

V.2 OC Robotics – Minimally invasive robots for confined spaces

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OC Robotics

V.2.1 Motivation, Initial Steps and Early Years

OC Robotics was founded in 1997 and raised venture capital in 2001 to develop snake-arm robots.

The business case for investment was based on identified needs for automated applications in confined and hazardous spaces. Existing industrial robots are generally designed to operate in open spaces and are of limited use in confined spaces. Confined and hazardous spaces occur in many industrial sectors including the aerospace, defence, petrochemical and nuclear sectors, as well as surgery.

Commercial drivers include the need to comply with health and safety legislation, avoiding expensive disassembly of components, and enabling new assembly processes. Asset management is a particular focus. Complex high value equipment requires regular inspection and maintenance, so solutions that maximise availability have commercial appeal.

The first period involved sustained design and development work. In these early years solutions to the basic mechanical design and software control issues were established. These are fundamental to the robust and reliable operation of snake-arm robots. At the same time OC Robotics won first customer contracts and completed a successful pipe repair at a Swedish nuclear reactor.

V.2.2 Today's Market Position and Outlook

Nearly a decade from the original investment, exceptional challenges still drive the company's employees, now over 20 in number, to innovate and seek unique design solutions.

As a result of securing vital long-term contracts with large, influential customers, OC Robotics has continued to grow through the economic downturn. OC Robotics continues to identify customers who are investing and who have need. The company is gaining a reputation for delivering challenging projects and developing new processes in addition to being a supplier of snake-arm robots. One route to exploiting the full potential of this technology is to partner with established suppliers in different sectors.

OC Robotics has won a number of awards including the Queens Award for Enterprise 2009. The founders were also awarded The Royal Academy of Engineering Silver Medal 2009. OC Robotics owns multiple patent applications and a number of granted patents.

V.2.3 A Snake-Arm Robot (Key-Product)

A snake-arm is basically a stack of flexible joints which behave like vertebrae. The arm is wire rope driven with the wire ropes terminating at various points along its length to define 'segments' that can be independently controlled. A motor is used to control the length of each wire rope while the control software calculates the necessary lengths of all the wire ropes to produce the desired shape.

OC Robotics has developed control software that enables the arms to "follow their nose" into confined spaces. Both off-line programmed and tele-operated versions have been created. The operator uses a joystick to drive the tip of the arm - much like operating a computer game. A powerful computer solves the complex mathematics to make the rest of the arm follow the tip. This tip-following capability enables a snake-arm robot to avoid obstacles and "snake" into complex structures. The operator can also control the arm in tool or world coordinates, whilst continuing to avoid obstacles.

The wire rope drive means that motors and drive electronics are located in the base of the

arm. All services are carried within the arm so that the external surface is smooth and continuous. This leads to a lightweight arm with constant arm diameter with a smooth exterior. These are important features when operating in cluttered and hazardous environments.

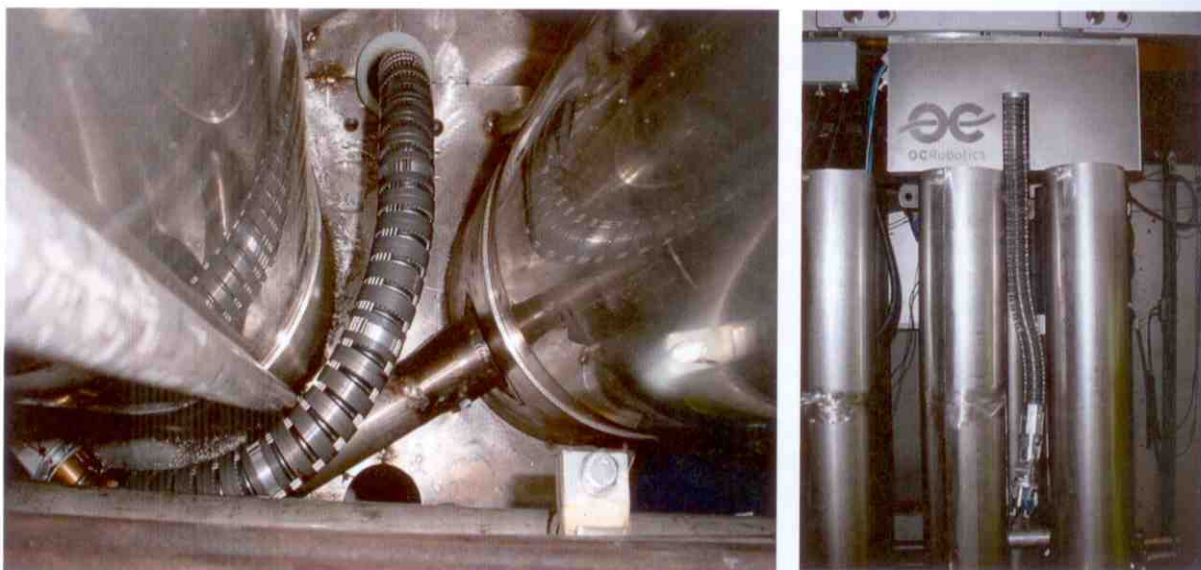
V.2.4 Bespoke Snake-Arm Robots

OC Robotics has designed, built and delivered numerous bespoke snake-arm robot systems to customers in the nuclear and defence sectors. Additional information is available at www.ocrobotics.com/applications.

V.2.5 Ringhals AB, Ringhals, Sweden

OC Robotics completed its first commercial nuclear contract in the summer of 2004. Working with Areva, two types of snake-arm robot were supplied to Ringhals AB to complete an urgent pipe replacement in an extremely awkward area below Ringhals 1. The Inspection Arm, the more flexible of the two snake-arms, was 1000mm long and 35mm in diameter and was used to get the ideal camera location to monitor the process. The Manipulation Arm, which was 800mm long and 60mm in diameter, was used to deliver the processing tools and fixtures, remove the old pipe, introduce the new pipe and conduct tasks such as welding and inspection. Replacing the leaking section of pipe involved more than 30 distinct procedures with the majority being conducted by the robots working cooperatively. It is reasonable to state that OC Robotics' technology was instrumental in keeping the plant operational, thus safeguarding an asset worth \$1bn.

Figure V.2: Ringhals Inspection Arm (left) and Ringhals Manipulation Arm (right)



V.2.6 Ontario Power Generation, Pickering, Canada

OC Robotics delivered a snake-arm to conduct inspections within the Upper Feeder Cabinet (UFC) of CANDU nuclear reactors in Ontario, Canada. The 2.2m long, 25mm wide snake-arm is mounted on a tracked mobile vehicle which is driven along walkways in the UFC. The snake-arm is stowed coiled for compactness and is deployed by unwinding and 'nose-following' between pipes. The snake-arm can be deployed at any angle to reach below or above the walkway, and was designed to inspect 100% of the UFC. Side and forward facing tool-mounted cameras are used for navigation and image capture. Pan-tilt-zoom cameras on the mobile and base units provide scene views and additional inspection capability.

Previously inspections were performed manually with cameras attached to the end of long

probes, with inspection times limited by radiation levels. The system increases the inspection scope which is critical for plant life extension, and decreases total operator dose. In addition to the health and safety benefits, operator dose reduction leads to substantial cost savings to the owner of the plant.

Figure V.3: Upper Feeder Cabinet



Figure V.4 OPG system: mobile unit with snake-arm stowed coiled



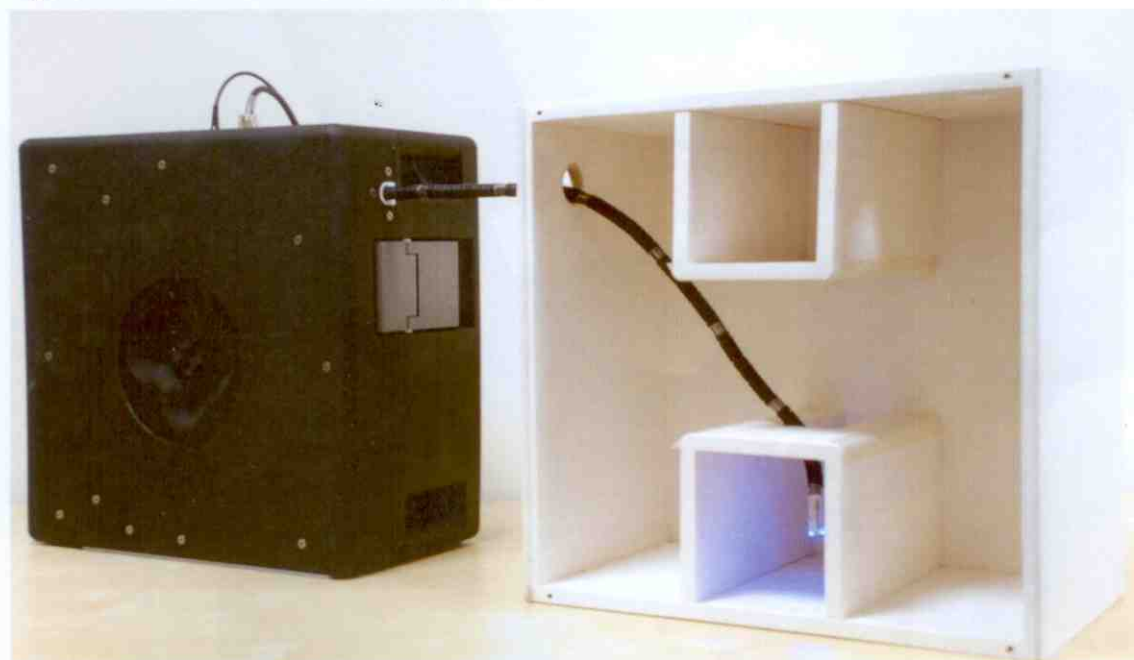
Figure V.5: OPG arm deployed below the walkway (in mock-up)



V.2.7 US Department of Defense, United States of America

OC Robotics has delivered two portable devices to the US Department of Defense for operational evaluation. They needed a way of inspecting and working inside confined or cluttered spaces - something not previously possible. OC Robotics designed two snake-arm robots which are just 12.5mm in diameter and 610mm in length. One snake-arm was equipped with a monochrome camera and LED lights; the other had a colour camera and tool. The arm uncoils out of briefcase-sized boxes where they are stowed.

Figure V.6: Snake-arm robot developed for USDoD



These snake-arm robots are extremely flexible and compliant. In essence they are 'controllable endoscopes', and the technology impacts on other industries outside security. Endoscopes are widely used in industry for remote inspection of engines, pipework and other confined areas of plant. Snake-arm robots enable personnel to reach further in free space than they could with a conventional endoscope as well as know more precisely where the camera or tool is in the plant. The scale of this device is also ideal for minimally invasive surgical applications including the emerging field of natural orifice surgery (often called NOTES).

V.2.8 Explorer range of Snake-Arm Robots

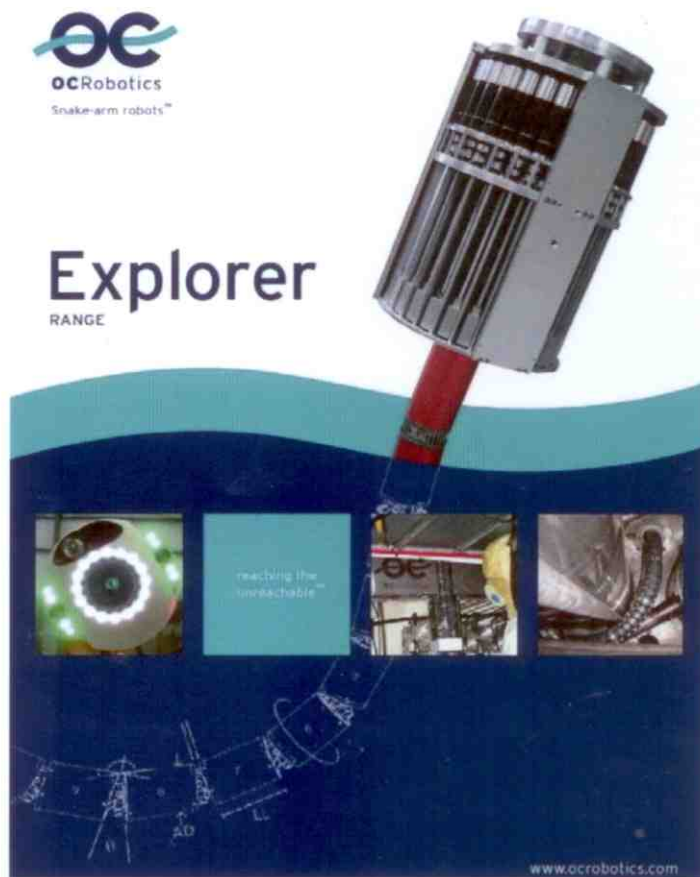
OC Robotics has released a range of snake-arm robots for industrial applications. The Explorer™ range showcases the capability and versatility of snake-arm robots and highlights the available options which will act as the basis of a customer's solution. The snake-arm robots in the Explorer range vary in size from 40 mm to 150 mm in diameter and from 1 m to 3.25 m in length. These dimensions represent the mid-range of our capabilities. The strength of the Explorer design is that it is scalable, so both smaller diameters and longer reach versions are possible.

Options include "quick release" mechanisms between the arm and the actuators, 1 or 2 degree of freedom wrists, and a variety of different tools. Snake-arms can be integrated with an introduction axis – a linear rail, industrial robot or vehicle – to enable controlled 'nose-following' motion.

The Explorer range of snake-arm robots is designed to operate as a standalone unit or with an OC Robotics introduction axis. Alternatively it can be integrated with a standard industrial robot, a crane or a mobile vehicle. Using industrial robots as an example, the Explorer range can be considered as a tool on the end of the industrial robot or as a flexible fore-arm for the robot. We see snake-arms being used as a plug-and-play addition to any automated production line. Our proprietary software controls both the industrial robot and the snake-arm to coordinate their motion.

The Explorer range is the result of 10 years of research and development into snake-arm robots, and is borne out of work successfully conducted in the aerospace sector. In the past OC Robotics has supplied only bespoke robotic solutions, but the catalogue explains all the available options and allows customers to specify an appropriate robot themselves.

Figure V.7: OC Robotics' Explorer range of snake-arm robots



V.2.9 Challenges and Lessons Learned

Owning and running any small company is both a privilege and extremely hard work. Small companies often have few tangible assets so cash generation from profitable contracts is essential. Intellectual property is really important but only if it has value. Getting products to market is the only way to build a sales order book. Building and maintaining a creative, motivated team who are able to respond to customer demands will always be challenging.

During the course of developing snake-arm robots, OC Robotics has been allowed access to a wide range of companies and organisations around the world. We are continually learning about our customers' technical challenges and striving to respond with innovative and commercially viable solutions.

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