Multi-Mission Maritime Aircraft Survivability in Modern Maritime Patrol and Reconnaissance Missions

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The Multi-mission Maritime Aircraft (MMA), scheduled to become operational in the 2012–2014 time frame, will be the next-generation U.S. Navy Maritime Patrol and Reconnaissance (MPR) aircraft, intended to replace the functionality of the P-3C aircraft. MMA will follow a long legacy of Navy land-based maritime patrol aircraft. The P-3 Orion entered service in 1962, replacing the P2V and P5M fleet, but was not designed for survivability. A number of survivability studies were done in the 1980s to assess the survivability needs of the P-3, concluding that the aircraft needed several enhancements to protect it during its maritime missions. As the MPR force operates more in littoral areas, there will be an increased likelihood that MMA will encounter land-based, as well as ship-based and air-to-air, threat systems. Survivability analysis of the P-3C against several radar-guided surface-to-air missile systems was performed to assist the Naval Air Systems Command, PMA-290, in developing survivability requirements for MMA.

INTRODUCTION

This article documents the survivability issues associated with the Multi-mission Maritime Aircraft (MMA) as it takes on new missions while continuing the legacy of the P-3 and its predecessors in anti-submarine warfare missions. The MMA will require new equipment and new modes of operation to meet the demands of more littoral missions, thus putting it at greater risk of flying into the engagement envelopes of many different types of threats.

The Navy's use of land-based patrol planes began before the attack on Pearl Harbor and our entry into World War II (see the article by Keane and Easterling, this issue). At that time, the Navy began acquiring HBO-1s (Hudson bombers) and PB4Ys (Privateers). In 1940, the Commander in Chief, U.S. Fleet, stressed the need for reducing patrol wing aircraft vulnerability. Later that year, the Chief of Naval Operations stated that some form of armor and fuel protection should be on all patrol wing fleet aircraft.[1] The Privateers and Hudsons were followed by the P2V/P-2 Neptune, which had its initial flight in May 1945. The P2V was developed using lessons learned early in World War II. In the 1940s and 1950s the Navy P2Vs endured numerous documented incidents of air-to-air and surface-to-air attacks[2] (Fig. 1). Survivability measures for the P2V included self-sealing fuel tanks, armor, and self-defense armament.

Figure 1. Example of the need for survivability: this P2V-5 was shot down by the Soviets in June 1955. (Photo courtesy of CDR Tom Bigley, USNR-TAR [ret.], tlbigley@home.com.)

The P-3 Orion was introduced to the fleet in the early 1960s. It is a derivative of the Lockheed Electra commercial airliner, which was not designed for survivability. More than 40 years later, it remains the Navy's sole land-based multi-mission aircraft. Several studies were conducted by the Naval Weapons Center at China Lake in the 1980s to assess the survivability needs of the P-3. Those studies concluded that numerous enhancements were needed, including a missile warning system, a countermeasures dispenser, a radio-frequency (RF) jammer of some type, fuel tank protection, dry bay fire suppression, and flight control system hardening. The P-3's infrared (IR) signature was in need of reduction, and an IR missile seeker jammer was required. Since its introduction, the P-3 has undergone a series of configuration changes to include several updates, the most recent of which addressed survivability with enhancements to the missile warning system, countermeasures dispensing system, and explosive suppressant foam to prevent fuel tank explosions.[3]

The Navy's desire was for MMA to build upon the P-3 lessons learned (i.e., configuration changes) and thereby address the following survivability issues.

- The two contractors involved in MMA Component Advanced Development (CAD) are working on designs that trace back to commercial airliners: the Boeing 737 and the Lockheed Electra. The radar and IR signatures of these types of airframes are quite large, and the aircraft are relatively slow. Without survivability enhancements, such aircraft would be quite susceptible to land-based, air-to-air, and ship-based radar and IR missile threats and to anti-aircraft artillery (AAA) and ship-based guns.
- There is an increased risk of "pop-up" threats. MMA littoral missions will increase the risk of flying into the envelope of land- and ship-based threat systems. Many of these threat systems are mobile and require only a little time to set up. This creates the higher risk of encountering pop-up threats during MMA missions.

POTENTIAL THREATS TO MMA

Land- and Ship-Based Surface-to-Air Missiles

The following sections describe potential land- and ship-based surface-to-air missile (SAM) threats that MMA might encounter when operating at sea or in the littoral. The threats are grouped by the range capabilities of the systems.[4,5]

Short-Range SAMs

Short-range SAMs have a maximum effective range of less than 15 km (8.1 nmi). This classification includes Man-Portable Defense Systems, or MANPADS (generally passive IR-guided), that are proliferated worldwide. The MANPADS' maximum effective ranges are on the order of 5 to 6 km (2.7 to 3.2 nmi) and their warheads weigh between 1.5 and 3.0 kg (3.3 and 6.6 lb). It should be noted that larger warheads are more effective for a given miss distance. Other systems in this category are generally radar command-guided, have maximum effective ranges of 5 to 15 km (2.7 to 8.1 nmi), and have warhead weights of 6 to 25 kg (13.2 to 55.0 lb).

Medium-Range SAMs

Medium-range SAMs (Fig. 2) have a maximum effective range greater than 15 km (8.1 nmi) but less than 30 km (16.2 nmi). Their warhead weights vary from 50 to 200 kg (110 to 440 lb). The guidance used by these missiles is usually radar command or semi-active homing; some active homing SAMs are starting to be deployed.

Long-Range SAMs

Long-range SAMs (Fig. 3) have a maximum effective range greater than 30 km (16.2 nmi). Their warhead weights vary from 70 to 200 kg (154 to 440 lb). Similar to the medium-range SAMs, the guidance used by these missiles is usually radar command or semi-active homing; some active homing SAMs are starting to be deployed.

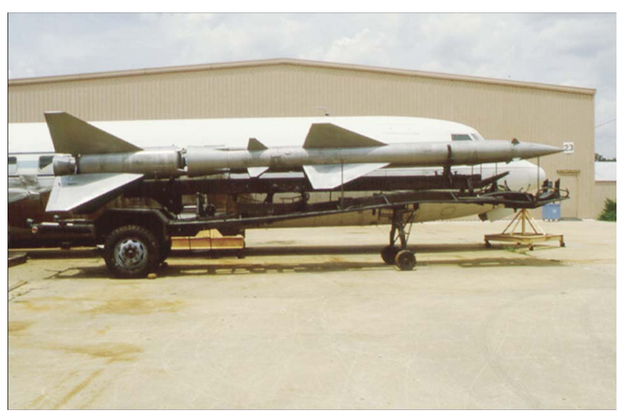

Figure 2. Example of a medium-range SAM system: an Iraqi SA-2. (Reproduced with permission from the National Air and Space Museum.)

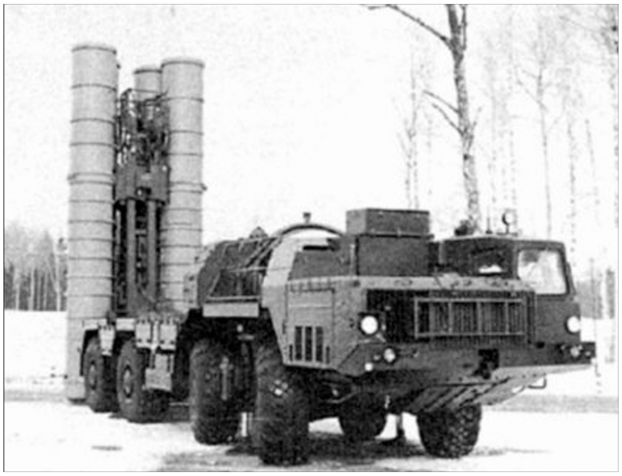

Figure 3. Example of a long-range SAM system: an SA-10 transporter-erector-launcher vehicle with the four missile canisters in the vertical position ready for launch. (Reproduced with permission from the Expeditionary Warfare Training Group, Pacific.)

Air-to-Air Missile Threats

Air-to-air missile (AAM) threats (Fig. 4) that the MMA might encounter while performing its mission generally fall into three classes of terminal guidance schemes: radar semi-active homing, radar active homing, or passive IR. Their ranges vary from 3 to 100 km (1.6 to 54.0 nmi). The IR missiles have a shorter effective range than the radar missiles. The warhead weights vary from 9 to 47 kg (20 to 103 lb).[6] Most fighter/attack aircraft also carry cannons (from 12.7 to 30 mm) that can be used to attack an MMA.

Anti-Aircraft Artillery and Ship's Air Defense Guns

AAA is ubiquitous throughout the world because it is the least costly type of air defense. Artillery and guns come in many sizes and calibers, ranging from 7.5 to 150.0 mm. Land-based guns are carried by personnel, mounted on vehicles, or towed. They can come singly or in twos and fours and be manually or automatically loaded. The rounds can be nonexplosive, timed-burst, or fused and can be aimed visually, using electro-optical sights, or by radar. AAA can be integrated into an air defense system or operate independently.

Almost all ships' guns (Fig. 5) can be used for air defense; they are the most common form of primary armament on small ships and secondary systems on bigger ships. They, too, come in many sizes and calibers but are generally installed in fixed mounts. These guns are integrated into the ship's fire control system by simple commands or by direct radar control.[4,5]

Figure 4. Example of an air-to-air missile: an AA-10 "Alamo" on an ejection launcher under an Su-27 "Flanker" aircraft. (Reproduced with permission from Jane's Information Group.)

POTENTIAL COUNTERMEASURES TECHNIQUES

Even though the MMA follow a long legacy of maritime patrol aircraft, they are considered combat aircraft with multiple types of missions that could put them into the engagement envelope of the threat systems previously discussed. Although MMA would not deliberately be flown into harm's way, pop-up threats, as noted above, justify the need for them to carry some basic countermeasures equipment to avoid or survive an engagement. Furthermore, when operating in the littoral, the risk of SAM, AAA, and AAM threats greatly increases, and countermeasures systems are necessary for mission and aircraft/crew survival. In this section we discuss various RF and IR countermeasures techniques that could increase MMA survivability to acceptable levels.

On-board Warning Systems

Electronic support measures detect, identify, and measure the angle of arrival of radar signals. It is important that the MMA carry such equipment to warn of threats and their locations. This equipment would enable

Figure 5. Example of a naval gun system: OTO Melara's 127-mm/54-cal lightweight gun mounted on-board the Italian frigate *Bersagliere*. (Reproduced with permission from Jane's Information Group.)

the appropriate and timely use of countermeasures techniques and evasive maneuvers. Note that for an aircraft such as MMA, its size and speed impose limitations on the effectiveness of the evasive maneuvers.

A missile warning receiver can provide knowledge of missiles being launched. Three types of missile warning receiver are available: continuous-wave Doppler radars, ultraviolet rocket plume detectors, and IR rocket plume detectors. The radar has the disadvantage of emitting radiation that might be detectable, while the two detectors are passive. The passive detectors have problems with false target declaration; however, improvement can be gained by using two IR spectral regions (i.e., two colors) simultaneously.

Electronic and Infrared Countermeasures

Many countermeasures techniques have been developed and fielded since World War II. The world of countermeasures is constantly changing because, as a technique is fielded and used, it is immediately noted and counters are developed and implemented. Today, most countermeasures systems have associated or internal computers that can be programmed to use the appropriate techniques based on recognition of a particular radar's signal. However, this presupposes knowledge of that radar's latest counter-countermeasures.

On-board Jammers

On-board jammers, such as the AN/ALQ-126B and AN/ALQ-165, are reprogrammable systems that are carried aboard fighter aircraft such as the F/A-18 and F-14. They receive radar signals and transmit the jammer power from the aircraft and can be programmed for multiple electronic countermeasures (ECM) techniques.[7,8]

Off-board Jammers

Off-board jammers, such as the AN/ALQ-214, are reprogrammable ECM systems. They receive radar signals on the aircraft and pass the jamming technique, via a fiber-optic cable, to a towed decoy (e.g., the AN/ALE-55) that then amplifies and transmits the signal (Fig. 6). They can be programmed to use individual and combinations of ECM techniques, and may or may not be coordinated with countermeasures dispenser systems.[9–11] Some towed decoys, such as the AN/ALE-50, operate solely with self-contained receivers; these effectively only produce repetition of the radar signals.

Towed decoys are the most successful technique available for use against RF semi-active and active homing-guided missiles. (Note that decoy systems that receive jamming modulation from an on-board receiver can also be effective against command-guided missiles.) The decoys present a more favorable target to these types of missiles, thus drawing them away from the tow vehicle.

The decoy gain is an important characteristic since it sets the effective radar cross section (RCS) of the decoy.

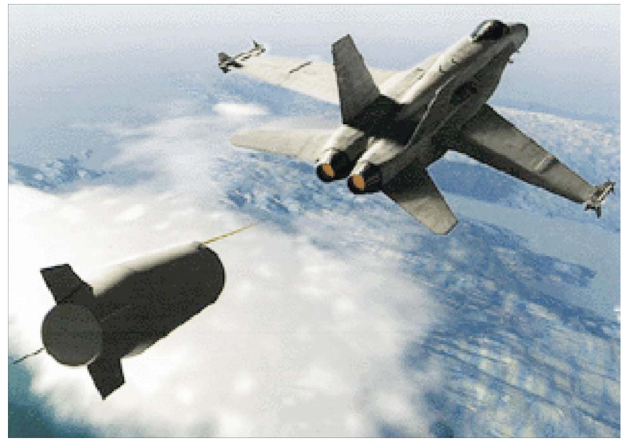

Figure 6. Example of an off-board jammer: an F/A-18 Hornet towing an AN/ALE-50 towed decoy. (Reproduced with permission from the U.S. Navy's Office of Information.)

The effective RCS remains constant until the decoy approaches a range from the illuminating radar at which the decoy's maximum power level is reached. The decoy effective RCS then starts dropping as a function of the square of the range. A rule of thumb for decoy effectiveness is that its effective RCS exceed that of the target by about 10 dB or more.

Expendable Devices

Chaff is composed of metallized foil particles of different sizes that provide reflections to radars of various frequencies.[12] The release of chaff by many aircraft involved in a raid can cause confusion in an air defense system area that might include a number of search, acquisition, and fire control radars. Confusion can create delays in target designation and fire control acquisition, consequently reducing the number of weapon launches.

The MMA will, in general, be flying alone. Its release of chaff would not cause such confusion because radars would view it as a target ahead of a number of almost stationary chaff clouds. Furthermore, a chaff cloud slows rapidly enough after its launch that it becomes invisible quickly to pulse Doppler and continuous-wave radars. For these reasons, the use of this ECM technique would probably not protect the MMA.

IR countermeasures consisting of disposable flares provide false targets to IR-guided missiles, thus drawing them away from the target. The spectra provided by flares have been modified to accommodate changes in the operating wavelengths of IR missile seekers over the years. Several different spectral flares are commonly used for each release from the aircraft. Two methods are typically used for flare release: preemptive or reactive. In the former, flares or groups of flares are released periodically when the aircraft enters an area with known or suspected IR threats. The latter method would be used when an alert is provided by a missile warning receiver. Clearly, the preemptive method would use up the contents of the flare magazine much faster than the reactive method.

SURVIVABILITY ANALYSIS

Modeling tools, such as the Enhanced Surface-to-Air Missile Simulation (ESAMS), permit examination of some of the tactical situations presented in the article by Lilly and Russell, this issue. Examination of multiple, different on-board and off-board countermeasures configurations permits MMA survivability to be assessed in the context of specific mission and threat combinations.

The survivability of the MMA was examined analytically by using threat characteristics (e.g., radar detection range, SAM effective range) to estimate the engagement results. P-3C physical size, RCS, and IR signature were assumed to be representative of the MMA concepts being considered by the Navy. The RF survivability analysis was conducted using ESAMS, an engagement-level, one-on-one computer simulation used to model the interaction between a single airborne target and a SAM air defense system. In this analysis, MMA survivability was assessed while the aircraft was flying straight and level, at different altitudes, and at a constant speed. MMA was assessed without RF countermeasures (RFCM) to baseline the "dry" aircraft and with RFCM to determine the relative improvement in effectiveness over the dry cases. The effectiveness improvement provided by the RFCM was then analyzed and quantified to help the Naval Air Systems Command develop survivability requirements for MMA.

In all cases, it became apparent that MMA's mission would be rendered ineffective if it came within the engagement envelope of a missile threat. These envelopes varied in the tens of kilometers for the longest-range threat. It was determined that the use of appropriate RFCM would increase the probability of survival by a significant degree when the MMA was faced with such threats.

The general conclusion that may be drawn from this analysis is that the MMA has a far greater chance of surviving and a much greater chance of being able to complete its missions if it is equipped with appropriate countermeasures to deal with both radar- and IR-guided threats.

CONCLUSIONS

In general, an MMA without countermeasures is susceptible to a mission kill when it enters a missile engagement envelope because of its large multi-spectral signature, which allows detection, acquisition, designation, and tracking by threat systems, thus resulting in launch, guidance, and lethal fusing of the associated missiles.

Radar warning systems are vital for providing the MMA crew with knowledge of the threat environment. Such equipment would permit the crew to use appropriate countermeasures, whether electronic or escape maneuvers.

RFCM systems similar to the AN/ALE-50 and -55 or fiber-optic towed decoy (FOTD) were used in the study as representative RFCM capabilities. Results indicated that such an off-the-shelf RFCM capability could provide significant increases in MMA survivability against a single pop-up threat and that an AN/ALE-55 or FOTD-equivalent capability would be preferable because of the greater breadth of threat coverage. The study results provided the basis from which the MMA RFCM capability requirement was derived.

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