Military technology

Evolving weapons and sensors for rotary wing platforms

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The evolution of sensor and weapon systems for rotary wing platforms has followed a path over recent decades, driven as much by the pressures of changing roles as by the technology in weapons and sensors.

When helicopters entered widespread military use during the early 1950s they were almost exclusively specialised for observation, liaison and transport roles.

The advent of helicopters large enough to lift a squad of troops opened up a range of new possibilities, and initiated the evolutionary path for helicopters as platforms for sensors, weapons or both. Helicopters were used to support land forces, and helicopter types were developed for naval applications.

Even today, while basic airframe designs are shared between land based and naval helicopter variants the avionics/sensor suites and weapons packages tend to be fundamentally different, reflecting differences between land and maritime warfare.

The evolution of helicopter ISR (Intelligence Surveillance Reconnaissance) capabilities reflects several threads of evolution.

Late model USMC AH-1 Cobra launching an AIM-9M Sidewinder air to air missile during trials.

Maritime Helicopter Weapons/Sensor Evolution

Maritime helicopters were the first to be fitted with sophisticated sensors and complex weapons packages, reflecting the high value of the helicopter's vertical lift capability in an environment where deck space is a critical constraint to the deployment of any airborne capability.

Initially, helicopters were used as replacements for catapult launched and crane recovered seaplanes used for reconnaissance, and to a lesser extent movements of critical personnel/documents and search and rescue.

Once payload performance became viable helicopters were employed for Anti-Submarine Warfare (ASW).

ASW is a challenging role since it combines specialised ISR capabilities with specialised weapons capabilities and period technology limits. Basic physics also impose limitations on the capabilities of an ASW helicopter.

ASW weapons payloads, therefore, start with simple depth charges and rapidly evolve to a succession of lightweight and increasingly smart ASW torpedo designs. Any contemporary maritime helicopter will be armed with a minimum payload of some kind of light ASW torpedo design.

Anti-Shipping Cruise Missiles have displaced guns as the primary armament of surface combatants, initially arming cruisers then destroyers and finally frigates, with helicopters increasingly used for Over The Horizon (OTH) targeting of ASCMs.

OTH ASCM targeting requires initial acquisition of the target surface vessel, tracking of the vessel, and until the advent of highly autonomous ASCM guidance, more than often midcourse and terminal guidance support for the missile. The sensor of choice in these roles has been centimetre band radar, as it permits antennas small enough to carry on a helicopter, yet provides acceptable penetration of adverse weather, especially cloud and rain.



While variants of the UH-1 Iroquois were the first operational gunships, they were soon supplanted by the specialised AH-1 Cobra, which in turn set the pattern for later designs like the Mi-24 Hind (right) and AH-64 Apache (below).

Most Western helicopters fitted for OTH ASCM targeting employ derivatives of existing maritime surface search radars developed for Long Range Maritime Patrol aircraft, but usually with more compact antennas compatible with helicopter carriage in a deck launched environment. The wide range of squat ventral circular radomes used in such designs is typical and intended to provide typically circular surface search capability and sector search capability.

A departure from this model was the Soviet development of the OTH targeting Ka-25Ts (tseleukazaniye / targeting) Hormone B, the first use of helicopter as a dedicated ISR platform. It was followed in the West by the British development of the AEW&C Sea King following the Falklands war, and the Soviet Kamov Ka-31 Helix AEW&C helicopter, the latter with a large folding ventral planar circular search antenna. This style of carriage has since been adopted for other radar sensors, such as the French Orchidee battlefield surveillance moving target indicator radar.

The advent of radars on maritime helicopters intended to target shipboard ASCMs led progressively to the adoption of ASCMs as direct armament for the helicopters themselves.

The range of missiles now carried by maritime helicopters is large, ranging from variants of the European Exocet and Otomat/Marte on larger helicopters, the Norwegian Penguin on mid range helicopters, and the UK Sea Skua on the Lynx series. The Chinese have emulated the same model.

More than often the approach followed by maritime weapon system architects is that the helicopter is armed with shorter ranging and lighter missiles intended to cripple opposing surface combatants or sink patrol boats, missile boats and speedboats. The helicopter is thus used to protect its launch vessel against smaller threats, and support the launch vessel in attacks against larger threats.

Radar is a wonderful sensor, in its ability to penetrate bad weather and cover large areas. But with the increasing emphasis on littoral naval warfare the limited capability of radar to reliably identify targets, especially smaller targets, forced the expansion of the sensor suites fitted to helicopters.

Passive radar warning and geolocation sensors, essentially Electronic Support Measures (ESM) and Emitter Locating Systems (ELS) have become an increasingly common feature of maritime helicopter avionic suites. The intent of these is in part to acquire and target threat surface combatants, and in part to provide warning against threats.

Stabilised thermal imaging cameras have also become ubiquitous, used not only for identification of unknown surface contacts, but also for search and rescue operations.

The high cost in most contemporary maritime helicopter designs reflects largely the complexity of the avionics and weapons packages carried. Such a helicopter will typically be equipped with an ASW sensor package, comprising sonobouys and receiver, Magnetic Anomaly Detector (MAD), often a dipping active/passive sonar, and usually a datalink for integration with the launch vessel.

A multimode radar will be fitted to provide ASW search capability against snorkelling subs, as well as missile targeting for own and shipboard weapons. An ESM/ELS receiver package will be fitted for self defence, as well as targeting ships and submarines on the surface. A thermal imager will be used for identification, and a plethora of other purposes.

ASW weapons are dominated by lightweight torpedoes while ASCMs of varying sizes are used for surface targets. In addition, where Combat Search and Rescue (CSAR) is encompassed, door mounted hand-aimed machine guns of varying calibres may be fitted in ad hoc or more permanent pintle mounts.

Long term trends will be limited primarily by the size of most maritime helicopter airframes, which impose hard limits on stores payloads and sensor apertures such as antenna sizes, optical turret sizes, dipping sonar sizes, and sonobouy dispenser payloads. While Moore's Law driven improvements will continue in sensor basic technologies like computing, communications chips, and daylight and thermal imaging cameras, the resulting capability improvements will be mostly in areas like image quality, jam resistance and stealth rather than raw range or area coverage.

A future helicopter thermal imaging turret may combine a 4 Megapixel thermal imager with an 8 Megapixel daylight camera, while a radar may be a direct derivative of an AESA fighter radar.

Battlefield Helicopter Weapons/Sensor Evolution

Helicopters developed for operation over land have evolved along much more diverse paths than their maritime siblings, reflecting the much tougher constraints which arise from shipboard operations.

The evolution of sensors and weapons packages has reflected evolving and expanding roles as well as available technology.

The first generation of helicopters to carry permanently fitted weapons were assault helicopters, initially armed with ad hoc pintle-mounted machine guns, later fitted with more elaborate and diverse installations. The intent was to provide suppressive fire during assaults to reduce the risk to the exposed helicopter and the deploying troops in a hot landing zone.

Western helicopters were mostly fitted with door-mounted guns of varying calibres, whereas the Soviets fitted a ventral gunners station to the 1950s Mi-4

series, and a glazed nose gunner station to the 1960s Mi-6 Hook heavy assault helicopter.

Flexible door mounted guns are now 'de-riguer' for most assault, transport and CSAR helicopters. While single barrel infantry weapons predominate, flexibly mounted 7.62 mm and 50 calibre Gatling guns are also available for many assault helicopters.

The 1960s were a period of explosive growth in helicopter use and rapid evolution in technology, driven in a large part by the South East Asian conflict and Soviet emulation of Western developments.

One of the first important developments was the introduction of the 'helicopter gunship', produced by adding forward firing batteries of machine guns on standard assault helicopters. Single barrel infantry light machine guns were rapidly displaced by Gatling guns, as these could deliver a devastating 6,000 RPM rate of fire. The 'infantry centric' character of much of the fighting in South Vietnam biased the use of lower calibres, as the vehicle killing punch of a 50 calibre or 20 mm gun was often less useful than the rate of fire of a 7.62 mm weapon.

External pylon mounted fixed gunpods with calibres from 7.62 mm remain available in the market as accessories for most widely used assault helicopters, offered as a substitute for more specialised attack helicopters.

As external fixed forward firing guns were fitted to early gunships, externally carried pods with unguided rockets became a valuable supplement, allowing gunships to deliver a destructive barrage of heavy fire, especially against protected positions such as buildings, gunpits and trenches.

The gunship proved enormously successful and popular in Vietnam but the bulky fuselage design of an assault helicopter made them vulnerable to defending gunfire. This, and the geometrically limited field of fire available to door mounted guns led to the first operational attack helicopter, the AH-1 Huey Cobra. While the Cobra used the rotor, gearbox, engine, aft fuselage, tail and control design of the UH-1 assault helicopter it has a narrow forward fuselage with tandem crew stations. The forward station was occupied by a gunner with a daylight optical targeting system for a steered turret under the nose. The turret contained a Gatling gun and grenade launcher. Pylons were used to carry a mix of gunpods or rocket pods.

The Cobra set the pattern for the later AH-64 Apache and the Soviet Mi-24 Hind series, which acquired larger calibre guns and a wider range of fixed forward firing weapons.

Vietnam was also the debut of the wire-guided anti-tank missile, initially deployed on a pair of UH-1B Huey demonstrators to stop advancing NVA tanks at An Loc. Two helicopters were credited with destroying 24 NVA armoured vehicles in just over a month, using the BGM-71 TOW missile.

The Army is currently introducing the European Tiger ARH, intended to cover both reconnaissance and attack roles.

The potential of the helicopter as a tank-killer resulted in the rapid evolution of weapons and sensors to support this role. The US through the 1970s developed specialised TOW armed variants of the AH-1 as tank killers. The Europeans soon followed with a range of light utility helicopters for the role. The Soviets introduced the large Mi-24 Hind, based on the Mi-8 Hip assault helicopter airframe, and capable of carrying a small number of troops.

The evolution of specialised attack helicopters with a bias toward killing armour resulted in the rapid evolution of further weapons and sensors.

A key innovation was the introduction of the AH-64A Apache fitted with helmet eyepiece projectors for a pair of nose mounted sensors. The upper thermal imager was slaved to the pilot's helmet line of sight, while the lower turret was slaved to the gunner's helmet, or driven by handgrips and a fixed optical sight. This weapon system targeted the laser guided AGM-114A Hellfire anti-armour missile. The Apache typically positioned behind terrain to ambush approaching armour, unmask from behind terrain, illuminate the target with the laser and guide its Hellfires to impact.

The Soviet response to the TOW Cobra and Apache was to develop and deploy the potent SA-13 Gopher, SA-15 Gauntlet point defence SAMs and the SA-19 Tunguska SPAAGM. These weapons were built to react quickly and down the helicopter before its Hellfires could reach their intended target.

In turn, the Americans reacted by developing the AH-64D Longbow Apache, armed with an active millimetre wave band radar seeker equipped AGM-114L Longbow Hellfire, a 'fire and forget' missile. The Longbow Apache would pop-up, acquire its targets, salvo the Hellfires and immediately descend behind cover to avoid exposure to incoming SAMs. While the Longbow Hellfire was an important innovation in its own right, the AH-64D also introduced two new sensors: a mast mounted Northrop-Grumman APG-78 Longbow fire control radar, and a Lockheed-Martin AN/APR-48 Radar Frequency Interferometer (RFI). The radar is used in single sweep or continuous sweep mode to detect and identify moving vehicles, and software then presents prioritised targeting for the gunner to salvo multiple Hellfires against multiple independent targets. The RFI is used to sniff out hostile SAM and SPAAG systems for attack, a role the AH-64D performed well.

Like the AH-1 Cobra, the AH-64D stimulated the development of competing non-US radar sensors for helicopters. Surveillance and targeting radars have since emerged for other platforms, including the EU Tiger series procured by Australia.

Air-to-air missiles for anti-helicopter combat achieved a brief zenith at the end of the Cold War, with the US trialling pylon-mounted installations for the AIM-9M Sidewinder and the FIM-92 Stinger. The only missile known to be designed specifically for this role is the Chinese TY-90 series.

The complexity of contemporary sensor and weapons suites on attack and reconnaissance helicopters is now comparable to that of lesser fast jet tactical fighters, as a result of which these have also become very expensive, not unlike maritime helicopters. While no rule of thumb estimators have been published, it is likely that the avionics are 60–70 per cent of unit price.

For the forseeable future only incremental advances in helicopter sensor and weapons suites are expected, such as the introduction of laser-guided derivatives of earlier unguided rockets. This reflects the absence of political interest through the West in maintaining, let alone developing capabilities to defeat opponents other than insurgent forces. As the historical evolution of helicopter sensor and weapons suites shows, all significant advances over the last 60 years have been driven by opposing technological advances through the Cold War arms race.

Vietnam provided the stimulus for most key advances in sensors and weapons used to date.