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THE EFFECTIVENESS OF A SYSTEM-OF-SYSTEMS FOR COUNTERING ASYMMETRIC THREATS IN PORTS & HARBOURS

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Abstract *A small boat loaded with explosives has been used by terrorists to attack military and civilian maritime surface vessels at berth or at anchor. For example, suicide bombers attacked the USS Cole using a small boat while in Yemen harbour (2000), and the Limburg while carrying 300,000 barrels of oil (2002). NATO is currently examining systems to protect High-Value Assets (HVA) in ports and harbours from terrorist attacks using a surface craft. Trials have already begun to explore the operational capability of these systems in various harbour scenarios. The work explores the effectiveness of a system-of-systems to counter maritime threats to vessels and infrastructure in a port or harbour environment. Normal shipping traffic, usually high, within the harbour makes it difficult to promptly identify the intent of the threat, thus resulting in many contacts to manage and track simultaneously. Consequently, a single suicide bomber gradually closing-in on the HVA amongst the shipping traffic could mount a successful attack. Currently, we do not consider a coordinated attack by multiple threats. The response against a potential threat must be a gradual one to avoid harming innocent traffic. Furthermore, to achieve protection from asymmetric threats, any defence system must function with a high degree of efficiency and automation to minimize the resources needed to provide continuous protection. The proposed system comprises a radar detection and tracking component coupled with an unmanned surface vehicle (USV) equipped with a non-lethal effecter. By means of simulation the study shows that existing Radar and USV technology may be used to protect a HVA from realistic contact inter-arrival rates. Furthermore, the intent of these contacts may be determined at sufficient range to allow the HVA to defend itself if necessary.*

Keywords: *Harbour protection, Radar, Force protection, Unmanned Surface Vehicles, Non-lethal effectors*

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1. INTRODUCTION

This report explores the effectiveness of a system-of-systems concept to protect maritime surface vessels from attacks by a small craft containing an improvised explosive device (IED). The methodology is sufficiently generic such that it may be applied to ships berthed, or at anchor in a harbour or to the vulnerable harbour infrastructure itself.

Normal shipping traffic within the harbour makes it difficult to identify the intent of the threat. That is, a radar contact of a small boat tells us nothing of its intent (hostile or otherwise), especially if the contact is matching the speed and general behaviour of all other traffic. For example, an attack could be achieved by a suicide bomber gradually closing-in on the High-Value Asset (HVA) amongst normal shipping traffic.

A further challenge is that the response against a potential threat must be a gradual one to avoid harming innocent contacts. Furthermore, to achieve protection from asymmetric threats, any defence system must function with a high degree of efficiency and automation to minimise the resources needed to provide continuous protection.

2. SCENARIO AND CONTEXT

The scenario is a generic port or harbour, with varying shipping activity within the harbour. The High Value Asset (HVA) to be protected could be a ship at berth or vulnerable harbour infrastructure. As a worst case the (stationary) HVA may be at anchor and require protection from 360 degrees.

A characteristic feature of the small surface maritime threat is that although it is relatively easy to detect and track, its intent is very difficult to identify. The physical attributes and initial behaviour may be indistinguishable from that of any other innocent small surface craft. One countermeasure is to use physical above-water barriers, for continuous protection with an inherent capability to identify the threat's intent. A disadvantage with physical barriers is their deployability and the possible interference with shipping traffic [1].

An alternative is to warn all potential threats in a non-lethal manner and observe their reactions. Non-compliance betrays intent. This requires a system-of-systems to defend the HVA within defined reaction zones. The outer reaction zone is the minimum range from the HVA at which a contact must be detected and tracked by the radar. The inner reaction zone is bounded by the minimum range at which the intent of a contact must be determined such that the HVA can defend itself in time. This range is determined from the speed of the threat and the time required by the HVA to defend itself.

Sensors integrated with an automatic/smart data management system provide the situational awareness within the harbour. For example, a radar (mounted in the harbour or on the HVA) displaying tracks of inbound and outbound contacts can enhance the situational awareness. This is especially the case when such information is geo-referenced and overlaid onto a map of the port. The fusion of radar data with an electro-optical device further enhances the situational awareness. However, these two systems can only aid in identifying suitable contacts within a harbour environment based solely on their size, course, speed and behaviour. The contact's true intent may never be known until it is too late. Coupled to the detection system is a small Unmanned Surface Vessel (USV) with non-lethal effectors ([2]) to intercept and warn all contacts within a pre-defined range of the HVA. The USV can be co-located with the HVA or loiter in its vicinity. Radar contacts of interest are passed to the USV for interception. Non-lethal effectors on board the USV could be a loud acoustic hailer

(LRAD) or an optical dazzler to warn the possible intruder. The intent of the contact is determined by its actions following interception by the USV.

Detection and tracking of all contacts is handled by the HVA keeping the sensor requirements on board the USV to a minimum. GPS positional data will be available, further reducing the risk of collision between USV and friendly objects. Some emergency short range collision avoidance system might also be installed on the USV.

Our overall approach to the problem is more capability based than sensor centric, such that we include the important step of determining intent of the threat rather than weighting analysis towards detection systems [3]. Modern radar systems are capable of detecting small surface threats at ranges in excess of those required for this study as demonstrated during HPT07 [4].

We assume that the surface threat starts to approach the HVA from a position near the outer reaction zone. This zone is assumed to be well within the radar's detection range.

We do not consider threats that maintain a constant high speed from the limit of the radar detection range. The intent of such a contact is more easily determined due to the threatening nature of its behaviour and would not require interception by a USV.

We consider that the threat is a single platform operating alone. In this study we do not consider a swarm attack by multiple platforms at the same time. However, having determined the hostile intent of a single contact the HVA will be at a high level of alert and will likely identify any other co-operating threats in subsequent moments. Importantly, the single threat is assumed to operate within normal port traffic and so multiple contacts may require investigation at any given time within our scenario.

3. MODELLING ASSUMPTIONS AND PARAMETERS

The model simulates the combined system used to protect an HVA at berth or at anchor inside a harbour area. The elements that constitute the system are a main radar to detect and track small surface contacts installed onboard the HVA or in a port facility; an information fusion system to elaborate radar data and, eventually, discard a priori known friendly contacts; an USV used to intercept incoming contacts identifying their intent and deterring friendly contacts from approaching the HVA; an acoustic hailer onboard the USV; an emergency obstacle avoidance system mounted on the USV; a reliable communication channel to exchange data with and control the USV; surveillance cameras onboard the HVA and USV for visual inspection (electro-optical and IR).

The radar used for detection and tracking is considered fully effective. This assumption is reasonable considering Commercial Off The Shelf (COTS) navigation radar models. Working at range of interest (300 - 700 m), the probability of detection is, in practice, 100%. The radar data processing is not simulated. It is assumed that there exist COTS tools, or that such tools can be easily implemented, to collect radar data, build target tracks and produce data to be used as inputs for USV when intercepting contacts.

All surface contacts are on a direct intercept course with the HVA. It is likely however that the radar will hold a number of additional contacts but these will not be passed to the USV.

A simple kinematic model is used to control the USV and all surface contacts. All are assumed to be a point mass to which thrust, braking and steering forces may be applied. The various USV behaviours (intercept, hail or loiter) result in a desired heading and speed being passed to the kinematic model which acts accordingly.

The USV is required to maintain a certain safety distance from the HVA to avoid potentially damaging collisions. Obstacle avoidance is applied such that the USV will alter course so as not to enter a user-defined box around the HVA. This can serve to increase the time required to intercept some contacts.

If the contact inter arrival rate is such that at times no contacts require investigation by the USV it will return to a pre-defined loiter position. This position minimises the average distance of the USV to all points along the outer reaction zone. Having been intercepted by the USV hailer system, friendly contacts are assumed to alter course such that their Closest Point of Approach (CPA) is no longer within the inner reaction range.

A contact is declared intercepted if the distance between USV and contact is less than a critical value (e.g. 75 m) or the contact reacts positively to the USV hailing action, which commences when the distance between USV and contact is less than a given value (e.g. 150 m).

The asymmetric threat initially blends in with other contacts by maintaining a low speed. Once intercepted by the USV the threat is assumed to ignore the non-lethal effectors, accelerate to maximum speed and continue to approach the HVA. It is at this point that the intent of the threat is determined to be hostile and the HVA is alerted to act accordingly.

The command & control system is assumed to be 100% effective throughout the engagement as are the USV and radar. We assume that the acoustic hailer always functions but that the probability of the threat hearing the signal is 90%. Consequently, we require that the interaction between USV and threat consists of a number of hails in quick succession. The hailing system is an LRAD capable of 120-150 dB of sound emission. The USV follows the contacts as they reverse course in order to confirm their intention. This interaction requires approximately 10 seconds, and is considered a reasonable amount of time to hail the incoming threat and to confirm that it is reacting positively.

Simulations were performed with the following parameters: contact inter-arrival rate from 30 to 120 contacts/hr; outer reaction zone from 300 to 700 m; contact initial speed of 8 kts; USV patrol speed of 5 kts; USV maximum speed of 25 kts and acoustic hailer range up to 300 m.

An example of the USV behaviour is shown in Fig. 1 in which the inner (300 m) and outer (600 m) reaction ranges are shown together with the track of the USV and contacts. It can be seen that five contacts were successfully intercepted and hailed prior to reaching the inner reaction range.

4. MEASURES OF EFFECTIVENESS AND SIMULATION RESULTS

The aim is to assess how overall system performance is affected by the parameters in the scenarios. The measure of effectiveness (MOE) of the system is the probability of intercepting, and thereby determining the intent of, a contact before it reaches the inner reaction zone. The range of this inner reaction zone must be set such that the HVA has sufficient time to further warn and subsequently prosecute those contacts that are hostile. Assuming that a threat will accelerate to 25 kts having been intercepted by the USV, and that the HVA requires approximately 20 s to react, we require that the inner reaction zone should be somewhat larger than 260 m. For the purpose of this study we require that contacts are intercepted prior to reaching 300 m from the HVA.

The modelling will examine the dependence of the MOE with, contact inter-arrival rate, relative speed of threat and USV and the inner and outer reaction range. A result will be a requirement in terms of USV speed and outer reaction range that provides 100% interception of threats prior to reaching an acceptable inner reaction range. In order that this nominal system-of-systems be feasible the results in terms of USV speed and outer detection range must be within the capability of current USV and radar technology.

Fig. 2 presents the minimum intercept range as a function of outer reaction range and contact arrival rate. The minimum intercept range is recorded over the course of a simulation representing 2 days of operation, and shows how close to the HVA a contact may approach before being successfully intercepted by the USV. We see that at lower contact rates there is an advantage in increasing the outer reaction range, however this benefit is reduced as the contact rate is increased. In all cases the benefit of increasing the outer reaction range is diminished as the range itself increases.

The outer reaction range represents the range from the HVA at which a contact track will be passed to the USV for subsequent interception. The range should not be so large that all traffic within the port requires investigation. An outer reaction range of 600 m is used for the following analysis.

Fig. 3 and Fig. 4 present the probability of successfully intercepting contacts as a function of both inner reaction range and contact rate for 360 degrees and 180 degrees scenarios respectively with a 600 m outer reaction zone. Fig. 3 shows that a USV capable of travelling at 25 kts can intercept 100% of contacts at ranges greater than 300 m up to an inter arrival rate of 70/hour. Fig. 5 presents the performance values for 180 degrees scenario with inner and outer reaction ranges set to 300 meter and 600 m respectively. The probability of intercepting contacts outside the inner reaction range is shown as a function of USV maximum speed. The results show that a USV with a maximum speed of 15 kts can still maintain a probability of interception of 98%.

5. CONCLUSIONS

This study has shown that a system coupling radar and USV is able to intercept and therefore determine the intent of threats at ranges greater than 300 m for a contact rate of up to 70/hour. This is considered sufficient to allow the HVA time to further warn and prosecute a threat.

The system requires minimal sensoring by the USV since the HVA radar is used to detect and track all contacts. Also the HVA command and control system is used to vector the USV to the appropriate contact. The USV is required to have a basic collision avoidance system fitted together with GPS and an acoustic hailer. The system-of-systems may be automated such that the manning requirements for long term protection are minimised.

Additional enhancements to the performance of the system may include more advanced contact queuing and optimum path planning by the USV. This may further increase the minimum intercept range and will form the basis of subsequent studies.

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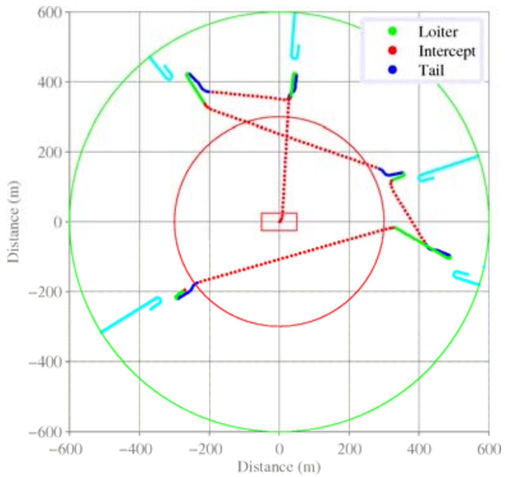

Fig. 1: Example scenario.

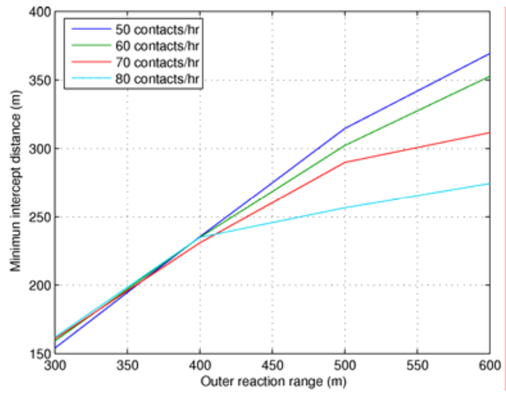

Fig. 2: Minimum intercept range as a function of outer reaction range and contact rate.

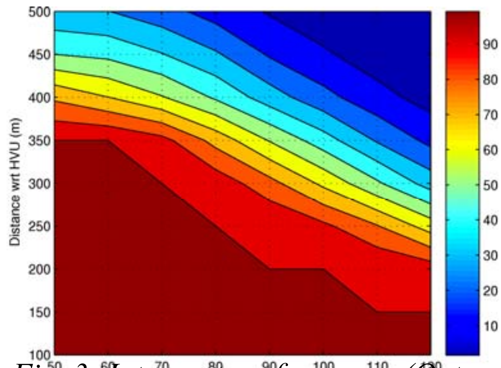

Fig. 3: Intercept performance (Outer range 600 m, 360 degrees coverage).

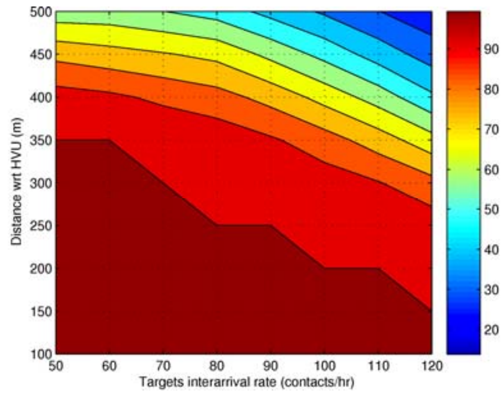

Fig. 4: Intercept performance (Outer range 600 m, 180 degrees coverage).

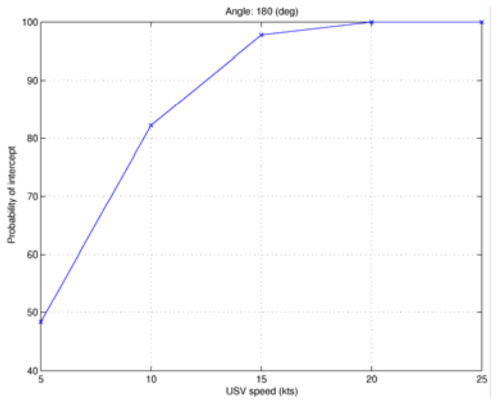

Fig. 5: Intercept performance versus USV speed (Outer range 600 m, inner range 300 m, 180 degrees coverage).

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