Extreme measures: land forces take cover from environmental challenges

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NATO and partner forces have of late been focused on operations in a narrow range of conditions, however, the requirement to deploy in austere and challenging environments where extreme cold or heat is encountered persists. *Andrew White* and *Kelvin Wong* report on some of the developments.

Special Operations Forces (SOF) pride themselves on retaining the capability to operate across a wide range of environments. However, the operating environment over the past decade has seen even the most advanced units entirely focused on counter-terrorism (CT) and counter-insurgency (COIN) missions conducted primarily in urban and suburban environments.

As much as these units attempt to incorporate exercises in extreme environments into their regular training cycles, the current high operational tempo sometimes denies them the chance to reacquaint themselves with specialist skill sets.

Hence the reason why organisations like the US Special Operations Command (USSOCOM) are currently preoccupied with considering current and future capabilities to operate across extreme environments including cold weather operations (CWO), maritime operations, desert, and jungle warfare.

This includes moves across the Naval Special Warfare Command (NSWC) to refamiliarise US Navy SEAL teams with the capability to conduct Arctic Warfare, a capability up until recently only regularly maintained by SEAL Team Two.

Defence sources associated with USSOCOM explained to *IHS Jane's* how an undisclosed Joint Special Operations Command (JSOC) force element had approached another tier 1 unit from the NATO SOF community with regards to fighting in tropical environments, an area in which they had lost a certain amount of expertise over the past decade or so due to the predominance of military operations in urban terrain (MOUT). This request, it was explained, had not been made in reference to training requirements but, instead, ahead of a CT mission at an undisclosed location in Africa.

Environmental requirements

However, there is good reason why even the world's top SOF units find it hard to maintain the competitive edge across these extreme environments. According to the Society for Human Performance in Extreme Environments, such conditions comprise those in which humans are "not naturally suited and require much effort for adaptation.

"Operating within these conditions often affects and significantly compromises human performance. Among the environments considered extreme in nature are special [operations], undersea operations, arctic and isolated environments, mountaineering, nuclear, chemical, and all other environments in which the human must perform under highly stressed and challenging conditions," a society spokesperson explained.

"The importance of maximising human performance and health in these environments is easily realised. While forums exist for displaying efforts directed primarily towards physiological and engineering adaptation to extreme environments, no such forum exists which places emphasis on the behavioural (psychological, cognitive, perceptual, psycho-physiological, social) and human-technology interface aspects of human performance," it was added.

This is one particular area which is proving of significant interest to the international SOF community, particularly relevant to future soldier technology demonstrations including USSOCOM's Tactical Assault Light Operator Suit (TALOS), which aims to provide enhanced mobility, protection, lethality, and connectivity to Special Forces operators working in urban environments.

The TALOS Joint Acquisition Task Force (JATF), which comprises a team of operators from across USSOCOM's various frontline commands, is considering the integration of a man-wearable base layer with integrated technology, providing an 'interface' between the TALOS exoskeleton suit and the operator.

Speaking to *IHS Jane's* , sources from the JATF explained how such a move remained a high priority for the office in fiscal year 2016/17. The solution, it was explained, will include a series of integrated biometric sensors providing personalised situation awareness for an operator during a mission, allowing their vital signs and other relevant information to be monitored by a tactical operations centre at reach.

Additionally, the JATF is looking at other ergonomic issues relating to the wearing of an exoskeleton in extreme environments such as the Arctic, jungle, littoral, and desert areas of operation, as well as enhanced use of padding systems and ventilation for extended survivability during operations. However, the programme remains highly classified with no further details yet available for TALOS utility in these conditions.

Once complete, such options are expected to be unveiled with the final TALOS technology demonstrator system in 2018, programme officials explained.

In the maritime environment, USSOCOM continues to address a similar issue as it explores options for the US NSWC's Maritime Assault Suit System (MASS) and Lightweight (L-MASS) variant.

According to a request for proposals (RfP) first unveiled to the market on 8 February 2016, the L-MASS solution requires an over-garment capable of enabling US Navy SEALs and other maritime special operators to 'transition' from wet to dry (and other) environments and vice versa without a requirement to change clothing.

As the solicitation, which highlighted maritime, land, airborne, and shipboard environments, reads, "The MASS and L-MASS shall keep the operator dry in maritime and terrestrial extremes and all weather conditions without interfering with typical mission movements or compromising range of motion for activities including swimming, running, assault movements, and weapons manipulation.

"Both [MASS and L-MASS] versions must be lightweight, fit comfortably and must be able to keep the operator dry while immersed in water, without significant weight gain, [while remaining] adequately quiet during typical mission movements with ease in donning and doffing," it added.

NSWC is expected to release a requirement for an initial order of approximately 1,000 MASS/L-MASS suits for an initial operational trial and evaluation process where operators are expected to consider the suit for future procurement.

On 1 September 2016, NSWC also released a Special Purpose Clothing requirement seeking non-conventional equipment enabling Special Forces to operate across a wider range of "extreme environments" with "prolonged, continuous wear".

The solicitation called for the delivery of "rugged/tactical-type and casual-type civilian clothing to support NSW personnel deployments [across] unique situations that require clothing items not normally stocked as part of the traditional military uniform inventory.

"Special operations in diverse and dissimilar environments create the need for a considerable range of rugged/tactical-type and casual-type civilian clothing items that require purchase and delivery on relatively short notice".

USSOCOM sources confirmed to *IHS Jane's* that selected apparel will be utilised by US Navy SEALs as well as other force elements from across the Command, with selected vendors' delivery solutions to the Joint Expeditionary Base Little Creek in Virginia and the Naval Amphibious Base in Coronado.

Similar emphasis is being made in Russia where Spetsnaz Brigade force elements recently trialled specialist warm weather clothing on exercise in Egypt.

According to official reports from Moscow's Ministry of Defence (MoD), Russian airborne units conducted the exercise in the first half of October 2016 in collaboration with Egyptian force elements with scenarios comprising small unit tactical drills and live-fire ranges through to cultural engagement.

The MoD's press office refused to comment on specific technology but explained how the uniforms, which "passed" a series of operational tests and evaluation in Egypt, had been specifically developed for "hot climates" with the inclusion of high moisture and thermal control characteristics.

Chemical Protection

Also emerging in line with requirements from the Contemporary Operating Environment (CoE) is demand for improved chemical/biological warfare clothing with one option on display at the Association of the US Army (AUSA) event in Washington, DC, in October 2016.

WL Gore, a clothing designer and manufacturer of Gore-Tex technology highlighted its latest base-layer solution, which it claims protects operators from chemical and biological weapons similar to those employed by the Islamic State in Syria and northern Iraq.

Manufactured using Chempak material, WL Gore's solution could replace bulky legacy charcoal-layered suits previously worn by conventional and non-conventional units, which were considered unsuitable for enduring operations, especially in hot climates.

The Chemical/Biological Protective Clothing System comprises a breathable solution using a permeable fabric enabling minimal thermal impact on a wearer. A spokesperson for WL Gore explained how the undergarment's stretch fabric allows maximum range of motion, "enabling increased mobility and operational effectiveness in traditional and catastrophic environments.

"Its versatile design enables the undergarment to be easily integrated with other equipment in a variety of ensembles for CBRN response missions such as special operations," it was claimed.

NATO SOF sources present at the event explained to *IHS Jane's* how such a solution could be easily integrated into existing clothing solutions such as the popular range of Crye Precision combat apparel and field wear, which includes the G3 combat shirt and trousers; and outer layers such as the FieldShell 2, LWF jacket, as well as HalfJak Insulated jacket and Compact Assault Ghillie suit.

Tactical vehicle cooling

The challenge of extreme operating environments also extends beyond dismounted soldiers to combat vehicle operations, with the requirement to maintain acceptable temperatures for crew members and onboard C4ISR equipment.

The engineering objectives and technical specifications that govern the design and implementation of military vehicle heating, ventilation, and air conditioning (HVAC) systems are essentially similar to those employed for commercial platforms. These systems are expected to be effective in hot, dusty, and humid conditions, while being able to fit within the space constraints of the cab, and be easy to maintain.

Moreover, the inherent dangers of military operations often require crew members and personnel to be ensconced within armoured hulls for protection against hostile fire, with few options to cool themselves should temperatures rise, and therefore adequate climate control has become not just a matter of comfort but also personnel safety.

The Seattle-based Red Dot Corporation entered the military HVAC market in 2004 after the company was awarded an urgent operational requirement (UOR) contract by the US Army Tank-Automotive and Armaments Command (TACOM) to develop a HVAC solution for up-armoured High-Mobility Multipurpose Wheeled Vehicles (HMMWVs). The company stated that it created a prototype cooling system that proved capable of lowering the temperature inside the vehicle's cab by up to 30°F, which eventually entered production within three months with nearly 30,000 HMMWV HVAC kits delivered to the US Army and US Marine Corps (USMC). Other US military platforms include the mine-resistant ambush-protected all-terrain vehicle (MATV) as well as the Family of Medium Tactical Vehicles (FMTV).

"The typical requirement is to get to 80°F from an ambient temperature of about 130°F in about 60 minutes," Randy Grover, military sales manager at Red Dot Corporation, told *IHS Jane's* . "Based on the space that is given to us we try to fit the components that can provide the highest BTU per hour ratings.

"We have to try to fit the largest heat exchangers - the evaporator and condenser - that we can in the vehicle," he added. "Many times that space is encroached upon by other government furnished equipment [GFE], such as radios, so the biggest challenge for us is to hit those [aforementioned] performance specifications within those constraints .... It's a constant fight for real estate."

The latest success for Red Dot Corporation is the US Department of Defense's (DoD's) Joint Light Tactical Vehicle (JLTV) programme, which seeks to replace a number of ageing HMMWV platforms with a vehicle that can provide increased force protection, survivability, and improved payload capacity. Unlike the HVAC systems developed for the US military's existing vehicles, the cooling system will be integrated into new-build JLTV vehicles.

"[For example] on the FMTV programme the housing for the [HVAC] components was a sheet metal box that sat proud and visible inside the crew cab between the driver and the commander," Grover noted. "However, on the JLTV it's an under the dashboard installation much like a commercial application and Oshkosh elected to go with a plastic housing … so the difference between the system on the JLTV and a commercial vehicle is minimal - it's just a matter of size and shape."

Combat vehicle cooling

Thermal management for the crew and vehicle electronics are also as important, if not more so, on the other end of the military vehicle spectrum. Under a contract from General Dynamics Land Systems (GDLS), the company has developed the Model 3212 Thermal Management System (TMS) for the M1A2-SEP (System Enhancement Package) Abrams main battle tank (MBT), which is specifically designed to remove the excess heat produced by onboard electronic systems to maintain optimal performance.

According to the company, the TMS features a modular design comprising of a 30 inch [76 cm] long, 16.5 inch wide, and 18.4 inch tall Vapour Compression System Unit (VCSU) that contains the hydraulically driven refrigeration equipment. The VCSU itself is housed in a protected container located in the turret bustle rack, and produces cooled propylene glycol and water that is delivered to the Air Handling Unit (AHU) through protected tubes. The AHU in turn provides up to 7.5 kW (25,600 BTU/hr) of cooling capacity to the interior of the MBT through bulk air discharge into the crew compartment, not only drawing the warm air inside it using a heat exchanger and cooling it to temperatures as low as 65°F, but also countering the heat generated by the vehicle's electronic systems via direct contact with a cold-plate.

Meggitt has also developed the Auxiliary Cooling and Power System (ACPS) that features both thermal management and auxiliary power capabilities in a self-contained, compact unit that does not require power from the vehicle to operate. The ACPS comprises three major components: the Auxiliary Cooling and Power Unit (ACPU), the AHU, and a control module, and is stated to be capable of providing up to 7 kW of cooling and up to 7 kW of 28 V DC power for up to eight hours of operation without refuelling. The ACPS' power is derived from a heavy fuel generator which can run on diesel, JP 4, JP 8, as well as Jet-A fuel.

The AHU - comprising a 28 V DC electrically driven fan and liquid-to-air heat exchanger - is based on the system employed by the TMS for the M1A2 SEP MBT. This provides conditioned air to the vehicle's crew members as well as its onboard electronics.

The perils of inadequate cooling capabilities have been well-documented around the world. A notable example is the Indian Army's T90S MBT fleet, which suffered serious performance degradation due to the absence of air conditioners. In a parliamentary report released in 2014, the country's Comptroller and Auditor General (CAG) criticised the service for spending INR90.83 billion (USD1.35 billion) to acquire 657 Russian T90S MBTs that were not equipped with cooling systems, revealing that the performance of the MBTs' fire-control system (FCS), thermal imaging (TI) sights, and missile firing mechanisms was affected by their prolonged exposure to heat and dust ingress with crew discomfort also reported.

It is understood that a significant number of the Indian Army's T90S MBT fleet has been deployed in the Rajasthan desert region where daytime temperatures in the country's summer season can exceed 55°C, rising to as high as 70°C inside the vehicles. To address this challenge, the Defence Research and Development Organisation's (DRDO's) Chennai-based Combat Vehicles Research

and Development Establishment (CVRDE) unit - which is also responsible for the R&D of the service's Arjun MBT and armoured fighting vehicles (AFVs) - has embarked on a range of efforts to develop solutions for operations in similar conditions.

"To dissipate the heat rejected by engine coolant, engine oil, and charge air and transmission oil, a compact cooling system is used in modern AFVs," CVRDE stated. "AFVs in India often operate at ambient temperature higher than 50°C.

"[However], space is premium in AFVs as any increase in volume of the subsystems will lead to [an] increase in weight," it added. "Therefore the proper configuration and design and development of [the] cooling system for AFVs is very critical."

In practice the cooling system of an AFV manages the waste heat generated by the vehicle electronics and engine throughout the entire operating spectrum via active heat exchange. According to CVRDE the pressure loss through the cooling system - which typically comprises the coolant pump and cooling fans - has to be kept at a minimum in order to reduce its drain on the vehicle's available hotel power. However, this process is complicated by the difficult local conditions in which the vehicles must operate, which often reduces the efficiencies of the cooling system with exposure to dusty conditions and high ambient temperatures.

The challenge is made more acute when considering the short supply of usable space. To maximise the effectiveness of the cooling systems that must somehow be fitted within the confines of an AFV, CVRDE engineers have developed a range of compact aluminium plate and fin matrices with higher surface area heat transfer properties per unit volume than conventional fin designs, and have applied the technology in some of its latest indigenously manufactured heat exchangers.

According to the agency, the aluminium plate and fin matrix used by CVRDE for its cooling systems in indigenous vehicle powerpacks features a higher heat transfer area per unit volume of up to 1,800 m^2/m^3 compared with commercially available systems, which typically provides around 1,100 m^2/m^3 of cooling performance. These include multi-louvered fin and offset strip fin type designs with heat transfer performance in the 1,100-1,700 m^2/m^3 range, with a complete system typically comprising a 720x880x120 mm radiator with 380 kW heat dissipation capacity, a 430x280x210 mm charged air cooler with 150 kW heat dissipation capacity, a pair of 500x200x76 mm transmission oil coolers with 75 kW heat dissipation capacity each, and a 325x225x50 mm fuel cooler with 10 kW heat dissipation capacity.

This is also supported by a series of high-speed fans that are capable of moving a higher volume of air through the cooling system, while specially designed air ducts enable the vehicle to maintain acceptable temperatures for the crew during low-speed manoeuvres, such as fording. These fans are required to ensure cool air flow with a specified range and overcome resistance in the airflow passages caused by impurities or other environmental factors.

"Since these fans are required to run at 5,500 rpm, its radiographic quality needs to be very good and the fan has to be dynamically balanced," the agency explained.

"Due to space limitations, it is not possible to provide cooling capacity up to 55°C. Hence to control thermal load on cooling system, [we have] incorporated automatic power regulation protocols that [actively manages] coolant temperature at higher ambient temperatures," it added.

COMMENT

As armies increasingly rely on electronic systems for the full spectrum of dismounted and mounted operations the importance of thermal management will only continue to rise. This will likely bring increased emphasis on integrating adequate cooling or insulation technologies into field-deployed equipment or vehicles earlier in the design phase, rather than as retrofitted kits, as exemplified by legacy vehicles and systems.