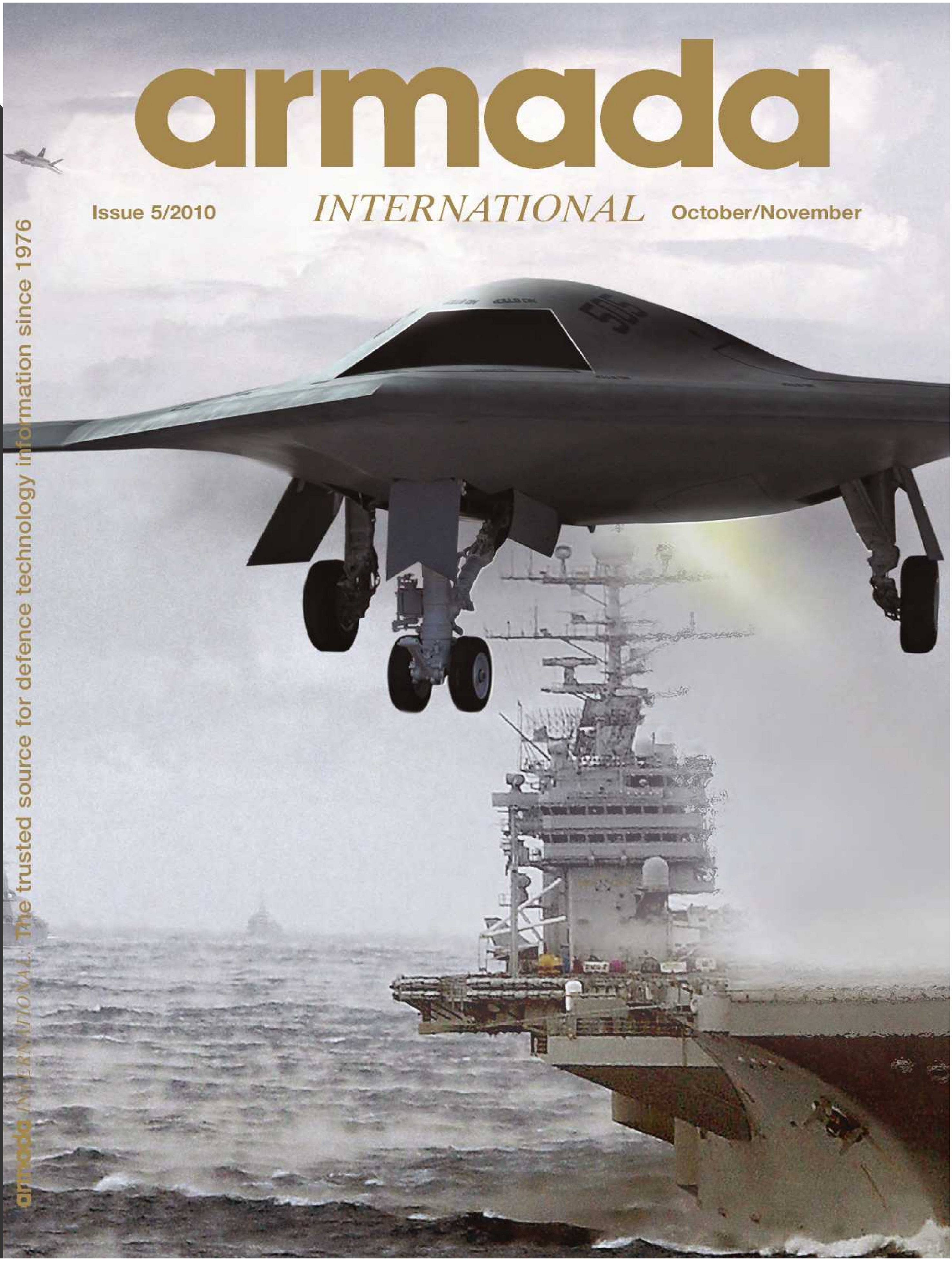
armada
Issue 5/2010
INTERNATIONAL
October/November
armada INTERNATIONAL The trusted source for defence technology information since 1976

The Incredible Hulks

Lockheed Martin's self-financed, powered exoskeleton project, the Hulc, allows its user to manoeuvre at speed over rough terrain and obstacles with heavy loads

The Caterpillar P-5000 Power Loader was designed to handle cargo and perform heavy maintenance. In the 1970s, it represented a fine example of the powered exoskeleton, namely a machine which could be worn by a human being as a frame incorporating lumbar support with powered arms, hands, legs and feet to dramatically increase his natural strength, enabling him to effortlessly lift loads weighing up to four tonnes. However, the only drawback of the P-5000 was that it was not for sale but rather to be the star of James Cameron's 1986 Aliens science-fiction masterpiece.

Thomas Withington

Fast-forward to May 2010 and cinema audiences are once again appreciating the awesome capabilities of the powered exoskeleton in Iron Man 2, the sequel to the eponymous film that brought the 1960s Iron Man comic character to the big screen.

Hardiman

As popular culture has illustrated, the thinking behind powered exoskeletons is not new, and several firms have been working on such machines since the 1960s. For example, General Electric developed the Hardiman, which was designed to allow wearers to lift weights normally beyond their natural capability. With the Hardiman, a 110-kg mass would feel to the user like lifting four kilograms. However, the Hardiman suffered many flaws and because of this it was never tested with a human operator as it moved in a violently unpredictable way. Moreover, the Hardiman had no military application given its 680-kg weight, which would render it unable to move quickly and easily around the battlefield.

The interest shown by the US military in the Hardiman illustrated that the powered exoskeleton had a clear military application. This is especially true today. The amount of equipment that the modern soldier must carry, in terms of electro-optical equipment, radios, computer-controlled battle management systems (which may or may not be located in a radio), batteries, body armour, a water supply, replacement ammunition and a weapon, not to mention a rucksack with clothing and rations, means that the infantry soldier is increasingly weighed down. For example, today's soldier can go into battle with equipment weighing up to 60 kg. Moreover, today's wars are very much infantry affairs, particularly when the terrain may be unsuitable for large vehicles, with troops being required to move quickly around the battlefield.

The powered exoskeleton could provide the answer to these challenges as a wearable suit that would help carry the weight of the infantry soldier's equipment, enabling him to move at speed. Not only will this make the soldier more responsive on the battlefield, but also it will help to reduce fatigue and thereby make the soldier more alert when contact time comes.

For their propulsion, exoskeletons typically use computer-controlled hydraulics powered by either on board batteries, fuel cells or an internal combustion engine. Alternatively, they can be tethered to allow the system to be plugged into an external power source. While this would be impractical for a soldier, it could prove useful for those designed to perform maintenance and logistical tasks, such as unloading an aircraft, or replacing a main battle tank engine.

Body Electric

Two of the key technological advances which have moved powered exoskeleton research forward have been the reduction in the size of microprocessors and improvements in the sensitivity of bio-electrical sensors required to measure the electrical impulses emitted by muscles when they move. The latter development was imperative to ensure that the exoskeleton could mimic the wearer's movements in real time. After all, there's no point using such a machine if it takes one or two seconds to replicate your movements – particularly when you may need to run fast or move suddenly in the heat of battle.

Several academic institutions are performing important research into powered exoskeletons. One such project is being pursued by the University of California's Baskin School of Engineering, which has developed a set of prototype exoskeleton arms. (BSE/JM)

Lifesuit

In terms of the development of powered exoskeletons for military applications, one of the most important steps was taken by Monty Reed. Reed is a former US Army Ranger who suffered a broken back in a parachute accident. During his convalescence, Reed was given a copy of Starship Troopers, a science fiction novel by Robert Heinlein, later made into a highly successful feature film. Heinlein's novel features vivid descriptions of powered exoskeleton equipment known as Mobile Infantry Power Suits.

This prompted Monty Reed to consider developing his own powered exoskeleton. The result was known as the Lifesuit. Since 2001, when the first Lifesuit 1 was built, several prototypes have been produced including the Lifesuit 6, which was able to accurately mimic human walking. Later versions included the Lifesuit 12,

The Lifesuit was designed by an injured US Army Ranger called Monty Reed, who was inspired in his work by the science fiction novel Starship Troopers. The Lifesuit, which he subsequently designed, has been cycled through a number of prototypes. (S. Newbold)

which participated in a race known as the Saint Patrick's Day Dash in Seattle. The Lifesuit 12 also set the land speed distance record for a powered exoskeleton walking almost five kilometres in 90 minutes. The Lifesuit 14 that followed enables its wearer to lift objects weighing up to 92 kg and to walk over one and a half kilometres on a full battery charge.

Nevertheless, the development of exoskeletons such as the Lifesuit, and earlier efforts like the Hardiman, were important steps in illustrating the technical and physiological challenges in designing and using powered exoskeletons. In fact, the United States defence establishment has continued to watch the development of such technology closely, and the country's Defense Advanced Projects Research Agency (Darpa) now feels that the technology has reached a sufficient level of maturity that it has begun funding studies into the application of powered exoskeleton technology for military applications. This has yielded the Concepts of Operations for Exoskeletons for Human Performance Augmentation programme – a $ 75 million initiative launched by the agency in 2000.

Bleex

One of the Darpa-funded projects is the Berkeley Lower Extremity Exoskeleton (Bleex), which has been developed by the University of California's Berkeley Department of Mechanical Engineering. The Bleex is primarily designed to enhance the strength of the wearer's lower body. The first prototype developed included legs, backpack frame and a power supply, allowing the user to run up and down slopes, step over objects, walk, twist, squat and bend.

The Bleex uses a network of over 40 hydraulic actuators and sensors that determine the movements of the user. This information flows to the Bleex's onboard computer, which then activates the hydraulic actuators to ensure that the loads carried by the wearer are distributed evenly to eliminate fatigue. Nevertheless, the Bleex is not the only powered exoskeleton project, which has involved Berkeley's mechanical engineers. Other initiatives have included the Exohiker, the 2005 prototype of which allowed the wearer to carry loads of up to 68 kg at an average speed of four km/h across a range of 67 km using lithium polymer batteries. The Exohiker is joined by the Exoclimber, which enables the wearer to carry a similar load while ascending heights up to 183 metres. The Exoclimber was evaluated by US Army Rangers in October 2005 at the Flat Irons Mountain Range in Boulder, Colorado, where it

The University of California's Berkeley Department of Mechanical Engineering has developed the Bleex (Berkeley Lower Extremity Exoskeleton) machine which was the result of Darpa funding. (University of California)

received a favourable assessment. In addition, the Laboratory is also involved with the Hulc (Human Universal Load Carrier) initiative.

Hulc

Lockheed Martin is leading the Hulc development and took the opportunity of the Association of the United States Army's Winter Symposium in February last year to showcase this self-funded programme. The Hulc (see title picture) is designed to allow the wearer to carry up to 91 kg at speeds of up to 16 km/h. In fact, the Hulc allows the wearer to crawl, crouch, walk and run. It uses electric motors that are powered by four lithium-ion batteries offering up to 20 hours of operation. These are positioned over the small of the back. However, additional power can be gathered by converting the downward energy exerted by user each time they take a step into electricity,

Lockheed Martin's Lift Assist Device has been developed to complement the company's Hulc. It connects to the Hulc and allows the user to lift and carry heavy loads. (Lockheed Martin)

which can flow back into the battery. The Hulc detects its passenger's movements with footpad-mounted sensors that send information regarding the movement's characteristics, such as direction, to a computer, which will then direct the Hulc's hydraulic system to assist that particular movement. Thanks to its hydraulic design, the wearer can comfortably move over the roughest terrain carrying a heavy load.

Lockheed Martin has developed an addition to the baseline Hulc called the Lift Assist Device. This is mounted on the back of the exoskeleton and works as a power-assisted device to help the user lift heavy loads. The secret of the Lift Assist Device is a counterweight which positions the centre of gravity close to the user to prevent the assembly from toppling over, the movement system mirroring that developed for the Hulc, using lithium-polymer batteries which power microprocessors driving the system's actuators. One of the useful design features is that the Lift Assist Device's actuators include a heat sink that allows cooling without the need for additional fans. The Lift Assist Device has a lift capacity of 68 kg.

Xos

Lockheed Martin is joined in military powered exoskeleton research by Raytheon. The latter firm has purchased Sarcos, an engineering and robotics company based in Utah, which developed the Xos powered exoskeleton. This uses sensors that detect the amount of strength being exerted by the wearer, for example, to move an arm. The sensor's information is then sent to a computer that makes a calculation on how much assistance to then provide to that movement via hydraulically powered actuators. These actuators then move cables that act in a similar fashion to tendons, to move the limbs. In total the Xos includes up to 30 actuators working as joints.

The Xos has been in development since 2002, although the initial prototype was unpowered, with work on the hydraulic actuators beginning one year later to finally yield a working prototype in 2005. Development funds are now taking the project further to produce a prototype military version. Furthermore, studies are ongoing into a power pack for the Xos, which presently uses a tether to supply energy. Although the suit weighs 68 kg, it allows the wearer to repeatedly lift up 91 kg. The US Army is expected to use the Xos production models for logistical tasks, although future incarnations could be used for war fighting.

Myomer Fibres

The exoskeletons discussed above are primarily built around hydraulically actuated frames that the user wears. Dr. Ray Baughman at the University of Texas has taken a slightly different approach, and is working on so-called myomer fibres. Dr. Baughman and his colleagues received funding from Darpa in January 2007 to develop myomer fibre technology involving a fabric consisting of horizontal and vertical lines of carbon nanotubes. When an electric current is passed through the latitudinal nanotubes, they repel each other causing the fabric to expand at a rate roughly 4000 times faster than a human muscle. When the electricity is applied to the longitudinal nanotubes they move closer together, causing the material to contract. It is possible that in the future, myomer fibres could be used to provide fabric suites that soldiers could wear with a power pack to provide them with extra strength on demand without needing to wear a bulky exoskeleton.

Several exoskeleton projects are ongoing in the academic and civilian worlds, which could develop technology that could be spun out into military applications, such as this University of Maryland's Exoskeleton Rehabilitation System. (University of Maryland)

Raytheon's purchase of Utah-based Sarcos has given the company a portfolio of exoskeleton expertise. The firm's Xos is expected to be developed as a prototype suit for the US military to assist logistical tasks. (Raytheon)

The advent of the exoskeleton has far-reaching applications, not only for the military, but also to assist in heavy industrial work like building construction, search and rescue tasks such as lifting and carrying casualties and, it almost goes without say, assist individuals suffering from muscle or bone disease, or those who have lost limbs. When coupled to a machine, the already impressive strength of the human frame will take an important step forward.