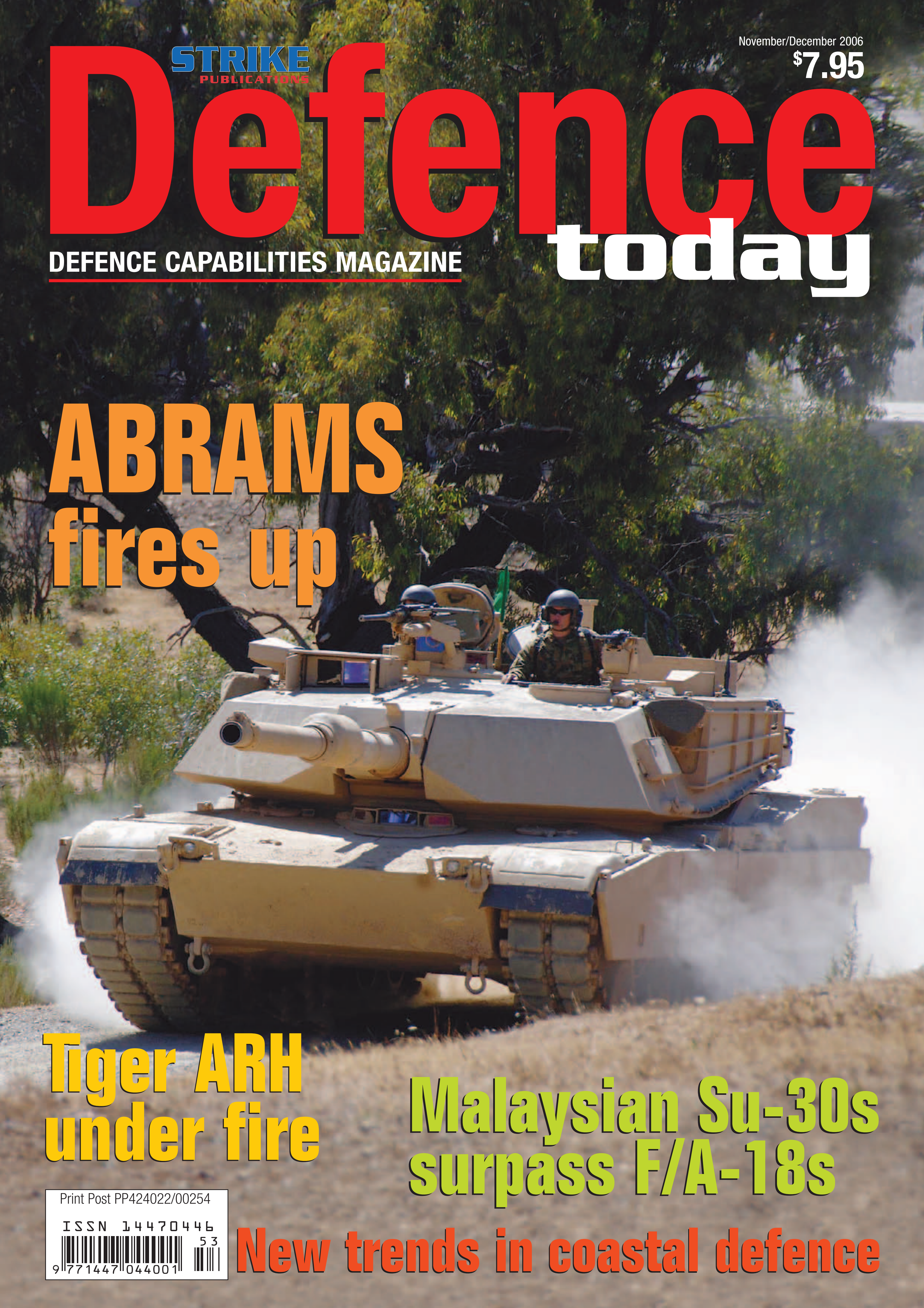
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Directed Energy Weapons

part 3

Dr Carlo Kopp

Tactical High Energy Laser (THEL)

In the first two parts of this special report on lethal Directed Energy Weapons we covered the early development of airborne lasers, the technical difficulties faced in the adapation of lasers as weapons, and the groundbreaking US Air Force YAL-1A ABL program. In this final part we analyse remaining US high energy laser weapons programs.

The THEL is a laser weapon jointly developed by the US and Israel, with the program initiated in 1996. The THEL is to be built in two configurations, the static baseline THEL and relocatable Mobile THEL (MTHEL).

The design aim of the THEL systems is to provide a point defence weapon that is capable of engaging and destroying artillery rockets (Katyushas), artillery shells, mortar rounds and low flying aircraft.

The THEL demonstrator was trialled repeatedly between 2000 and 2004, destroying 28 122 mm and 160 mm Katyusha rockets, multiple artillery shells and mortar rounds, including a salvo attack by mortar.

The demonstrator THEL system was built around a deuterium fluoride chemical laser operating at 3.8 microns wavelength. The combustor in this laser burns ethylene in toxic and corrosive Nitrogen Trifluoride gas to produce the excited deuterium fluoride lasing medium, which is then mixed with deuterium and helium and fed into expansion nozzles similar to that of other chemical lasers such as the carbon dioxide GDL and COIL. A complex exhaust diffusion and pressure equalisation system must be used, including a neutralisation stage to soak up the highly corrosive and toxic deuterium fluoride exhaust efflux gas.

The first deuterium fluoride laser to be trialled was the US Navy's MIRACL, or Mid-Infrared Advanced Chemical Laser, coupled to the Sea Lite Beam Director optical turret. This research system was trialled extensively after 1983 at the High Energy Laser Systems Test Facility (HELSTF Directorate) at White Sands in New Mexico. This was a MegaWatt class weapon.

The THEL program yielded excellent trial results, using a phased array radar to track incoming targets and direct the beam. Unlike the ABL, the THEL is a relatively short-range weapon used for the terminal defence of a local area, not unlike a point defence SAM or AAA system.

The sheer bulk of the demonstrator made it impractical for operational deployment, leading to the second generation MTHEL system. MTHEL was to initially have been in three semitrailers, but now appears to have been repackaged into a single container-sized semitrailer. A prototype was to be deployed by 2007 but more recent reports indicate funding difficulties and thus uncertainties in timelines.

The YAL-1A ABL prototype carried in a Boeing 747-400F airframe of the United States Air Force.

right: Close-up of the ABL optical turret subsystem, used to direct the lethal near-infrared beam at targets, using a large primary mirror.

The THEL/MTHEL system was developed by a team including TRW/Northrop-Grumman, Ball Aerospace, Elbit/El-Op, IAI/Elta (who developed the radar and fire control system), RAFAEL and Tadiran.

Like the ABL, the THEL/MTHEL suffers the same weather and propagation limitations imposed by atmospheric physics. While Israel, with dry desert climatic conditions, may be optimal for THEL operations, the same is not apt to be true for humid tropical environments or northern temperate environments where moist air, fog, low cloud and similar propagation impediments are much more common.

In strategic terms the impact of the THEL is yet to be determined, unlike the ABL, which is set to change the game fundamentally. The current MTHEL development effort is sustained and yields a viable product and is likely to become a feature of ground based air defence over the coming decade.

directed energy weapons

Advanced Tactical Laser (ATL)

The ATL program is an effort to exploit the technology developed for the ABL to provide a cheaper and smaller system suitable for carriage on aircraft such as the AC-130 Spectre or V-22 Osprey, as a close air support weapon. In January this year, the US Air Force's 46th Test Wing provided Boeing with a C-130H Hercules for trials of the prototype weapon, claimed to be in the MegaWatt class, which uses COIL technology. The intent is to mount the laser prototype in the aircraft and perform lethality trials in 2007 against a range of ground targets. L-3 Communications/Brashear developed the optical turret, and the laser is being built by AFRL at Kirtland Air Force Base in Albuquerque, New Mexico.

Solid State High Energy Laser

An alternative HEL technology now under development is the solid state electrically pumped laser, popularised extensively in 2002 as part of the Joint Strike Fighter marketing campaign.

This category of laser is based on the humble laser diode, which first emerged twenty years ago as a technology for use in optical fibre communications. Laser diodes are evolved siblings of the common Light Emitting Diode (LED) found in household appliances and now even battery powered torches. Light emitting diodes, usually made from Gallium based alloys, generate light as a result of electrical current flow through a minute semiconductor junction, which has been doped with additives which become excited by the electrical conditions in the junction. An LED is an incoherent and relatively broad emitter compared to a laser. Current LED technology spans colours from infrared through to blue. The distinction between an LED and Laser Diode is that the latter is fabricated with a miniature optical resonator to induce oscillation and thus laser action. To narrow the bandwidth of the cavity, most communications lasers now also include a diffraction grating in the design, in addition to the resonant cavity. A simple description of a laser diode is that it is a special type of LED designed to exhibit laser action. At this time Laser diodes are manufactured in vast quantities for CD and DVD burners and also for communications and industrial applications.

The solid state laser effort led by the US Air Force at the Air Force Research Lab aims to develop a 25 kiloWatt weapon, scalable to 100 kiloWatts and suitable for carriage by aircraft, ground vehicles and ships as a close-in weapon. The attraction of this technology is that electrical power is easy to supply and toxic propellants are not required. The idea behind these high power lasers is to couple together a very large number of much smaller laser diode modules, which then pump the laser medium with energy. This is essentially a scaled-up equivalent to the laser dioded pumped 1.55 micron eyesafe rangefinding lasers now in use.

The principal problems currently faced with this technology are cost, scalability and power handling capability. Conversion efficiency from electrical power to optical output for these systems is typically of the order of 10 per cent, which means that 90 per cent of the electrical power put into the laser is converted into waste heat, which needs to be removed. The individual laser diodes are also not very powerful, typically emitting around one Watt each. A laser rated at 25 kW with a 10 per cent conversion efficiency would require 250,000 diodes. At $10 per diode, this results in a multimillion dollar investment in lasers alone. Public reports on this program largely vanished over the last three years, suggesting it is no longer funded.

High Energy Liquid Laser Area Defense System

The High Energy Liquid Laser Area Defense System (HELLADS) effort was launched following a research breakthrough by DARPA in 2003, with a budget of around US$75M. Its aims were described by the US DoD thus:

'The goal of the High Energy Liquid Laser Area Defense System (HELLADS) program is to develop a high-energy laser weapon system (~150 kW) with an order of magnitude reduction in weight compared to existing laser systems. With a weight goal of less than 5 kg/kW, HELLADS will enable high-energy lasers (HELs) to be integrated onto tactical aircraft and will significantly increase engagement ranges compared to ground-based systems. The HELLADS program has completed design of a revolutionary high energy laser that supports the goal of a lightweight and compact high energy laser weapon system. An objective system laser module with integrated power and thermal management will be fabricated and demonstrated at an output power of 15 kW. Based on the results of this demonstration, additional laser modules will be developed and integrated with a beam control subsystem to produce a 150 kW laser weapon system demonstrator. The performance of the demonstrator will be characterized in a laboratory environment.

Program Plans call for the following developmental milestones:

- Develop and test a 15 kW objective system laser module with integrated power and thermal management subsystems.
- Complete preliminary design of a 150 kW laser weapon system.
- Complete detailed design and fabricate a 150 kW laser weapon system.
- Demonstrate performance of a 150 kW HEL system.'

In practical terms, HELLADS is to produce a 750 kg laser capable of producing 150 killoWatts of power, compact enough to be carried by aircraft, ground vehicles and UAVs. The technology is a liquid laser, in which the lasing medium is a fluid containing the active chemical species pumped for laser action. No details of the design concept have been released so far but it is reasonable to speculate that the liquid is actively cooled, thus avoiding the problems inherent in solid state lasers. The pump mechanism has not been disclosed. If pumping is performed using laser diodes, it is reasonable to speculate that the liquid also cools the pump lasers.

General Atomics is the prime contractor, with Lockheed Martin providing integration. HELLADS will, like the ABL, use a wavefront sensor and active mirror technology for beam wavefront correction. A demonstration is planned for 2007.

Summary

The next ten years will see the emergence of high energy lasers as an operational capability in US Forces' service. These weapons will have the unique capability to attack targets at the speed of light and are likely to significantly impair the effectiveness of many weapon types, especially ballistic weapons. Constrained by propagation physics, these weapons will not provide all weather capabilities, and will perform best in clear sky dry air conditions.

Australia needs to carefully analyse and monitor the development and deployment of this class of weapons, as they have the potential to be highly valuable for a number of niche roles. They will, however, not be a panacea.

Editor's Note: Other beam weapons such as Laser Induced Plasma Channel, anti-personnel Millimetric Wave systems, and electromagnetic bombs will be discussed in a future article, as these are not technically speaking, directed energy weapons.

Clockwise from right:

THEL engagement scenario.

A 160 mm Katyusha artillery rocket engaged by the THEL system.

THEL optical turret subsystem. Note the cassegrainian primary aperture (US Army).