UAVs in an Australian maritime environment

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DISCLAIMER

The views and opinions expressed in this paper are those of the author and are not necessarily those of the Australian Defence Force or the Government.

ABSTRACT

This paper proposes a concept of operations of maritime unmanned aerial vehicles (MUAVs) that takes into account the unique force structure of the RAN, particularly the crewing arrangements of current helicopters. The paper highlights the autonomous operations philosophy underpinning RAN rotary wing operations and how they can be augmented with UAV systems. The paper then considers the operational use of UAVs without the use of advanced long range communication networks such as satellites. The paper concludes by proposing a concept of operations that requires control of the UAV autonomously from the helicopter to perform a specific surveillance task in a hostile environment. It recognises the unique advantage of UAVs as having the potential to reduce risk to aircrew in combat operations, but also applies a level of operational realism to the scenario in allowing the command on the surface ship the tactical option of not transmitting electromagnetic radiation in a hostile environment.

INTRODUCTION

Undoubtedly the biggest selling points of UAVs as far as military leaders and politicians are concerned, are the possibilities of reducing costs and risk for personnel in combat operations [1]. The loss of a UAV in combat is more palatable than the loss or capture of valuable aircrew. This paper is a synopsis of the author's Masters Thesis that proposes a concept of operations that satisfies a capability gap, is cost effective through life, and fits into the RAN's current and planned force structure. It does not propose to replace the embarked helicopter with the UAV in the short term. Instead it recognises that there are many constraints in operating from small ships at sea including space, personnel and cost. These factors cannot be over looked and it is for this reason that Australia's solution may be uniquely different from the US or UK solutions. The paper also recognises that the UAV, given current technology, is unable to fulfil all the roles undertaken by the helicopter at sea, and as such, no ship's Commanding Officer is likely to give up limited hangar and flight deck space to a UAV in preference over a helicopter. The concept of operations must be based on the MUAV augmenting the existing helicopter fleet out to at least 2025.

DOCTRINE

Both Australia's Defence White Paper 2000 and the Defence Capability Plan (DCP) recognise that UAVs offer a great deal of potential for surveillance, reconnaissance, information gathering and eventually the delivery of combat power [2]. Two specific UAV projects are planned; JP129 seeks to deliver a tactical UAV capability to the Land Commander, and JP2062 seeks to acquire the Global Hawk system. Both have an in-service date of 2007 [3]. In addition, these documents also recognise that the Seahawk and Super Seasprite helicopters provide an important and integral part of the surface fleet surveillance, anti-submarine and anti-surface warfare capabilities. To that end, the Australian Government plans a major mid-life upgrade of the Seahawk, also commencing in 2007. There is an understanding, within the doctrine, that embarked helicopters will continue to underpin the maritime air environment for the next twenty-five years. This is also reflected in the Navy's 30-year vision, more commonly known as Plan Blue, which envisages a future force operating MUAVs from 2010 [4].

DEFINING THE CAPABILITY GAP

Both Seahawk and Seasprite helicopters are very expensive platforms crewed by highly trained operators and fitted with extensive active and passive sensors including radar, Forward Looking Infrared (FLIR) and Electronic Support Measures (ESM). It is neither sensible nor cost effective to put such valuable assets in harms way. Yet, despite the integration of the latest technology sensors onto these platforms, they will not be able to complete all tasks beyond the range of lethal threats, particularly if the hostile unit adopts an emission control posture. Such a tactic removes the helicopters opportunity to correlate a threat emitter on ESM with a radar contact.

If the helicopter, from a standoff distance, cannot reach a required level of identification, then there is currently no alternative other than to conduct a probe. Probing a contact forces a helicopter to descend to low level, less than 200 feet, and approach whilst not radiating on any active sensors such as radar, to a distance that will enable visual identification. This is an extremely vulnerable, high workload situation in which the helicopter and crew are also without communications with the parent ship for an extended period.

Hence, the developing capability gap is one of being able to conduct effective passive surveillance in a high threat environment, whilst minimising the risk to expensive manned platforms and aircrew (see figure 1). This includes tasks of surface surveillance, targeting, and BDA. Furthermore, future improvements in the regional range of ship's surface-to-air missile systems will expand this capability gap to distances in excess of 20 nm. What is required is an off-board sensor for the helicopter.

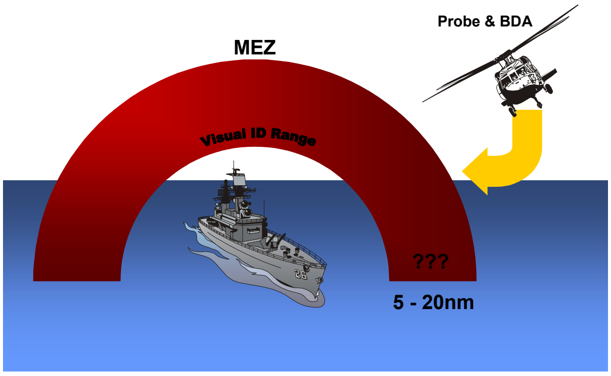

Figure 1 – Capability Gap

MANPOWER

Given the fact that the RAN will continue to operate Seahawk and Seasprite helicopters at sea for the next 25 years, and that all frigates are already minimum manned, it seems that the best solution to operate and maintain a MUAV at sea is to utilise the skills of existing aircrew and flight maintainers. The proposed crewing arrangements for the Fire Scout UAV system on USN ships include two dedicated flight crews each consisting of a pilot, mission commander, sensor operator and a maintenance crew of six. For a USMC detachment the structure is much larger consisting of 43 personnel. The scale of this emerging capability is truly appreciated when, in order to support the UAV flights at sea, it is envisaged that up to four separate VTUAV squadrons will be formed [5]. This is an order of magnitude beyond Australia's requirements, and is particularly relevant when considering the overall cost of the project, including net personnel operating costs (NPOC) for the duration of service of the UAV system.

COMMUNICATIONS

It is acknowledged world wide that there is an increasing requirement for satellite communications and relay of near real time (NRT) video imaging from both manned and unmanned platforms back to command centres for analysis and processing. Notwithstanding the advances being made commercially in compression and automatic recognition software, this technology requires access to large amounts of satellite bandwidth and almost exclusive use of a satellite constellation. Given that Australia does not operate it's own dedicated military satellite system, such a concept of operations relies on maintaining a high priority access to a third party's satellites, an access that could be denied in time of conflict.

An alternative approach to sending huge amounts of video stream back to the ship might be to only send snapshots of the required imagery to the helicopter for onboard processing by the crew. This technology already exists in the form of the Improved Data Modem (IDM), which is a production, flight qualified terminal that supports multiple data link message protocols using conventional aircraft UHF radios. The system is in use on F-16, Jaguar and WAH-64 Apache aircraft.

Improvements to the data link have included the addition of a video interface module (VIM) that allows the capturing, display, compression and transmission of images comprising line drawings, photos, and FLIR. By utilising wavelet compression techniques, a single picture takes 20-25 seconds to transmit, while a collection of three images requires 40 seconds of UHF transmission time. The Naval Research Laboratory (NRL) in Washington has also managed to reduce the size of the IDM to a PCMCIA card. [6].

LAUNCH AND RECOVERY

The largest challenge of operating embarked MUAVs from ships is the launching and recovering of the vehicle. Considerable effort and money has been spent in developing an autonomous landing system for a vertical takeoff and landing UAV. In hardware terms the system requires a transponder in the vehicle, the rest being aboard the ship and transmitting real time data on the ship's motions to the vehicle, allowing the aircraft's flight control software to synchronise the movements and pick the right moment to set down.

A different approach to the problem is for the UAV to be carried onboard the helicopter. By adopting such an approach all the issues of vertical take-off and landing; pitching and rolling decks; crosswind; recirculation; gusts; hot exhaust gases; high levels of remote piloting skills; transitioning between hover and forward flight; and control of the vehicle on final approach to the deck disappear. It may also reduce some of the Radiation Hazard (RADHAZ), and personnel hazards associated with UAVs on decks at sea. Such a concept relies on having smaller UAVs more closely represented by the concept of micro UAVs (MAV). These smaller vehicles also make it possible to consider parachuting the system into the water for later recovery. Ultimately, if the cost could be kept to a minimum then it could be treated as a disposable item.

COMMAND AND CONTROL

Research into current technology indicates that it is possible to achieve semi-autonomous control of very small UAVs and to gain useful imagery data from these platforms through miniaturised data links and radios. The NRL in the US has developed a MAV for naval force perimeter protection based on the Dragon Eye UAV. The hand-launched electrically powered air vehicle, weighing just over 2kg (4.4lbs), carries a nose mounted colour or monochrome television camera that relays imagery back to the ship via a line of sight datalink [7].

With regard to controlling UAVs from helicopters, the US Army has already embarked on a three-year program to develop the concept of operations for 'teaming' UAVs with helicopters. Flight trials were conducted in March 2001 at Fort Rucker between an Apache Longbow flying with a Hunter UAV. It is anticipated that Apache units will have the first helicopter to UAV connectivity beginning in 2005 [8].

MUAV CONCEPT OF OPERATIONS (TINY TIGER)

Limitations of space, personnel, bandwidth and infrastructure point towards a concept that involves air launched UAVs from helicopters at sea, codenamed 'Tiny Tiger' by the author. The UAVs involved would need to be much smaller, and therefore less capable than previously proposed for operations at sea. The research examined two sizes. The first involved designing a UAV of Penguin missile, or Mk 46 torpedo size, capable of carriage and release from a standard BRU-14 bomb rack. However, this solution was discounted based on cost, the provocative nature of launching a UAV system that resembles an air to surface missile, and the impact that this solution would have on the helicopter capability by effectively removing 50% of its external weapon or fuel carrying capacity.

The second solution concentrated on designing a UAV of such a size and weight that it can fit into a standard 'A' size sonobuoy container (see figure 2). This is a cylindrical container 0.9 m (3 ft) in length and 14 cm (5 in) in diameter. Sonobuoys vary in weight between the lightest bathythermograph buoys of 8 kg (18 lbs) up to an active sonobuoy or a passive broadband Barra sonobuoy that each weighs 18 kg (39 lbs). By aiming for this sized container it is envisaged that the MUAV could be carried and launched from standard gravity launchers. This standardisation in size also significantly reduces the storage and handling problems onboard small ships, and would enable the deployment of such a capability onto other platforms including the AP-3C Orion maritime patrol aircraft and even Black Hawk and Tiger Attack Reconnaissance Helicopter (ARH) helicopters with minor aircraft modifications.

Figure 2 – Standard 'A' size sonobuoy, 3 ft in length by 5 inches in diameter, up to 18 kg (39 lbs) in weight

Initial concerns centred on the payload and power constraints associated with such a small UAV. However, research into existing systems revealed that the technology is relatively mature. Examples considered included the Pointer, Mite and Dragon Eye. These systems demonstrated suitable levels of vehicle control, sensor performance and data linking capability that would be required from the Tiny Tiger MUAV concept. They also indicated that Lithium Sulphur Dioxide ($LiSO_2$) battery technology could provide the performance required by such a capability – that being endurance up to 1 hour at speed up to 60 kts.

However, the engineering complexity to fit the current wing design of these MAVs into a sonobuoy container seemed prohibitive and an alternative design approach was required. Conceptual calculations revealed that by combining sonobuoy technology with UAV technology, a hanglider type wing with a 1.5 m^2 wing area could generate sufficient lift to satisfy the performance requirements, whilst offering a simpler folding and lighter solution within the constraints of the sonobuoy package. The wings would be made from material with shaped aerofoil leading edges that fold against the body under spring tension. The size of these wings could be increased by having spring loaded telescopically extended sections within the leading edges, to almost double the size of the wing (see figure 3). This type of technology is used on current sonobuoys to fit very large arrays into the container. The entire package could be achievable within an all up weight of 17.5 kg (38 lbs).

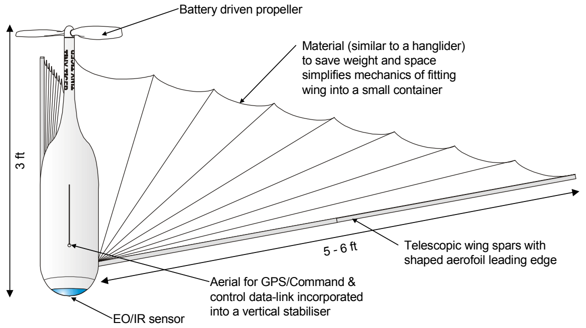

Figure 3 – Artist's impression of the Tiny Tiger

At the crews discretion Tiny Tiger would be launched from the helicopter to complete its dangerous probing or BDA task from a suitable height that allows time for deployment, nominally 2000 ft. The sonobuoy-sized container would fall away from the aircraft under gravity from the launch tube in the floor of the aircraft. A flap on the top of the unit would lift up in the airflow and pull out a parachute under spring tension (see figure 4). Attached to the tail of the MUAV, the parachute would pull out the vehicle from the sleeve and slow its descent. Once clear of the sleeve, the wings of the MUAV would deploy under spring tension. The GPS and data link antennas would spring up into position on top of the body section forming a vertical stabiliser. A timing switch would then release the MUAV vehicle from the parachute after approximately 5 seconds, pulling out a pin that starts the electric engine. The MUAV would then gently pull out of the dive, and fly a predetermined heading and altitude until it receives signals from the controlling helicopter that adjusts its next waypoint data and altitude (see figure 5).

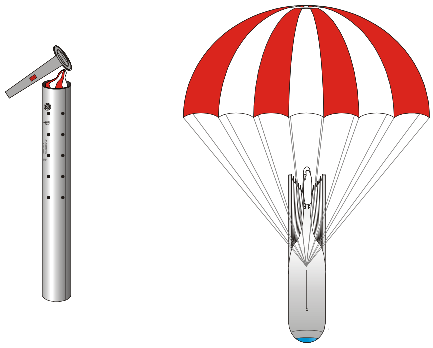

Figure 4 – Launch sequence for the Tiny Tiger

The helicopter would transmit GPS waypoint data, generated as a flight pattern on the existing helicopter display software. The MUAV would fly in a semi-autonomous mode to the next allocated waypoint, which would then sequence when the MUAV position was within capture range. If only one waypoint was generated, or the MUAV lost communications, it would enter an orbit pattern at the next waypoint until command is resumed. Simultaneously, the MUAV would pass back to the controlling aircraft its GPS position and altitude providing sufficient situational awareness for the crew.

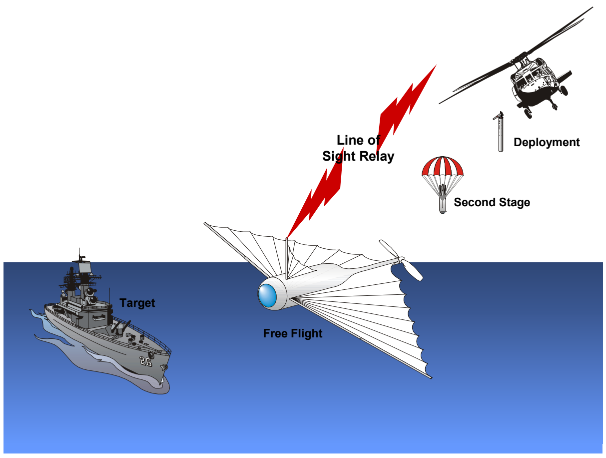

Figure 5 – Concept of Operations for Tiny Tiger

The ultimate aim of Tiny Tiger is to reduce the cost to the point where the unit becomes disposable. This should be achievable in the next decade, and is a concept of operations that has wide acceptance in the ASW community. Alternatively, the UAV could be recoverable by having it ditch in a pre-determined position, inflate a flotation collar, and then be winched up into the helicopter at the end of the mission. This would enable at least the sensor pack to be reused and recorded data to be returned to the ship for further detailed analysis. Such a recovery in a high threat environment may not be deemed necessary, and instead a capability to 'scuttle' or sink the MUAV by a radio transmitted command, like a sonobuoy, would be considered a better tactical option.

CONCLUSION

A key assumption in this paper is that control of a MUAV launched from an Australian Naval vessel should not rely primarily on satellite relay for control of the vehicle and data dissemination. A further assumption, based on doctrine, is that this capability, and derivatives there of, will supplement existing rotary wing assets from 2007 to at least 2025. This paper therefore, proposes a solution that relies on the control of the UAV autonomously from the helicopter to perform a specific surveillance task, whilst the helicopter remains outside lethal range of the hostile contact's weapon systems. The concept of controlling UAVs from helicopters is a relatively new idea having, only in 2001, been the subject of a US Apache helicopter trial. However the concept developed here is a unique application for maritime operations.

This concept of operations requires the design of a disposable MUAV packaged in an A size sonobuoy container which would be launched by the crew to counter a capability gap that exists between detection and identification of unknown surface contacts. Such a concept allows for maximum use of existing onboard operator expertise to make tactical decisions, and to act as a filter for information being passed back to the parent ship or task group. It reduces the requirement for the transmission of large amounts of data via satellites and allows the ship's Command the tactical option of remaining silent in a hostile environment. It also addresses the competition for space on ships between UAVs and helicopters and provides an alternative solution to the technical complexity of launching and recovering a UAV at sea by carrying and then launching the UAV from the helicopter itself. The UAV is then used in a teaming arrangement with the helicopter to extend the sensors whilst reducing the risk to the crew. Such a system will better complement existing legacy equipment, be easier to fit onto and operate from a ship, and has minimal through life operating costs.

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