

# Saddle up: military motorcycles receive boost from new propulsion technologies

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**While the humble motorcycle does not have the same visibility as larger mobility platforms, military forces have nevertheless benefited from the unique advantages they provide. *Kelvin Wong* examines how motorcycles' utility may yet increase as new technologies mature**

Motorcycles have served military forces around the world for well over a century, with their compact size and inherent manoeuvrability filling niche roles in military operations by enabling troops to travel with speed and agility over terrain that larger vehicles cannot traverse. These two-wheeled platforms have often been used as the vehicle of choice for military messenger, delivery, and reconnaissance duties.

Motorcycle use expanded significantly during the First and Second World Wars, during which hundreds of thousands were manufactured and used in all theatres. However, their popularity has since diminished significantly, with few notably new military driven developments - most military customers rely largely on commercially available vehicles with minor modifications.

While well-known international marques such as BMW, KTM, Harley Davidson, Honda, Husqvarna, and Kawasaki have previously supplied military forces, it appears that the military motorcycle market is now being led by smaller enterprises and bespoke technology developers that have introduced a number of innovations.

## **Hayes Diesel Technologies M1030M1**

Although not the most recent innovation, the US Marine Corps (USMC) M1030M1 military motorcycle stands out as the first production motorcycle to be equipped with a purpose-built diesel engine. While diesel-powered motorcycles existed before the introduction of the M1030M1 introduction of the 1030M1 into USMC service in 2005, these largely comprised attempts to retrofit motorcycles with industrial diesel engines - such as those used in generators and construction machinery - with mixed results.



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*The M1030M1 motorcycle, seen here in desert camouflage, is the first production military motorcycle to be equipped with a purpose-built diesel engine. (Hayes Diesel Technologies)*

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The 167 kg M1030M1 is 2.15 m long with a wheelbase of 1.44 m and has a ground clearance of 27 cm. It was developed by the California-based Hayes Diesel Technologies (then known as Hayes Diversified Technologies - HDT) under a US government Small Business Innovation Research (SBIR) grant to meet the military's requirement to simplify its logistics operations with a single fuel type - the kerosene-based JP-8 fuel used to operate military aircraft - using the commercially available Kawasaki KLR650 cross-country motorcycle as a basis.

The key feature of the M1030M1 motorcycle is its liquid-cooled 611 cc single-cylinder, four-stroke diesel engine, which has a stated power output of 29.5 bhp. This unit enables the motorcycle to accelerate from 0-100 km/h in about 9.7 seconds, and achieve maximum speeds in excess of 144 km/h. With its 15 litre fuel tank, the M1030M1 motorcycle can travel for over 600 km at a tested average speed of 88 km/h.

HDT noted that there were only two types of petrol-fuelled systems in the US military when the requirement was raised: small field generator sets (gensets) and motorcycles. Although diesel engines offered significantly higher fuel economy compared to petrol engines, they were largely overlooked by major motorcycle manufacturers due to comparatively poor power-to-weight ratio and narrow power band characteristics. Genset manufacturers have produced a range of diesel-fuelled options but motorcycle manufacturers were less keen to shift from well-proven petrol engine types, and HDT said "diesel-fuelled motorcycles [were] neither commercially practical, cost effective, or in some cases even possible given the performance requirements".

To address this technological gap, HDT partnered with Cranfield University in the United Kingdom to advance a diesel engine design that was being developed as a technology demonstrator. According to the company, the main aim for its design was to provide the best possible power and torque without the use of turbocharging.

This was achieved using a thermally robust (heat resistant), free-breathing four valve cylinder head in combination with an indirect injection (IDI) combustion system and carefully controlled fuel injection characteristics. IDI also reduced combustion pressure, enabling lighter engine construction and generating less 'knock', a common occurrence in diesel engines. When taken together these optimisations resulted in a compact, lightweight engine that produced more than twice the specific power output of conventional small diesel engines. The usable engine speed range is also much greater than other diesel engines on the market; peak power is developed at around 5,800 rpm, with usable power available in excess of 6,000 rpm, and this provides a high degree of drivability when combined with its low-speed torque.

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### **Logos Technologies SilentHawk**

Virginia-based technology developer Logos Technologies is continuing to advance its hybrid-electric SilentHawk tactical motorcycle prototype, company officials told *Jane's*. The company partnered with electric motorcycle builder Alta Motors (formerly BRD) to develop a hybrid-electric tactical motorcycle using research funding from the US Defense Advanced Research Projects Agency (DARPA).



*Logos Technologies is developing the hybrid-electric SilentHawk prototype motorcycle for the US Defense Advanced Research Projects Agency. (Logos Technologies)*

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The 158 kg prototype has a wheelbase of 1.45 m and the capacity to carry a 34 kg payload. It is based on Alta Motors' electric Redshift Motorcross (MX) motorcycle, which was originally targeted at civilian off-road racing enthusiasts. However, Logos Technologies said the SilentHawk will include a number of enhancements to enable the prototype to meet DARPA's requirements for a stealthy, all-terrain capable, single-track platform for military applications.

Logos Technologies told *Jane's* in January 2015 that the key aim of SilentHawk was to develop an aircraft-deliverable platform weighing about 160 kg. The vehicle is envisioned as travelling faster than 80 km/h on unpaved roads with the company's proprietary multifuel - aviation fuel, diesel, JP-5, JP-8, and petrol - and field-swappable hybrid-electric drive system comprising a liquid-cooled rotary engine genset and Alta's 14,000 rpm electric motor, which provides up to 40 hp of peak power.

SilentHawk can travel up to 273 km without refuelling, including up to 2 hours of continuous operation on a single battery charge in full-electric propulsion mode. Logos Technologies also said

the prototype vehicle is quiet, with noise levels below 75 dB at a distance of 7 m with its genset, and less than 55 dB when in 'silent mode' with the electric propulsion system engaged. In contrast, a conventional cross-country motorcycle powered by a petrol-engine can easily exceed 113 dB.

"We were to deliver a two-wheel drive, multifuel extended-range motorcycle that has an auxiliary power and user display interface along with equipment storage and asked to demonstrate its technical feasibility," Doug Rombough, vice-president of business development at Logos Technologies, told *Jane's* .

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Rombough said the company will be required to deliver two prototypes for Phase IIB: one will be a two-wheel drive full-electric vehicle, and the other an improved two-wheel drive multifuel hybrid prototype. These will undergo a series of trials to compare handling performance and range potential.

The SilentHawk's hybrid-electric system, which is a compact module that integrates the genset, muffler, radiators, and electronic power control architecture, can be replaced with a lighter, all-electric system in about 30 minutes if necessary, and features a regenerative capability that could enhance fuel efficiency by more than 16% depending on terrain conditions, according to the company's tests.

The hybrid-electric system provides a nominal and peak power output of 7.5 kW and 30 kW respectively and is capable of functioning as an independent power generator when the SilentHawk is stationary. This can either be employed to charge the motorcycle's 5.8 kWh lithium-ion battery pack, or to operate and recharge mission devices via the system's configurable, three-port 24 V DC supply which offers up to 500 W of power. *Jane's* understands from Logos Technologies that the battery pack is also designed with cell-level fusing, which enables it to absorb damage and continue to supply the necessary voltage to power the motor.

"Some changes that we are going to do to this next go-around is to optimise those subsystems so we can reduce the current weight of the demonstrator, but also to improve performance and manufacturability of the motorcycle," Rombough said. "What our engineering team will do is to isolate the subsystems to make them into kits: the auxiliary power interface, user display interface, equipment storage ... that would be kit one, and then the second kit would be a front-wheel drive system, a third kit would be the [hybrid-electric] system."

He added, "We are planning on making these kits so the operator could take the hybrid system off of the back of the motorcycle with three connections - the fuel, the high-voltage power, and the communications line - and then, [by removing] four screws, they could take the whole hybrid system off the back and replace it with a standard diesel engine.

If they determine that the mission, for example, requires only 50 miles of range, they could take the hybrid system off ... they don't need the size and weight of the hybrid system so they have a small and nimble electric motorcycle," Rombough said.

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### **Christini AWD 450 Military Edition**

Philadelphia-based manufacturer Christini Technologies Inc (CTI), which began as a mountain bike developer in 1995, has found domestic and international success with its All-Wheel Drive

(AWD) 450 Military Edition motorcycles in service with Special Forces operators in the US Navy (USN), US Border Patrol, and the armed forces of Jordan, United Arab Emirates (UAE), and the United Kingdom. A number of other undisclosed NATO forces have also received these vehicles.



*Christini Technologies' AWD 450 Military Edition motorcycle features a patented all-wheel drive system for improved handling performance. It is in service with the US military as well as a number of military forces around the world. (Christini Technologies Inc)*

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"We also have samples that are going to Australia, Ireland, Norway, and to other groups who deploy with the US special forces in some way," Steve Christini, CEO of CTI, told *Jane's* .

The AWD 450 Military Edition motorcycle, which weighs 126 kg and has a wheelbase of 1.5 m, is largely similar to the civilian model and extensively employs commercial off-the-shelf (COTS) components, including a liquid-cooled 450 cc single-cylinder four-stroke engine that provides maximum speeds above 96 km/h and an operating range of 144 km with a standard 2.5 gallon (9.4 litre) fuel tank.

However, the key feature of CTI's AWD motorcycle is its proprietary technology, which is claimed to offer improved traction and stability, cornering and hill climbing ability, and faster acceleration. The vehicle is distinct from the two-wheel drive approach utilised in the SilentHawk, which employs an electric motor in its front wheel hub. Rather, the mechanical AWD system - which weighs around 6.8 kg in total - is integrated with the motorcycle's structure and delivers power from the transmission to the front wheel through a series of chains and shafts that are enclosed within the frame and head tube, terminating in a patented front wheel hub. It is equipped with two one-way

clutches that enable the wheel to transfer power when required and freewheel when not under power.

According to CTI, power is transferred to the front wheel only when the rear wheel loses traction or when the front wheel skids. This instantaneous response ensures the rear wheel provides a continuous transfer of the engine's power to the ground instead of spinning. The use of one-way clutches in the front hub enables the front wheel to be driven at about 80% of the rear wheel's speed, limiting any adverse steering effects. The front-to-rear speed ratio can be changed with a simple sprocket adjustment to optimise the AWD system for a particular riding style or terrain.

"One of the biggest issues with the motorcycle industry is that everybody seems to think that you need to go faster, the reality is that the military wants to go slower and get there, so we like to call this an inverse technology ... the reality is that the biggest benefit for any motor vehicle is not horsepower, but traction," said Christini. "You can never use all the horsepower that's in a bike. The less skilled the rider, the more benefits they derive from AWD."

These claims have been validated by customer feedback, including a 2010 assessment by the US Army's Special Operations Research Support Element (SORSE) aimed at determining the suitability of the AWD 450 for the special operations forces (SOF) community, which in an unclassified evaluation of the tests concluded that "the AWD motorcycle is far superior to a conventional single-wheel drive motorcycle."

The motorcycle's "AWD system provides superior rough terrain negotiating capabilities as the front wheel is always pulling, effectively doubling the traction over standard motorcycles", SORSE reviewers stated. "Increase in traction stabilises the bike, reducing the fatigue on the operator while negotiating rough terrain and enables the bike to go places a standard motorcycle would not be able to [such as] deep sand and steep inclines."

Christini said CTI's present product line of 250-450 cc cross country motorcycles was developed based on experience gained over a decade of testing with international motorcycle developers such as Honda, Husqvarna, and Kawasaki, as well as producing aftermarket motorcycle kits for some of these companies. CTI launched its own range in 2013 and soon secured its first contract with the USN to supply its SEALs with AWD 450E Military Edition motorcycles. These were deployed with the SEAL units to Afghanistan, where they were used for rapid transportation across often austere and challenging terrain in support of security, reconnaissance, and pursuit operations.

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## **Zero Motorcycles MMX**

California-based electric motorcycle developer Zero Motorcycles unveiled a militarised variant of its Zero MX electric motorcycle called the Zero MMX, which weighs 124 kg and has a 1.43 m wheelbase. The Zero MMX was developed exclusively for SOF use and provides riders with a number of tactical advantages over traditional combustion motorcycles with its all-electric powertrain that is designed for rapid movement in near silence with minimal heat signature.



*Zero Motorcycles is offering an all-electric military motorcycle called the Zero MMX. The motorcycle promises to provide special forces personnel with a stealthy mobility platform that is capable of near-silent operation. (Zero Motorcycles)*

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"In 2012, Zero was approached by the US Special Forces to develop an electric, off-road capable, electric motorcycle," Chris Heimbuck, director of global marketing at Zero Motorcycles, told *Jane's*, revealing that the company delivered eight Zero MMX motorcycles for operational testing. "Their main interest was the low sound and heat signature of these models, as well as their much lower maintenance and no fuel requirements ... since then, other military and police agencies (including the Los Angeles Police Department off-road unit) have acquired this model for similar reasons."

At the heart of the motorcycle is an air-cooled Z-Force 75-5 brushless motor, which the company said generates a peak torque of 106 Nm and a peak power output of 46 hp at 4,300 rpm. This enables the motorcycle to attain a maximum speed of 121 km/h, although this can be boosted for short periods to 137 km/h if necessary.

A hot-swappable lithium-ion battery pack with a maximum and nominal capacity of 6.5 kWh and 5.7 kWh respectively, enables a stated road operating range of 114 km, or an endurance of 60-160 min when performing 'reconnaissance riding'. When aggressively driven, this figure falls to around 40-140 min. Regenerative braking enables some energy to be recovered to extend run time. The battery pack can be fully recharged in 5.9 hours, although this can be significantly reduced with scalable quick-chargers or the CHAdeMO accessory to as low as 1 hour.

"One of the key requirements of the US Special Forces was for us to deliver 'less than 60 seconds' charging," Heimbuck noted. "Since there is still no chemistry today that can deliver such charging, the only real way to meet this requirement is through swappable batteries."

This led to the development of "a patented technology for a fully modular dual-battery system that allows for our MMX models to be ridden with one or two battery packs, while spare charging or

charged batteries can be kept at [a facility such as] a central building, truck, tent, or even dropped or cached ahead", he explained. "With this system, when the motorcycle starts running low on charge it can [be resupplied] in less than 60 seconds so that it's quickly ready to continue its duty."

*Jane's* understands that since the Zero MMX's electric powertrain is fully sealed and has only one moving component - a brushless motor rotor shaft - it requires minimal maintenance with no pistons, valves, clutches, transmissions, intake, exhaust, radiators, coolant, oil, and other mechanical concerns to address.

Zero Motorcycles has continued to improve on the MMX design since its introduction in 2013. For example, the 2015 iteration featured a new suspension system developed by Japanese automotive technology firm Showa and Zero engineers, which was designed to improve the motorcycle's behaviour over small bumps as well as enable predictable control of bigger impacts. The company also increased the torsional rigidity of the front end for improved handling while a hollow front axle reduced its curb weight. Further refinements included improved braking systems, weatherproofing, and a new rear accessory rack.

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