEX products. For example, automotive companies have acquired the rights to develop pressure-sensitive car seats that help increase safety. KINOTEX sensors are also being considered for incorporation into energy absorption bumpers for cars to determine the severity of crashes and collisions with pedestrians. So, thanks to the sense of touch developed for robots in space, we may be able to travel much more safely in our vehicles!

GOOD VIBRATIONS

Movements and vibrations inevitably occur when many different parts are brought together to build a car or a spacecraft. In both cases, it is necessary to find out how these components interact before they are assembled.

Special simulation software used by ESA to design the Columbus module for the International Space Station can assess the behaviour of complete systems even



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before they are built and sent into space, thus avoiding the prohibitively high costs otherwise involved in fixing problems afterwards.

The same software can help car manufacturers to simulate vehicle dynamics and then diagnose any vibration problems. This software has already attracted the attention of the automotive industry and companies such as BMW, DaimlerChrysler, Rover, Bosch and Iveco are now using it to develop virtual prototypes of entire cars and heavy goods vehicles.

The Prost Formula 1 racing team was using another type of technology, known as the SPADD (Smart Passive Damping Device). This system was developed by the French company Artec Aerospace to protect satellites and space structures from the strong vibrations occurring during launch. However, the SPADD system can also be used to reduce (dampen) vibrations in a racing car, so leading to improved driver safety. Incidentally, the same technology is also being applied to reduce the noise and mechanical shocks in concrete mixers!



04

Patent EP1070844A1

SPACE TECHNOLOGY STARTS A BETTER MOTOR

When the Rosetta space probe, one of ESA's main science Cornerstone missions, is launched in 2003 to study comet Wirtanen, it will use a clever piece of technology which will soon benefit engineering applications nearer home.

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A CAD image above right, and an original drawing above left, of the novel actuator device from Cedrat. The device is an actuator for implementing fine movements developed by Cedrat Recherche, a spin-off company from the Polytechnic Institute of Grenoble, and is based on the piezoelectric effect. This is a well-established phenomenon whereby a small voltage passing across a crystal such as quartz causes it to change shape (or vice versa - pressure on the crystal induces a voltage). The distances moved are small but the forces produced are large. The effect is exploited in many electromechanical devices such as quartz clocks and microphones, and is ideal for controlling movements fast and accurately and with little power.

Cedrat had already developed piezo actuators for the French Space Agency CNES, for micro-positioning and vibration damping of satellite optical systems. Further applications followed, including optical shutters, piezoelectrically-controlled valves and non-magnetic rotating motors for sensitive instrumentation.

Cedrat's actuators employ a clever combination of synthetic piezoelectric materials and mechanical engineering to give a much greater range of movement than previous piezo devices. So it is not surprising that these amplified piezo actuators have found many non-space uses, for example in instrumentation such as microscopes, camera shutters and hospital MRI scanners.

The technology is increasingly penetrating more established fields of engineering. The next generation of car engines already face enormous demands in terms of efficiency, power output and low emissions. They will need to respond rapidly to changes in driving conditions, constantly optimising engine performance. Microchips are already able to supply the real-time electronic commands needed for adaptive engine management, and new actuators are needed to translate these into the mechanical language of the engine. Much attention has been given to the improvement of fuel injection



systems where the electrical control of individual injectors can significantly affect engine performance. Amplified piezo actuators with their combination of very fast response times, low voltage operation, high operating forces and precise control offer one very promising approach to the automotive injector of the future. With this in mind, an automotive injector designed by Cedrat Recherche and Fiat, and based on the amplified piezo actuator, has recently been patented. So, a novel device used to control spacecraft will help build the next generation of greener, more efficient cars.

GEARING UP TO BETTER MOTORS

Nutation, from the Latin word to nod, usually describes the circular movements of a growing shoot or the wavy path followed by the Earth's axis as it travels around the Sun. It is also the motion of a coin, spinning like a top, as it slows and falls. Careful observation shows that as the coin slows it describes a circle on the table top. Interestingly, the diameter of this circle is smaller than the diameter of the coin itself. This means that for each nutation of the coin, the circumference of the circle traced on the table top is less than the circumference of the coin and the coin must therefore rotate. Even closer observation reveals that although the point of contact between the coin and the table moves very quickly, the coin itself rotates quite slowly. The visible effect is that of an apparent gearing between the two motions. This is not an illusion, but a real and useful effect which can be accurately described mathematically.

Many everyday appliances rely upon small electric motors to operate - video recorders, car window winders and seat adjusters, tape drives and CD players all have them. Often the required shaft speed of the motor is quite low but, to provide significant power, small machines work best at high speeds. To reduce the speed of rotation and so gain an increase in output torque, or twisting power, a gearbox is needed - just as in a car.

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If the difference between the speed of the motor and its load is great, conventional gears may need several stages of speed reduction. This leads to power loss, noise and expense. Unfortunately, large increases in output torque also cause large forces on the teeth of conventional gears, so larger teeth and better materials are needed.

Drawing upon the gearing effects of nutation, an Italian space company Stam srI has created a new form of gearbox that overcomes these disadvantages. The device, called SPACEGEAR, was developed for use in satellites and uses an arrangement in which one bevel gear nutates with another instead of rotating. The gear ratio is determined by the difference in the number of teeth of the fixed and moving gears and not, as with conventional gears, on the ratio of their circumferences. By applying the principle of nutation twice, very high reduction ratios of up to 3000 can be achieved. The design, which combines two pairs of gears, makes possible any ratio with the same simple configuration. Because the design ensures that at least two teeth are in contact at any one time, loadings are reduced and materials of lower strength may be used.

SPACEGEAR is particularly suited to electrically-driven automotive components where high reduction ratios are required but space is at a premium. Using nutator technology, smaller, faster electric motors can provide the same level of mechanical power as their conventional counterparts. At present, such mechanisms and their electric motors typically cost from 200 Euros for a small car to 2000 Euros for a luxury car. The European automotive industry produces about 15 million cars per year, offering a potential market of 4500 million Euros. The company is exploring materials for mass manufacture - in metal or plastic - and is developing a computer program for designing nutating-gear systems. In another application a similar gear has been developed for bicycles.

ROBOTS FOR AUTOMOBILE PRODUCTION

Robots, like people, live in an imperfect world. The notion that a robot, working alone in space, might be programmed with perfect knowledge of the environment in which it will carry out tasks with perfect accuracy is an impossible ideal. Errors and variations will always exist in the robot and its world, which will affect both precision and performance.

The traditional solution of human intervention through tele-manipulation is not always an option. As a result, ESA contracted the Belgian company Krypton Electronic Engineering to study ways of making robot control more precise. The aim was to support an in-orbit demonstration of ESA's Autonomous Interactivity Concept - a way of improving the competence of preprogrammed robots - and this required an accurate picture of the performance and responses of robotic manipulators under real-world operating conditions.

It was rapidly discovered that few commercial tools were available for calibrating robots. Existing data on performance - where it existed at all - was inadequate. As a result, measurement systems and procedures all had to be developed which would identify the differences between perfect robots in a computer-generated world and real robots working on the shop floor. Once these errors were known and compensated for, it would be possible to be confident that robotic tasks planned on Earth would be faithfully performed in space.

The system that evolved, Rodym, ensures that a robot consistently reaches its correct position during each of its programmed actions. To achieve this, a mathematical model is used to generate adjustments, compensating for the inevitable errors between the robot's actual and programmed positions. The position data needed for these calculations must be very precise indeed and, once again, no commercial measurement solutions were available.

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Rodym employs a multiple camera system, which can measure accurately the position and orientation of up to 256 infrared emitting diodes that are attached to, and move with, the robot. Once these are exactly located in relation to the operating environment, error corrections can readily be made. Using a similar camera / LED system, it is also correct the positioning of any tool that the robot is using.

Today, Krypton has become the market leader in the field of industrial robot calibration and testing. The methods and tools first developed for space applications have become mature and most constructors of industrial robots now own at least one Krypton measurement system. Robots that have been calibrated with Rodym positioning and compensation are capable of more accurate performances, leading to better quality, higher outputs and less down time - an advantage not lost on the car manufacturer BMW, which has decided to make Rodym a standard feature of its automobile production systems.



CLEANER FUELS FOR GREENER CARS

Space applications have long been a major driver in the development of fuel cells. These electrochemical devices, which provide electricity from simple chemical reactions such as the combination of hydrogen (the fuel) and oxygen (from the air in terrestrial applications) to produce water, are ideal for powering spacecraft. There are no moving parts, hydrogen is light, and the only waste production is water.

Based upon its efficiency, high power output and ability to operate for as long as the fuel is available, the fuel cell is also seen by many as the power source of the future for cars and other vehicles. It is roughly twice as efficient as a conventional petrol engine, with virtually no harmful emissions, and can be operated with fuels made from renewable sources. A car electrically powered by a fuel cell is quiet and easy to use.





A German aerospace company, Dornier, had made considerable progress in producing a compact, safe and reliable hydrogen fuel cell for use in spacecraft. When Dornier became part of the automotive company DaimlerChrysler, its fuel cell technology became available for automotive applications and from then on progress was rapid. In late 2000, two new fuel-cell vehicles were announced, the Mercedes-Benz A-class NECAR 5 and the Jeep Commander 2. Both vehicles are quiet and environmentally friendly, with fuel cell systems that occupy no more space than a conventional engine.

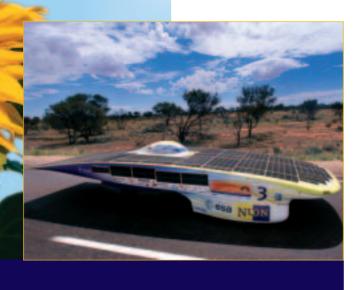
The two cars actually use methanol (a type of alcohol) as a fuel. Otherwise hydrogen would have to be carried on board a vehicle as a liquid under high pressure so there would be a danger of explosion. An alternative is to use various hydrocarbon or hydrocarbon-derived fuels that can be first broken down into hydrogen and carbon dioxide using a reforming catalyst. Methanol, which can be handled and sold like petrol or diesel, is an excellent choice to feed reforming fuel cells designed for domestic cars. Methanol is produced on a large scale from natural gas and oil and, ultimately, it will be available from renewable biomass. Fuel cells are also being developed that use methanol directly as the fuel.

Such is the promise of fuel cells that DaimlerChrysler aims to invest over 1 billion Euros to develop the new drive system for mass production.

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SOLAR-POWERED CARS

Many of us love the excitement of motor racing. Even people who are not fans recognise that the sport contributes an enormous amount to the development of new, efficient technologies. Unfortunately, one aspect that the race teams don't seem to worry about is the availability and cost of the fuel that powers their engines. However, there is one motor race in the world that does contribute to the development of an environmentally friendly energy source - solar power.



The World Solar Challenge is the biggest race in the world for vehicles powered solely by the energy of the Sun. The race, held every two years, crosses the Australian continent north to south from Darwin to Adelaide over 3010 kilometres, and the race teams have to deal with some of the most arduous conditions on Earth.

The first World Solar Challenge was held in 1987 in order to show the world the potential of solar power. The best solar cars perform extremely impressively, being capable of travelling 1000 kilometres for a cost of just over 2 Euros! This is about 50 times more efficient than an average family car. Some of the cars can also achieve speeds in excess of 160 kilometres an hour.



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The competition participants vary from multinational companies to high schools and universities. In 2001, the regular contestants were joined by a team from The Netherlands, consisting of students from the Delft University of Technology and the University of Amsterdam. One of the unique features of the Dutch entry was that their vehicle carried solar cells, provided by ESA, which were once employed on the Hubble Space Telescope. The Dutch team also used new cells designed by the same people who produced the original cells for Hubble to power the car. They are some of the best performing and most efficient solar arrays ever designed.

As well as providing solar cells, ESA supported the venture by providing technical expertise, and one of its former astronauts led the advisory team. Thus equipment and technology used in space was transferred directly to a technically challenging venture and this collaboration paid off because Nuna, the Dutch solar car, won the World Solar Challenge on 21 November 2001. Never before had a newcomer won the race at the first attempt and Nuna broke 4 world records in the process!

Time record:	32 h 39 m
Days record:	3010 km in 4 days
Record distance:	830 km in 1 day (8h)
Record for a Solar Car:	top speed >100 km/h (average speed: 91 km/h)

MORE SPACE IN YOUR CAR

There are a host of other technologies developed for or used in space which have also been spun-off to the car manufacturing industry. Examples include: car windscreens being used as antennas to transmit data; transparent heating systems for windscreens; the use of GPS satellites to provide navigation maps and route directions; and micro-coating of metals for car headlamps. Also special composite materials,



plastic panelling, resins and carbon fibres – already applied to spacecraft – are now made available by the plastics industry for car bodies. And it's not only plastics. The Audi car company is using silicon and manganese aluminium alloys for car parts, and there are special car bodywork electrocoatings with molybdenum disulphide to reduce air friction at high speed. Fabrics and pyrotechnic devices used in space are being used for airbags and safety belts in cars. Finally, technologies first developed for rocket propulsion are also used in the automotive industry. Examples include seals for fuel pumps, engine cooling tubes, shape memory alloys to optimise the performance of catalytic converters, and microfibre/ceramic insulation material for use in exhaust silencers.

So next time you get into your car, give a thought to what space technologies might have been transferred to it!



Benefits for our daily lives: The ESA Technology Transfer Programme

Over the past 35 years, the European space industry has gained considerable expertise in building, launching, controlling and communicating with satellites. From this long experience of how to overcome the hazards and problems created by such a hostile environment, many valuable new technologies, products and procedures have been developed. Today, this expertise is improving our daily lives by providing many innovative solutions for products and services on Earth.

Groundbreaking European space technologies are becoming increasingly more available for development and licensing to the non-space industry through the process of technology transfer. The ESA Technology Transfer Programme has already achieved over 120 successful transfers or spin-offs from space to non-space sectors.

This success is reflected by the fact that since 1991 technology transfer has generated more than 20 million Euros in turnover for European space companies and 120 million Euros for the non-space industries involved. Already 2,500 jobs and 12 new companies have been created, with 25 expected by 2003.

The ESA Technology Transfer Programme is carried out by a network of technology brokers across Europe and Canada. Their job is to identify technologies with potential for non-space applications on one side, and on the other to detect the non-space technology needs. Subsequently, they market the technology and provide assistance in the transfer process.



To learn more about ESA's Technology Transfer Programme please contact:

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or visit the ESA Technology Transfer Website: or the ESA-supported technology market places:

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