

# Reports and Surveys

## AUTONOMOUS LEGGED ROBOT

### 1. *Developing the RS-01 RoboDog*

What is claimed to be the world's most advanced, autonomous legged robot to be developed and marketed is called the RS-01 RoboDog. Produced with the aid of collaborative design software it is being marketed after less than a year's development and was available from April 2001 after its launch by its British developers, RoboScience. The company say that it is:

Intended to be both an advanced robotics technology demonstrator and a limited-edition commercial product, the RS-01 RoboDog incorporates breakthrough technology in a number of areas. This technology will form the platform for the next-generation lightweight robotics required for automating a wide range of industrial and domestic tasks and for eliminating the need for human involvement in high-risk industrial and military environments.

The size of an adult Labrador and powerful enough to lift itself up carrying a five-year old child on its back, the RS-01 RoboDog was developed in just seven months – from initial design concept to finished, working product thanks to an Internet-based collaborative engineering environment centred on the UGS\* product development and manufacturing software suite, Unigraphics.

The use of advanced software for such a collaborative project is now regarded as essential.\*\* RoboScience used the Unigraphics software suite and reports that:

“With the design team dispersed around different locations, we needed advanced software that would support a collaborative development environment by allowing complex design information to be shared over the Internet. UGS's software gave us that capability and allowed our development team to design the RS-01 RoboDog's 3,000 components in record time – and more importantly, have them fit together first time.”

### 2. *Design and technology breakthroughs*

Two of the most significant design and technology breakthroughs made during the development of the RoboDog

\* UGS (NYSE: UGS) is a software and services company which is dedicated to helping manufacturers optimise their product lifecycle process. It has been established for some 25 years, and operates worldwide. For further details: Contact: RoboScience: nick.witth@roboscience.com and UGS: kate.mills@ugs.com

\*\* Other companies with experience of the use of collaborative design software are also invited to contribute to this section.

were in the areas of its joints and in the body construction, where the use of the Unigraphics software suite was critical to the project's success.

The RoboScience developing team report that:

“The joints that we have developed can be thought of as the robot's muscles, combining elements that are usually separated, such as hinges, motors and a gearbox in a way that provides a far superior power-to-weight ratio than conventional designs. This is one of the secrets of the RS-01 RoboDog's advanced motive abilities and run time.”

During the design of the joints, design data from an external design spreadsheet was imported into the software where it was used in creating the basic geometry for the parametric 3D models. The final detailed design and assembly modelling of the joints was then completed in the usual way in the 3D CAD environment. Using Unigraphics, the design work and the production of manufacturing information was able to be completed in a matter of days, with the result that working prototypes of the joints were ready for testing less than a month after the design work had begun.

Meanwhile, the body presented another, altogether different design challenge. The RS-01 RoboDog body is an exoskeleton, or monocoque construction. So in fact, it is more like a crab or a scorpion than a dog.

The exoskeleton construction presented two main, difficulties. The first was that, because it was designed from the outside in, there was a chance that one could end up without enough space to fit everything inside properly. The second was that with an exoskeleton, the styling parts are the same as the structural parts and are always being adjusted during the design process. In fact, with RoboDog, a greater percentage of the structural parts are visible than on an aircraft or car.

A further important factor was that, because of the time constraints under which the development team was working, design of the body construction had to begin before the joints and other internal components had been fully tested and finalised.

### 3. *Integrating styling, engineering and manufacturing*

The use of advanced software at this stage of development was crucial. The design process was similar to that for the joints but this time, the issues were styling, surface modelling, packaging of the components and manufacturing – all of which were dealt with in a collaborative engineering environment, driven from the same mathematical master model and using the Internet to communicate design information between different members of the team.

To save costs and time, the decision was made to go to a fully working 'production' prototype without the luxury of building elaborate mock-ups first. All styling and engineering design decisions were therefore made within the Unigraphics 3D model environment.

The actual manufacturing of RS-01 RoboDog's components was handled by external suppliers, with final design data being transmitted to them over the Internet and imported directly into their CAM (computer-aided manufacturing) environment in native form using UGS' Parasolid XT format. This ensured an accurate and fast data transfer. The typical time to design tooling for a component was one hour, while the typical time to transfer that design over the Internet to the manufacturer was five minutes.

Throughout the design of the RS-01 RoboDog, particularly when it came to its body, UGS' UG/Visualise software – part of the company's Shape Studio industrial design software suite which fully integrates with Unigraphics – was used to create photorealistic visualisations for styling decisions and for use in future marketing activities.

RoboScience believe the development would not have been possible without the use of advanced collaborative design software, particularly in a tight development environment. This resulted in their ability to integrate the different processes in a single 3D model and communicate them over the Internet.

Apart from the operating system used in its robots (Microsoft, Windows) and some other secondary software components, RoboScience owns all of the intellectual property rights (IPR) and patents that are being pursued as a result of the development of the RS-01 RoboDog.

## INDUSTRIAL ROBOT SURVEY

A survey\* by the *United Nations Economic Commission for Europe* (UN/ECE) and the *International Federation of Robotics* (IFR), based on the available data for orders for industrial robots in Europe reports a boom in robot orders in Europe. Whilst most readers await data that includes the fourth quarter of 2001 with some apprehension this survey is able to record statistics that are particularly impressive in Europe.

### 1. Robot orders have boomed in Europe

"Never before have so many orders for industrial robots been placed by the European industry, pointing towards an acceleration in the drive to automate", says Jan Karlsson of the United Nations Economic Commission for Europe (UN/

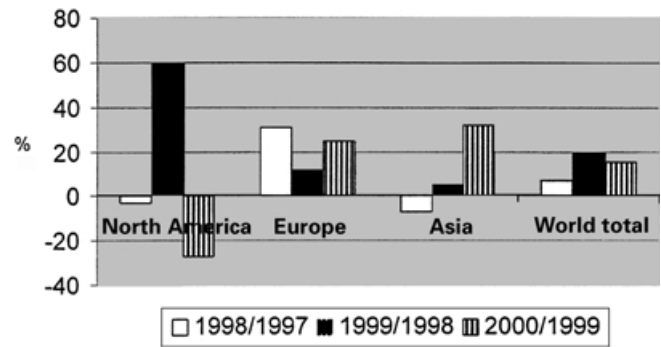


Fig. 1. Percentage change in order intake of industrial robots, 2000 over 1999, 1999 over 1998 and 1998 over 1997. Sources: United Nations Economic Commission for Europe (UN/ECE) and International Federation of Robotics (IFR). Figure supplied by UN/IFR

ECE), which together with the international Federation of Robotics (IFR), regularly survey the robot market. In 2000, orders for industrial robots in Europe were 25% higher than in 1999 (see Figure 1). Judging by the fourth quarter of 2000, which showed an increase of 24%, there is no slow-down in sight in the European investment activities, at least not as concerns robotics systems.

The figure for Europe is, in particular, impressive in the light of a 31% surge in 1998 followed by a 12% growth in 1999 (see Figure 1).

### 2. World-wide orders were up 15%

World-wide orders for industrial robots were up 15% in 2000 compared with 1999, slightly down from a growth rate of 20% in 1999 over 1998. The world-wide increase was concentrated to Europe, up 25%, and Asia, up 32% (see Figure 1).

After an impressive increase in orders of 60% in 1999 over 1998, it was expected that orders would drop in North America. A fall as high as 27%, however, is a clear indication of the slow-down in the American economy.

### 3. Non-automotive industries are stepping up their robot investments

Normally, it is the automotive industry that leads the drive to robotize. This was the case in 1999. In 2000, however, there was a significant turn around. World-wide non-automotive industries increased their orders with close to 40% while final automotive assembly only increased by 3% and automotive components with 9%.

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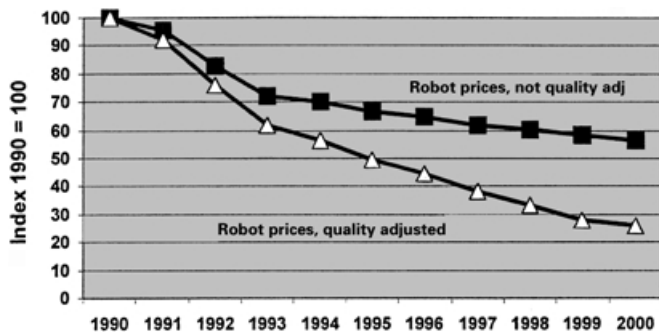


Fig. 2. Price Index of Industrial robots (based on 1990 \$ conversion rate), with and without adjustment for improved quality (performance). Sources: United Nations Economic Commission for Europe (UN/ECE) and International Federation of Robotics (IFR) . Figure supplied by UN/IFR.

In Asia and Europe, non-automotive industries increased their orders with as much as 56% and 41%, respectively. In North America a modest growth of 5% was recorded in orders from the non-automotive industries, in contrast to the automotive industry which recorded sharply falling robot orders.

4. Robotization spurred by plummeting robot prices

The surge in robot investments has several explanations. A central reason is that prices of robots are falling rapidly relative to labour costs. Robot prices in year 2000 were on average 44% lower than in 1990 (see Figure 2). At the same time today’s robots have much higher performance than those produced in 1990 with respect to versatility, speed, accuracy, and above all computer power.

A quality adjusted price index, that is an index in which consideration is taken to the continuous performance improvements, would therefore show an even higher price reduction. It is estimated that a robot in year 2000 costs less than one third of a robot in 1990 with the same performance.

5. Increasing labour costs

While prices of robots have plummeted and quality has increased, labour costs have risen steadily. In the United States, for instance, labour compensation in the business sector rose by 43% in the period 1990–2000 (see Figure 3). At the same time robot prices in the US dropped by over 60% without taking any consideration to improved robot qualities and performance. By taking the later into account prices would have dropped more than 80% showing that robots have had a price/performance development similar to that of personal computers. For every year, robots are becoming more and more cost-effective *vis-à-vis* manual methods of production.

“Rapidly falling relative prices of robots paired with shrinking labour supply, in particular to the manufacturing sector, in the years ahead will spur continued high growth in robot investment”, says Mike Wilson, chairman of IFR. “We have only seen the first phase of the robotization drive, which has mainly focused on the automotive industry. The food industry and all other manufacturing industries as well

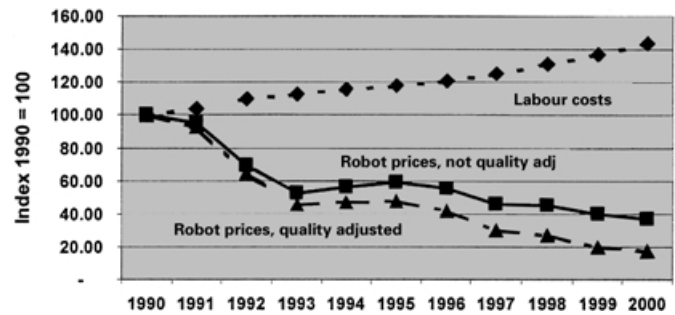


Fig. 3. Estimated price index of industrial robots in the United States, with and without adjustment for improved quality (performance). Index of labour compensation in the U.S. business sector.

as many non-manufacturing sectors, are as the year 2000 data clearly show, significantly stepping up their investment in robot systems” says Jan Karlsson, UN/ECE.

INNOVATIVE SYSTEMS

1. Broadband technology

In the United Kingdom broadband technology is providing a communications revolution. Unfortunately it needs to be publicised countrywide. The UK Government and business leaders are trying to remedy this, particularly for the small to medium companies. It now advertises ‘Broadband Britain’ in order to sell the latest tool in the electronic revolution. Government agencies say their biggest problem is that not many people know what it is nor what it can do for them. What has until now been available only to the big businesses and concerns at great expense is now finally available it says, for all, that is subject to the telecom companies and other service providers supplying the necessary access.

At the moment it is being sold as an ‘always on access’ to the Internet. This, provided the price is right, is a justification for many users to adopt broadband technology.

At present the multi-billion pound broadband communications networks can be used in many parts of the UK. The UK has set out its vision in its document *Broadband Britain—UK Outline: the broadband future*. The government says that it is on course to ensure that the UK has the most extensive and competitive broadband market among the G7 nations by 2007.

Currently the packages available will not be taken up in homes, councils, schools, hospitals, libraries and businesses until there is some understanding of what it is and what it can do.

Broadband covers a range of technologies including cable modems, Asymmetrical Digital Subscriber Lines (ADSL) as well as wireless data. It opens networks to provide unlimited bandwidths, that is the amount of information that can be sent over a communications link, usually measured in bits-per-second. Broadband technology allows information to move at 10, 20, 30 and 40 times faster than conventional links. It can provide virtually unlimited bandwidths capable of carrying the most complex multimedia content at high speed.

## 2. Broadband packages in the U.K.

The first broadband packages have been available since 2000 and some internet access services are designed specifically for it.

## 3. New systems and services

Current packages range in speed from 512 kb/s (kilobits a second) which gives downloading speeds nearly 10 times faster than the standard 56 K modem to 2 mb/s (Megabits a second) which is 40 times faster. Two widely available broadband systems are ADSL (Asymmetric Digital Subscriber Line), developed by British Telecom (BT) and another system using cable modems. The latter system connects premises to a fibre-optic cable network, offered by UK cable services companies NTL and Telewest. BT reports that it currently has 65,000 subscribers to ADSL and its unbundling of its local exchanges has allowed 170 independent operators to buy broadband wholesale to offer their own ADSL services to customers.

BT's mass-market internet business Btopenworld has also launched a satellite service to home-based firms and small/medium businesses. It will in due course be available in many parts of the UK. Most companies and home users see broadband as vital for their communications systems. Although slow in coming and being accepted, it is now regarded as vital for the new digital economy.

## 4. Smart Armour

The report that defence scientists are developing Smart Armour is not entirely unexpected, but the choice of system is certainly a surprising one. The reports say that researchers are developing a system that would use powerful magnets to melt and destroy incoming missiles and shells that threaten a military vehicle.

New super tanks are to be covered with the smart armour which, we are told, uses electrical fields instead of thick metal for its protection. It would mean that using this new technology the tanks would no longer weigh some 60 tonnes, because they would normally be constructed of heavy plating, but more likely a mere 20 tonnes. *The New Scientist* (August, 2001) carries research details of the new technology. It says that each tank would be covered with tiles made of strong plastic under which sandwich of different materials would be installed. First there would be a mat of optical fibres and then a thin sheet of standard armour plating. Underneath that would be a series of metal coils. The report describes its actions as follows:

When an anti-tank shell explodes on standard armour, the copper cone of its head is projected as a powerful jet of metal that travels at five miles a second. This jet forces an immense amount of energy on a tiny area and so can cut easily through several metres of dense material causing great damage inside the tank. In contrast if such a shell strikes smart armour, a very different reaction would occur. Initially it would sever optical cables in the mat below the tank's outer plastic cover. This would trigger sensors to activate electrical capacitors inside the vehicle which would send a heavy current through the metal coils

at the base of the smart armour. A massive electromagnetic field would be created inside the armour, as the high velocity copper jet begins to pass through it. The field would induce electrical currents in the copper. With enough current input into the copper it can be heated up and start pinching it in certain regions, making it unstable. The thin copper jet would be flattened and broadened out and so would be unable to cut through the thin standard plating at the base of the smart armour.

What happens is that electromagnets have been used to dissipate the energy of an anti-tank missile or shell, providing a force field to protect the tank. There are obvious 'spin-offs' to the use of magnetic pulses to provide a protective shield in other applications where such protection is required. Smart armour could well be developed for other uses such as the protection of vehicles, aircraft, installations, etc.

## 5. New digital radio system

The National Radiological Protection Board\* of the United Kingdom (NRPB) has produced a report on the possible health effects from Terrestrial Trunked Radio (TETRA). The NRPB say that:

Terrestrial Trunked Radio (TETRA) is a new digital radio system for use by commercial organisations and the emergency services. Its operation results in pulse modulation of the radiofrequency (RF) signal at a low frequency (17.6 Hz). Concerns have been raised about possible health effects of exposure to RF radiation that is pulse modulated (a form of amplitude modulation) at low frequencies. AGNIR has reviewed the features of operation of the TETRA system, the likely levels of exposure of people, and studies relevant to the assessment of any biological effects. It has noted that the signals from base stations are not pulsed whereas those from hand portables and from terminals built into vehicles are. AGNIR has concluded that although areas of uncertainty remain about the biological effects of low-level RF radiation in general, including modulated signals, current evidence suggests that it is unlikely that the special features of signals from TETRA hand portables and terminals mounted in vehicles pose a hazard to health.

This report by the National Radiological Protection Board's Advisory Group on Non-ionising Radiation (AGNIR)<sup>i</sup> gives advice on possible health effects of Terrestrial Trunked Radio (TETRA). It has been prepared, at the request of Government, as a consequence of a recommendation by the Independent Expert Group on Mobile Phones (EGMP)<sup>ii</sup> in May 2000 that ". . . as a precautionary measure, amplitude modulation around 16 Hz should be avoided, if possible in future developments in signal coding." For references (i) and (ii) see next page.

The IEGMP recommendation was made because of the results of a number of studies on the effects of radiofrequency (RF) fields on the rate of loss of radiolabelled calcium from the brain and other tissues. These studies, most of which were carried out in the late 1970s and early

\* NRPB Website: <http://www.nrpb.org.uk>

1980s, and mainly on isolated, non-living tissue, had suggested that when the RF signal was amplitude modulated at around 16 Hz the rate of leakage of calcium was increased. Calcium plays an important role in many biological processes, especially in the function of nerve cells. The IEGMP concluded that although no obvious health risk was suggested, as a precautionary measure, amplitude modulation around 16 Hz should be avoided, if possible.

TETRA is a new digital system for mobile radio. It is designed to replace the older analogue radio systems used by the emergency services and commercial organisations, and it offers a variety of new facilities such as data communication and improved security. In the UK, a TETRA system is currently operated by Dolphin for commercial use, and trials are underway for a system to be operated by BT Airwave for the Police and possibly other emergency services.

TETRA operates at around 400 MHz, using a network of fixed base stations to serve mobile terminals that are in the form of hand portables (similar to mobile phone handsets) or built into vehicles (called mobiles by the police). The TETRA base stations provide the service either directly or indirectly via repeaters that are generally built into vehicles.

The operation of TETRA results in power modulation of some of the RF signals at a pulse frequency of 17.6 Hz. As a consequence of the recommendation by IEGMP, concerns have been raised about any health implications of its use. The principal features of the system, the carrier and modulation frequencies at which it operates, and the characteristics of relevant hand portables are described in the report by AGNIR. It is noted that although the signals from mobile terminals and repeaters are pulse modulated, those from base stations are not. Therefore the RF fields from TETRA base stations, to which the general public will be exposed, are not only very low but are also not pulsed. Also considered are the likely exposures to RF fields of users of TETRA systems. All exposures are considered in relation to existing guidelines.

Experimental studies available for assessing any possible health effects arising from exposure to signals from TETRA are examined. The calcium-efflux studies carried out in the late 1970s and 1980s are reviewed and placed in the broader context of more recent studies that have examined the effects of amplitude-modulated and pulsed RF radiation on brain tissue over a range of frequencies. Other relevant studies are also considered, including those on the excitability of nerve cells, effects on brain electroencephalograms (EEGs), epilepsy and other possible biological effects. Although there have been no epidemiological studies on the consequences of exposures to TETRA systems as such, those studies relevant to RF exposure in general are also summarised.

Recommendations for further work are included in the report.

The principal conclusions of the review by AGNIR are given below:

“It is recognised that calcium plays an important role in many biological processes, especially in the function of

nerve cells. Moreover, as the Independent Expert Group on Mobile Phones pointed out, there is evidence suggesting that RF fields, amplitude-modulated at about 16 Hz, may influence the leakage of calcium ions from tissues. However, findings have been contradictory; they are more uncertain for living than for non-living tissue, and no associated health risk has been identified. It is notable that the signals from TETRA base stations are not pulsed whereas those from mobile terminals and repeaters are. Although areas of uncertainty remain about the biological effects of low-level RF radiation in general, including modulated signals, current evidence suggests that it is unlikely that the special features of the signals from TETRA mobile terminals and repeaters pose a hazard to health.”

Readers may wish to obtain more information and the following references have been included:

#### References (see previous page)

- (i) Report on Possible Health Effects from Terrestrial Trunked Radio (TETRA). Report of an Advisory Group on Non-ionising Radiation. Published on the NRPB web site 31 July 2001 [www.nrpb.org.uk](http://www.nrpb.org.uk). To be published later this year in the *Documents of NRPB*, Volume 12 No. 2 (2001). (ISBN 0-85951-464-1) £15.00. (Telephone: 01235-822742, fax: 01235-822746 or email [information@nrpb.org.uk](mailto:information@nrpb.org.uk).)
- (ii) IEGMP (2000). Mobile Phones and Health. Report of an Independent Expert Group on Mobile Phones. Chairman Sir William Stewart. (ISBN 0-85951-450-1) £20.00. Available from the NRPB (see 1. above) or on [www.iegmp.org.uk](http://www.iegmp.org.uk).

#### 6. A robot to stroke seedlings.

It is reported that a robot designed to stroke seedlings to make them grow faster has been developed by researchers. A research project at Greenwich University UK, has, apparently, confirmed that plants crave the human touch and they have in consequence developed a stroking machine which has been called Dr. Green. It is reputed to have many benefits for both gardener and the environment. The designers at the University's School of Engineering say that their robot can reduce reliance on fertilisers.

The robot was demonstrated at the London Chelsea Flower Show, where it highlighted thigmomorphogenesis, the technique for brushing the tips of young plants to produce sturdy specimens.

Currently the robot is being tested on a large scale by a UK bedding plant producer. The technique has also been used in research at the University of Pennsylvania where researchers found that a single gentle stroke from base to tip resulted in toadflax plants living longer and growing more quickly. When sulphur cinquefoil, another plant, was caressed once a week, it developed increased insect resistance. Indeed it is believed that stroking seedlings once a day makes them 30% stockier.

The prototype robot used at the Chelsea Flower Show had a 4 foot sweeper that stroked plants all day. In normal use, we are told, the robot Dr. Green would brush plants 30 times every morning and evening.

Such a robot would ultimately be part of a fully automated system which would be of great importance to plant producers. Such a system would require robust plants since plants grown in protected environments tend to be thin due to high temperatures, low light levels, plenty of nutrients and low wind speeds. Automated systems would be designed to give plants the opportunity to respond to an increased degree of physical disturbance from touch or wind movement and grow shorter and stockier. Robots obviously) have a role to play in such systems and Dr. Green is only one innovative device that will ultimately be in use.

### LIFELIKE ROBOTIC FISH

What is claimed to be the world's first lifelike robotic fish is being produced by Japan's Mitsubishi Heavy Industries (MHI). It is said to be the first such robot fish to be made available on the market that is both radio-controlled and also lifelike. Called the "*Mitsubishi Animatronics*". The animatronic device is in the likeness of a coelacanth, an ancient fish called a "living fossil." MHI is creating the lifelike creature in the hopes of marketing it and similar animatronic systems to amusement parks and aquariums.

The completed coelacanth, as well as a special water tank and a computerized control system, are scheduled to be delivered to the "Aquatom," which is a 3,000-square metre science museum currently being built in Fukui Prefecture, Japan. The robot fish will be exhibited to the public at the entrance hall of Aquatom.

The artificial coelacanth, measuring 70 centimeters long and weighing 12 kg, will be powered by an internal battery and controlled automatically by a computer. MHI has employed its *elastic oscillating fin propulsion control system* to reproduce the lifelike swimming motions of a real fish. The technology synchronizes fin movements on the fish to control both thrust and direction. The body of the fish is partly made of silicone plastic, an elastic material.

MHI describes the system as an:

Elastic oscillating fin propulsion control system where propulsion is produced when an elastic board is oscillated in the water. Based on the natural motion of fish, this technology was originally intended for application on propeller-driven marine vehicles. Advancements in computer and control technologies have, in this case, enabled propulsion by delicately controlling elastic fins on the fish.

Compared with a prototype model, the major feature on the production model is further improvements in movement. This has been achieved by increasing the number of controlled fins. While adding fins has made it more difficult to control the balance of the fish, the end result is superior lifelike movement. Synchronized ventral fins have been added to the production model, whereas pectoral fins and a caudal fin were already present on the prototype.

Another feature of the artificial fish is its fully automated operating system. When visitors press a button at the front of its holding tank, the coelacanth will start swimming and, when its battery runs low, the fish will automatically swim to a recharging unit. This feature eliminates the need for an operator during regular exhibition of the fish.

By incorporating its advanced technologies and accumulated experience, MHI has been able to reproduce the coelacanth, a rare, deep-sea creature, which the public would seldom have a chance to see in real life. The company's Mitsubishi Animatronics marketing division hopes to market its work to amusement facilities and aquariums.

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### NEW PRODUCTS FOR AUTOMATION

#### 1. Family of welding robots

The use of welding robots worldwide is now an accepted part of the international industrial scene. A report for the United Kingdom outlines new advances in design and application. It highlights the recent addition to the six ABB welding robots already in use with the bridge builder Mabey & Johnson at their Lydney plant in the UK. The company have ordered an IRB 2400L welding robot for immediate installation, because the head of the company's robot selection team believes that its advanced design was superior to that offered by other manufacturers. Others may disagree, of course, but he points out that its cutting-edge productivity features such as Bullseye® automated torch calibration and Advanced Welding Control 'Seamtracking' system as well as its commonality with and reliability of their current ABB robots were its main selling points (Plate 1).

The robot will provide extra capacity for new bridging contracts, particularly increased production of the Mabey Compact System of modular panel bridges, and will form the initial phase of a programme of re-investment in new automation.

As well as a wealth of civil applications throughout the world, Mabey & Johnson's Compact Bridging System was used for no less than 18 sites in Bosnia to fulfil the line of communication for the United Nations Protection force in Bosnia (UNPROFOR).



Plate 1.

The Compact is a readily transportable, prefabricated bridging system, which can be rapidly erected in only a few days by unskilled labour without plant, and requires minimal maintenance thereafter.

The system uses a high strength steel structure based on 3.05 m long vertical panels, with attaching transoms, reinforcement chords, frames, braces, steel decking units, kerbing and other basic components. To maintain simplicity, these are standardised and the number of different components kept to a minimum.

Welding/fabrication of the components is carried out primarily by six modular-based ABB robots, each mounted on a traveling column and organised into paired cells operating 24 hours a day, seven days a week. Although the function of each cell can change, normally cells 1 & 2 are dedicated to panel fabrication, cells 3 & 4 chords, and cells 5 & 6 decking.

The new IRB 2400L will form a seventh 'floating' cell that will process components as production contingencies occur, and form a back-up cell as individual robots are removed for upgrading.

The IRB 2400L is part of the IRB 2400 family of robots which offer a longer reach for welding, higher load capacities, improved motion performance, improved reliability and improved serviceability.

Each robot model uses an average 40 per cent fewer parts than earlier models and reliability has been increased even further with the introduction of maintenance-free gearboxes, better cabling and longer intervals between routine inspections (now a simple two-point check every three years).

Robot control and operation is through the well-proven S4C plus controller, with easy-to-use windows-style user interface, function keys and pull-down menus, while the QuickMove self-optimising control provides the robot with fast acceleration and constant high speed even with complex path following.

A key feature of the IRB 2400L, which won over the Mabey & Johnson specifiers, was its Bullseye® automated torch calibration system. Bullseye® ensures optimum quality and reduces downtime by enabling the robot to check its own tool centre point (TCP). The TCP is a crucial reference point that determines the position, accuracy and quality of the weld.

On most robots, TCP confirmation is normally a lengthy, arduous process that is carried out on a regular basis after occurrences such as collision with a fixture, changes in ambient temperature or a worn contact tip.

The IRB 2400L also features Advanced Weld Control (AWC) 'Through-the-Arc' tracking. AWC follows weld joints by sampling the welding current and voltage signals synchronized with the robot weave pattern, and provides vertical and horizontal correction signals to the robot controller to assure a consistent fill of the weld joint. Advanced tracking is required to accommodate special situations where joints vary, other special weld conditions apply or when a 'part fit' is less than desirable.

Mabey & Johnson tell us that: "The longevity, reliability and maintainability of our ABB robots has been excellent, with some of them having worked almost non-stop for 12

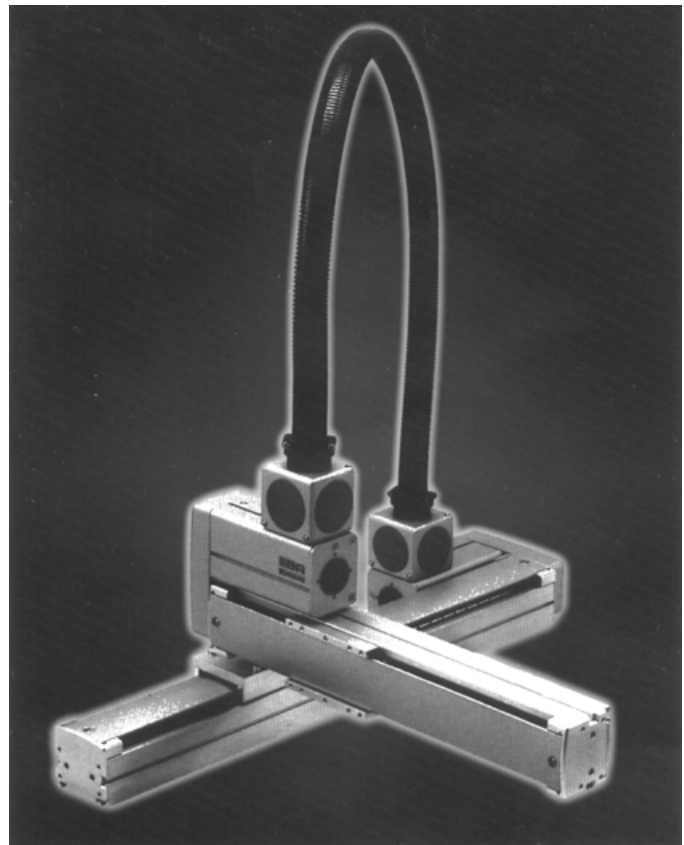


Plate 2.

years." We have no doubt that the new IRB 2400L and other ABB robots to follow will help us respond quickly and efficiently to future market trends.

Reports of new advances in design and application of welding robots will be continued in future issues of this journal.

## 2. Multiple actuators and Cartesian robots

The range of linear multiple actuators and Cartesian robots available in Europe has been greatly increased. Toshiba Machine (see Plate 2) and TM Robotics\* are marketing the BA series, more commonly known as the ROiBot. This uses a modular building block design, allowing single or multiple axis configuration to be built from the same standard components. This system allows for over 500 configurations whilst the compact design minimises space requirements.

TM Robotics say that:

Each axis can handle up to 100 kg and features AC servomotors, precision ground ball screws and high rigidity linear guides. Motors can be mounted on either side of the axis, or underneath, to reduce its overall length. The junction box unit can be mounted almost anywhere along the axis and allows cable to exit from any of five directions. The Robot is supplied with a unique flexible tube carrier system, which, can be mounted horizontally or vertically.

\* TM Robotics (Europe) Ltd, Concord House, Grenville Place, Mill Hill, London, NW7 3SA, UK (Tel. +020-8906-9825; Fax. +020-8959-0081)

The controllers are similar in size to a stand-alone AC servo driver and fit easily into an instrumentation panel. Built in I/O can eliminate the need for external PLC or sequencer controls and provides standard support for basic pick and place and palletising routines. Up to four controllers can be connected together in a multitasking system and each one can accept a pulse train input for movement commands, allowing an external motion control system to be easily integrated.

Many options are available the company claim. The standard model locates the home position sensor on the axis close to the motor.

In addition, we are told an optional home position-changing sensor is available, which allows it to be moved to the opposite end of the axis furthest away from the motor mounting. Changing the home position, TM Robotics say, can allow more efficient return to home operations in special configurations.

The unit can be programmed using familiar WIN-DOWS™ based programming tools and the programming language is carried over from existing ROiBot lines to facilitate the use of all equipment. As an option, the unit can be supplied with the TPH-2A teach pendant, which connects to a main controller and serves as an alternative programming device. It also provides the controller with home position, start, stop, reset and emergency stop instructions. It can display alarm conditions, current program step and current position data.

Further options include clean room and dust resistant options as well as regenerative discharge units.

### 3. Six-axis force/torque sensor system

Tatem Industrial Automation Ltd\* have produced the Gamma compact monolithic transducer which they claim is accurate to 1% of full scale and converts six component force/torque values into amplified analogue signals with a high signal to noise ratio. They are supplied pre-calibrated but can be easily re-programmed to provide a reliable and highly versatile plug-and-play system. Force and torque in X, Y and Z axes – in a single compact package!

These ATI transducers have been successfully used to monitor and control both force and torque associated with the grip and touch functions used in the development of surgical prosthetics. However, technological progress presages the ever growing use of the products in general industrial robotic applications for design, manufacture, assembly, testing and inspection over a very broad engineering spectrum which includes the nuclear industry.

Typical applications include:

- Remote force and sensing with nuclear telerobotics
- Real time force control
- Haptics feedback and prosthetic device testing and manufacture
- Robotic assembly
- Automotive and general engineering part testing
- Polishing
- Automotive seat tesing

\* Website: [www.tatem.co.uk](http://www.tatem.co.uk)

TIA Robotic Tooling Solutions in a recent release say that the extreme high strength of the Gamma transducer permits maximum allowance overload values of 6.9 to 31 times rated capacities. They also believe that the Silicon strain gauges provide signals 75 times stronger than conventional foil gauges, with amplified signals also benefiting from near zero distortion.

Three models are available covering sensing ranges of  $\pm 32$  to 400 N and  $\pm 2.5$  to 10 N-m. These can be stand alone units or computer interfaced, the latter providing 16 times greater resolution.

The products are manufactured from high strength aluminium with compact dimensions of approximately 75 mm diameter  $\times$  33 mm height, and weighing only 255 grams. They feature a removable adaptor plate to facilitate customised mounting requirements.

The transducers are supplied with a shielded high-flex cable and intelligent computer bus or stand alone controller for data output rates of up to 7800 Hz. This speed exceeds most robotic and data collection requirements, it is claimed.

Other suppliers who market robotic devices will also be featured in coming issues.

## REMOTE CONTROLLED ROBOTS

### 1. Innovative applications of remote controlled robots.

There are now numerous reports of the use of remote controlled robots. The range of applications seems to grow by the day. Industrial, Business, Military predominate, but medical uses now receive more coverage, often because of their direct human interest and frequently life-saving scenarios.

The biggest difficulty in all these applications is the means of communication. Telecommunication lines have been used in many instances with networks set up to speed operations. The Internet has been frequently used, as well as satellite links and other innovative systems. We are, of course, on the threshold of the development of these remote controlled systems, but it is encouraging to read of their practical successes. Several experimental systems have been reported in this section in an effort to publicise the transition from the theoretical research to the reality of practical application. One such application is reported in the following paragraphs.

### 2. Transatlantic operation to remove a gall bladder

Most developers are now afraid of using “the first ever” caption for their endeavours, whilst manufacturers have no qualms about making such claims. The recent report received about this transatlantic operation to remove a gall bladder proudly announced it to be the ‘first transatlantic operation’. It said that surgeons in New York carried out the operation using remote controlled robots to remove the gall bladder of a woman in France.

The procedure was carried out by three French surgeons at a control console equipped with monitor screens. We are



told that the careful and delicate movements of the surgeons hands in New York were electronically transmitted a distance of 4,300 miles to an operating theatre in Strasbourg, where a set of robot arms obeyed their commands.

The result was that the gall bladder was successfully removed in just under an hour and we are informed that the 68-year old patient was discharged from Strasbourg Civil Hospital 48 hours later.

### 3. Telemedicine

It is important to note the difference between this reported remote controlled operation and some others that have been held. Many 'telemedicine' operations have been confined to providing communication links and a limited degree of surgical expertise. In this transatlantic operation it is claimed that for the first time surgeons have completed a long-distance remote-controlled operation themselves.

One of the problems that such operations encounter is the 'time lag' which is, of course, caused by transmitting the information along the telecommunications lines or other linking system. In this case we are told a 'high speed optical network' was used in an attempt to increase the speeds of transmission of the data required by the remote robot-surgeons that are actually in contact with the patient being operated upon. Although advances in both communication, robotic devices and the visual interface between them and their surgeon-operators continues there will at present be some reluctance to use such systems for everyday routine surgery.

Although, as we will see in the detailed account of the Franco-American Transatlantic operation, the time delay in transmitting data for this particular surgical procedure was not a drawback.

### 4. Operation Lindbergh

The revolutionary procedure which is claimed to be the world's first example of intercontinental surgery and which is said to shatter distance records for the technique is called Operation Lindbergh. The team of Franco-Americans used 'virtual scalpels' linking them to a computer in New York to control the movements of Zeus, a robot in the operating theatre of the Strasbourg hospital. This machine replicated their hand strokes precisely. We are told by the team that the electronic commands and video footage made the round trip in 155 milliseconds and the actual operation on Mme Schall, the French patient, took less than an hour to complete.

Details of the surgery were published in Nature (September 2001), but we are told that on September 7, 2001, it was performed by Professor Marescaux and his colleague, Michel Gagner using a computer console at Mount Sinai Medical Centre in New York. Video footage of each scalpel movement was relayed to the doctors with, it is claimed, a time delay too short to be noticed by the human brain.

The Zeus equipment took 16 minutes to set up, and the procedure was completed in 54 minutes. Every aspect bar the initial incision and post-operative stitching was performed by the robot. Since the procedure was in a sense still

experimental a full team of surgeons were standing by in case of any problems.

### 5. New era for operations

The success of Operation Lindbergh heralds a new era in which surgeons will be able to operate on patients anywhere in the world without leaving their own theatres. What it means is that access to specialised skills and training will be completely transformed. Life-saving surgery by robots within metres of the battlefield will be possible for military personnel wounded in combat or in accidents, all at a minimal risk to the doctors involved in the procedure. Professor Marescaux of the Louis Pasteur University of Strasbourg, the leader of the surgical team believes that:

It was a milestone in medical history. We are looking at a technique that will make surgery completely global.

He also believes that similar methods could be applied to many other complicated treatments. For example, he said :

there are few things for which this is impractical. I am convinced that in less than a year we are going to see the first coronary bypass operation by telesurgery, and we will also see it being applied to other areas such as vascular and gynaecological surgery.

The views of David Rosin, a consultant surgeon at the UK's St Mary's Hospital, Paddington, London, were given to the Times newspaper (20.09.01). He took the view that:

For routine surgery, it will probably remain largely unnecessary, but for extremely specialised surgery which can be undertaken by very few surgeons throughout the world, then this is an absolute boon.

Even so, as with most advances in medicine that are related to the progress of high technology, it is difficult to foresee many of the 'spin-off' applications and uses. It could, for example, encourage the establishment of centres of surgical expertise which will make its services available both nationally and globally. In consequence we might see the hospitals as we know them change beyond recognition. There is, however, the certainty that these endeavours will bring about many of the changes robotics researchers and developers have predicted over the last decades.

## ROBOTIC PETS

### 1. Award winning robotic pets are potential big business

Some readers will need convincing that robotic pets are indeed serious business. We need only to be reminded, however, that the global market for domestic robots is estimated at over £68 billion and is more than double that of the world's industrial robot market to be convinced of its potential.

To support this sentiment the Royal Society for the encouragement of the Arts, Manufactures and Commerce

(RSA) of the United Kingdom, have introduced a new category into this year's RSA Student Design Awards\*

Called "Robot Technology" the new category is sponsored by the Japan-based Omron Corporation and by Europe's leading independent technology services company The Technology Partnership Plc. Students were asked to design a user-friendly robotic companion that makes effective use of interactive and responsive technologies to support and enhance the life of its owner.

## 2. Award winning work

Brendan Cusworth Bolger, University of Northumbria at Newcastle designed Munk.E, a robotic companion designed to alleviate loneliness and provide fulfillment through nurture and pet therapy. Munk.E is able to move around freely and utilises fuzzy logic systems to interpret his surroundings, allowing him to learn from experiences and respond to the needs of his owner. Audio and tactile sensors process and analyse touch and noise to determine Munk.E's responses. Munk.E's are able to communicate and exchange information with each other using blue tooth technology to create an interactive community of Munk.E's and their owners. Brendan Cusworth Bolger wins the Omron Attachment Award worth £5,000 and will be working with Omron's product design division in Tokyo and Kyoto.

Chris Tod, University of Salford, wins The Technology Partnership Attachment Award worth £5,000 with his stress management robot, MYSTIC. Designed to provide the user with an outlet for their stress and anxiety, MYSTIC responds to user interaction through touch, sound and movement sensors. MYSTIC responds to this interaction through a range of facial expressions, phrases and sounds including burping, breaking wind and sneezing to distract the user in stressful situations such as the office or a doctor's surgery. Chris Tod will undertake a 6-month attachment in the Product Engineering Division, working in a multi-disciplinary team environment where new products for many of the world's household names are developed.

\* The RSA Student Design Awards were established by the Royal Society for the encouragement of Arts, Manufactures and Conference (RSA) in 1924. Each year over 2,500 students from the UK and mainland Europe submit their designs for a wide variety of projects ranging from engineering design to fashion, glassware to postage stamps. Award winning students are given the opportunity of work experience with the sponsoring companies or overseas travel.

## UK AUTOMATION & CONTROL SYSTEMS INDUSTRY

### Manager's views on recession

A recent report on the UK Automation & Control Systems industry says that it is showing the signs of a recession. This was compiled early September 2001 prior to the world shattering events that followed. At that time over a third of the industry was reported to be exhibiting the signs of recession. The analysis finds companies must be adopting one of the four views on the current recession debate. These are, expressed as the "manager's view on recession"

- "I'm in a recession now"  
35% of the industry is losing market and profitability. These companies are finding the market tight and highly competitive.
- "There is no recession"  
28% are showing no signs of recession at all. These companies are powering into the market and uncovering great returns.
- "I'm preparing for the worst just in case"  
8% are adopting a steady approach trying for profits and in most cases, are using these profits to pay off debts.
- "I'll blast my way through"  
29% are going for it striving for as much market as they can get. Currently though these companies are showing poor returns for their efforts.

Table I provides some sample data from the report.

The assumption made in the findings reported is that a manager's view is inextricably linked to the performance of their own company. This has been used by the compilers to conclude how the 'players' in the Automation & Control Systems industry are feeling over this recession theme. One senior analysts suggests that it is market pressure that is forcing companies to associate with a recession rather than a slowdown in the market.

### 2. More research

Over a third of the 238 companies studied in the Automation & Control Systems industry are feeling they are in a recession. These 83 companies have seen sales decline a staggering 20.5% on average over the last year. Fifty seven percent are now at high financial risk according to the report and on average all of these companies are loss making.

These companies tended to be the smaller companies and are seemingly getting left out of an otherwise healthy market. Current market growth for the industry is a healthy

Table 1. Sample data from Plimsoll Portfolio Analysis: Automation & Control Systems.

	In Recession	Not in Recession	Prepared in case	Going for Growth	Industry Average
Sales Growth	-20.5%	21.7%	-15.3%	19.8%	5.6%
Profit Margin	-2.1%	6.6%	6.2%	0.0%	2.1%
Taking on more debt %	47%	54%	47%	68%	55%
High financial risk %	57%	34%	32%	61%	50%
Sales per employee	£82,000	£114,000	£81,000	£112,000	£95,000
Number of companies	83	67	19	69	238
Percent of Industry	35%	28%	8%	29%	100%

6%. Profitability is also low but on the right side of the red line at 2%. Efficiencies seem to be good at the moment and sales per employee numbers are healthy at around £95,000 per person.

Comparing dismal performance with the exceptional, it located 67 companies who grew way above the industry average with 21.7%! These companies would definitely not consider themselves to be in a recession at the moment and who could blame them?

For those 19 companies who are preparing for the worst in case of a recession, it found overall debt had remained level in these companies. Although profitability is steady at 6.2%, their compromise seems to have been sales growth. Last year saw a 15.3% drop in their sales. Motivation and future competitiveness for these companies should prove interesting.

Perhaps the most captivating are those companies who plan on going for growth no matter what the cost if a recession hits. These 69 companies are growing at 19.8% on average. Like those companies most fearful of recession, all of these companies are on average loss makers. This cavalier approach to recession is no doubt brave but perhaps a bit too risky.

The fact remains some companies thrive in a buoyant market and others lose ground commercially and financially. It could be suggested that in this virtual game of Snakes and Ladders, companies fearful of sliding into recession might be the most attractive to acquirers, the report analysts suggested.

### 3. *Some Conclusions\**

- (i) Research suggests that recession should not be measured by industry as a whole. "To generalise on company performance seems outdated and flawed. Recession will be more accurately determined by individual companies. It is up to individuals as to what stance they have on the issue and what strategies they will take to ensure survival," says the report's leading financial analyst.
- (ii) The more recent world events will, of course, have influenced the views of both managers and compilers. Even so, by using a simple method of assessing the individual companies, the Plimsoll Portfolio Analysis: Automation & Control Systems aims to lay bare the performance of each of the Top 609 companies which in itself provides valuable data.

*Obtaining the report:* (Readers of *Robotica* will receive a 5% discount off the £305 report when mentioning this article upon ordering).

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\* Plimsoll Portfolio Analysis: Automation & Control Systems - Plimsoll Publishing Limited, Middlesbrough TS1 5JA. Fax: (01642) 257806 e-mail: plimsoll@dial.pipex.com and on www.plimsoll.co.uk