# MCM planning and evaluation for a UxV Toolbox in a variable mine threat and environment

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## ABSTRACT

Modern expeditionary Mine Countermeasures (MCM) forces are required to operate against a prolific and varied mine threat, in a range of different environmental conditions. To counter the full range of threats, both mine hunting and mine sweeping are required. In order to meet this challenge, ATLAS ELEKTRONIK UK (AEUK) have designed multiple unmanned vehicle (UxV)-based MCM systems, based on the ARCIMS unmanned surface vehicle (USV) platform, including the UK Sweep capability. In addition to mine sweeping, the USV system can undertake environmental assessment and mine hunting using a towed sonar, so that the mutual benefits of both mine sweeping and mine hunting can be exploited. The agility of the toolbox creates the option of using both mine sweeping and mine hunting in a combined MCM operation, opening up a range of MCM tactics. The key to successfully configuring and operating an efficient, mixed MCM toolbox is understanding the encountered mine threat and the environment in which it has been laid. AEUK have developed a clearance coverage mapping process that enables integrated planning and evaluation of UxV MCM missions, whether they be mine hunting, mine sweeping, or a combination of both. The process enables mapping of effector performance P(y) in 2 dimensions, exploitation of modern geospatial intelligence, and account of through-the sensor assessment of missed coverage. For UxV mine sweeping, AEUK exploit their TMSS mine encounter model to determine P(y), and for UxV mine hunting, P(y) is characterised in terms of a combined detection and classification process inherent to the use of modern imaging sonars. The coverage mapping process is compatible with the currently used Bayesian approach of determining the a priori distribution of mines and estimation of risk, but flexible enough to accommodate the ability of UxVs to operate differently from MCMVs. This paper describes the new approach and its benefits.

## 1 INTRODUCTION

The evolution of autonomous UxVs affords the ability to conduct modern MCM through a range of Concepts of Employment (CONEMPs), which may differ from those traditionally used with Mine Countermeasures Vessels (MCMVs). Despite this, some organisations are using UxVs in a fashion consistent with Planning and Evaluation (P&E) approaches designed for MCMV operation.

UxVs offer agility for MCM operation, in terms of both platform manoeuvrability, and type of MCM mission conducted. AEUK have developed the ARCIMS USV to be a multi-purpose mission system, able to conduct both mine sweeping and mine hunting (as well as other military effects such as Anti-Submarine Warfare). Figure 1 shows ARCIMS USVs as part of the UK Sweep Capability, as the host of towed Synthetic Aperture Sonar (SAS) AQS-24B, and as the launch and recovery platform of the SeaCat Unmanned Underwater Vehicle (UUV). Deployment of multiple UxVs may therefore be capable of exerting an MCM effect via both mine sweeping and mine hunting. An MCM P&E process is therefore required that can cope with an MCM toolbox of UxVs, comprising systems of differing capability, type, and numbers, and operating different tactics.

This paper presents an approach to MCM P&E designed for operation with mixed UxVs. The approach allows full advantage to be taken of UxV flexibility, exploitation of modern Geo-Intelligence (GEOINT) products, modern CONEMPS, use of through-the-sensor information, and combination of mine sweeping and mine hunting.

**Figure 1. ARCIMS USV as part of the UK Sweep Capability (top) and with the AQS-24B towed SAS and Seafox mine disposal system (bottom). The USV can also launch and recover the SeaCat UUV.**

## 2 APPROACH

To design an MCM P&E process best suited for operation with UxVs, this work considered the issues associated with the use of traditional P&E tools with UxVs, and how to address them.

### 2.1 Issues using UxVs with traditional MCM P&E processes

Current MCM P&E processes generally evaluate MCM performance across a channel (through which traffic to be protected will transit). Within this context, cross-channel variability of MCM performance (P(y)) can be accounted for, but along-channel variability (or variability on tracks oblique to the channel) is not so easily represented. Simplification of P(y) to parameters used in traditional MCM P&E are not easily calculated in this 1-D approach. Consequently, optimum performance of UxVs, which may require operation on paths in multiple orientations, cannot be readily assessed.

The planning of track spacing for mine hunting UxVs may not be based on mine knowledge i.e. leg spacing is generally based on default sonar swath. Despite history to the contrary in traditional P&E tools, P(y) is not readily used in current UUV track planning tools. The mine hunting process using UxV sonars is different from that of forward-looking sonar on manned MCMVs. On an MCMV an operator will detect a contact, and then move toward, and manoeuvre around a contact to classify it. An operator examining sonar imagery from a UxV is arguably detecting and classifying contacts simultaneously.

The coverage of MCMV and UxV sensors is also different. MCMV sensors have relatively broad spatial coverage, and lower performance per coverage. UxV sensors tend to have lower spatial coverage, but higher relative performance per coverage. It is therefore possible to achieve the same statistical coverage as an MCMV sonar that has fully covered a region spatially with UxV sensors that have not achieved full spatial coverage. MCM planners need to consider whether this is acceptable or not. In addition, owing to their operation close to the seabed, UxV sensor coverage can be impacted by shadowing from seabed topography.

### 2.2 A 2-D coverage mapping approach

In order to optimise the use of UxVs, and mitigate the issues highlighted in Section 2.1, AEUK have developed a MCM P&E process based on 2-dimensional (2D) mapping of MCM coverage. The 2D approach inherently enables account of UxV sensor coverage at an orientation relative to a predefined channel or operating area. The process utilises P(y) curves mapped to planned or achieved UxV mission paths to create a performance map i.e. P(x,y). The operational area is represented by a grid of spatial points, so that account of multiple, overlapping coverages, from legs at any orientation can be used to calculate a cumulative performance map, as shown in Figure 2.

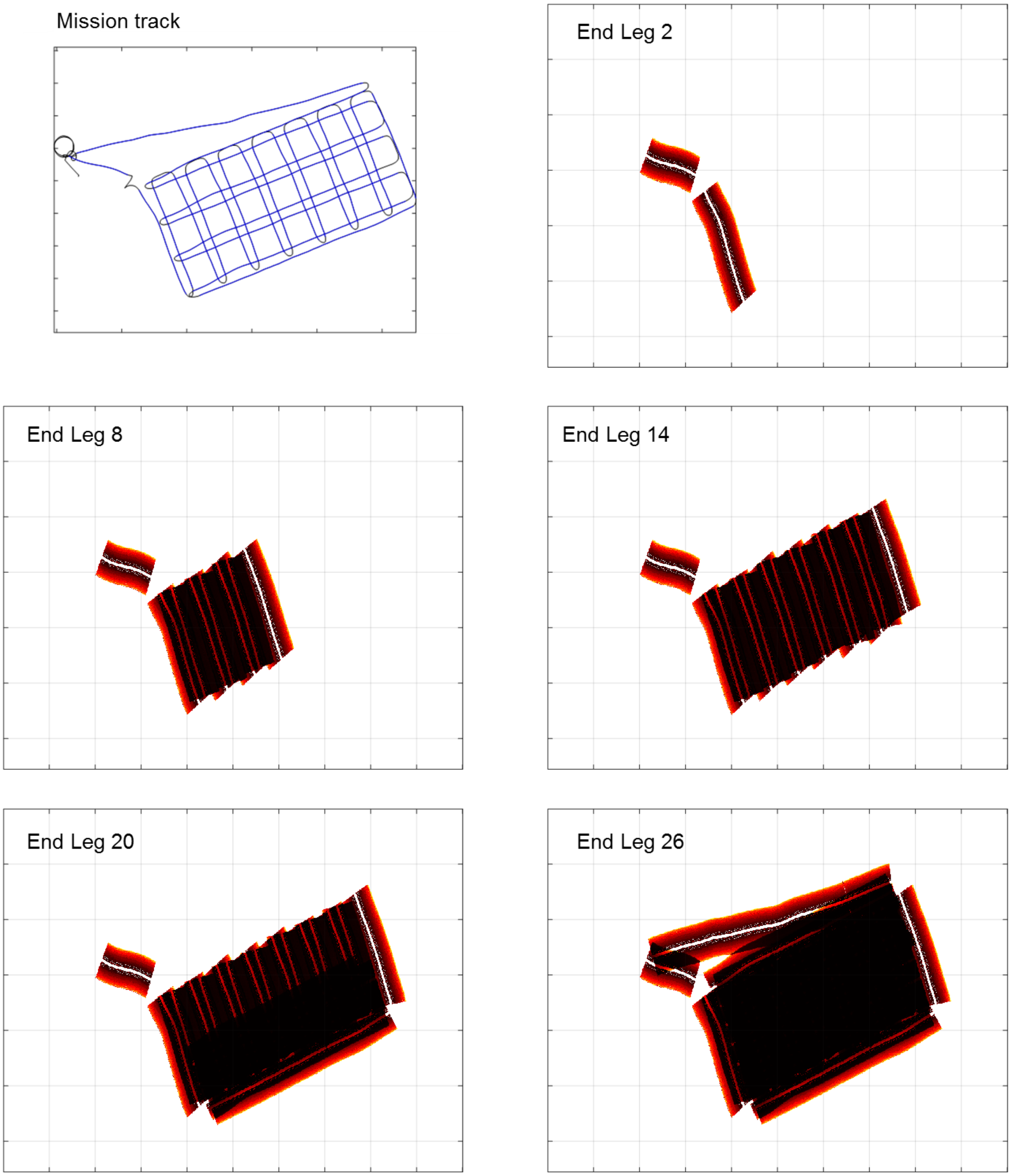

**Figure 2. Predicted cumulative probability of classification achieved by a UUV mission using multiple leg orientations.**

The P(y) curves used in the process may be modelled or empirical, but should be based on mine knowledge and environmental intelligence (GEOINT products) available for the mission, as implemented in the AEUK Sweep Tactical Decision Aid, which calculates optimum P(y) using the Total Mine Simulation System (TMSS). In order to predict the equivalent UxV mine hunting P(y), AEUK use an adapted Information-based model, which is capable of modelling the combined detection + classification operator process (see Figure 3).

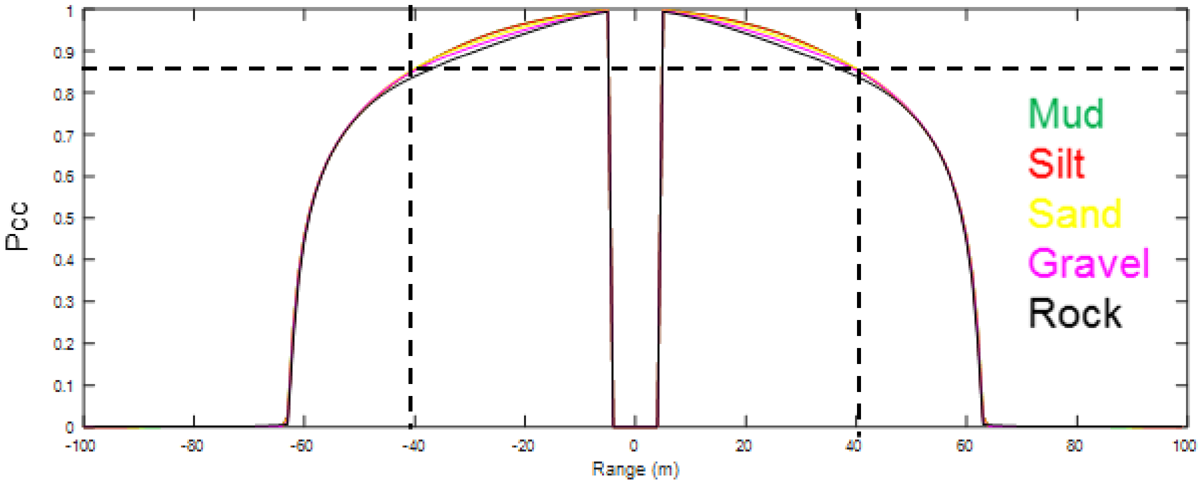

**Figure 3. Predicted P(y) (Probability of detection + classification versus range) for COTS sidescan sonar vs small bottom object (<1 m dimensions) in different environments using the Information-based model. Note that to achieve required classification performance, the effective range may be narrower than the default sonar range.**

AEUK have also developed through-the-sensor missed coverage evaluation (see Figure 4) that can be directly incorporated in 2D coverage evaluation, enabling the operator (or autonomous behaviours) to respond in-mission.

The process can also be used to evaluate mission evolution over time.

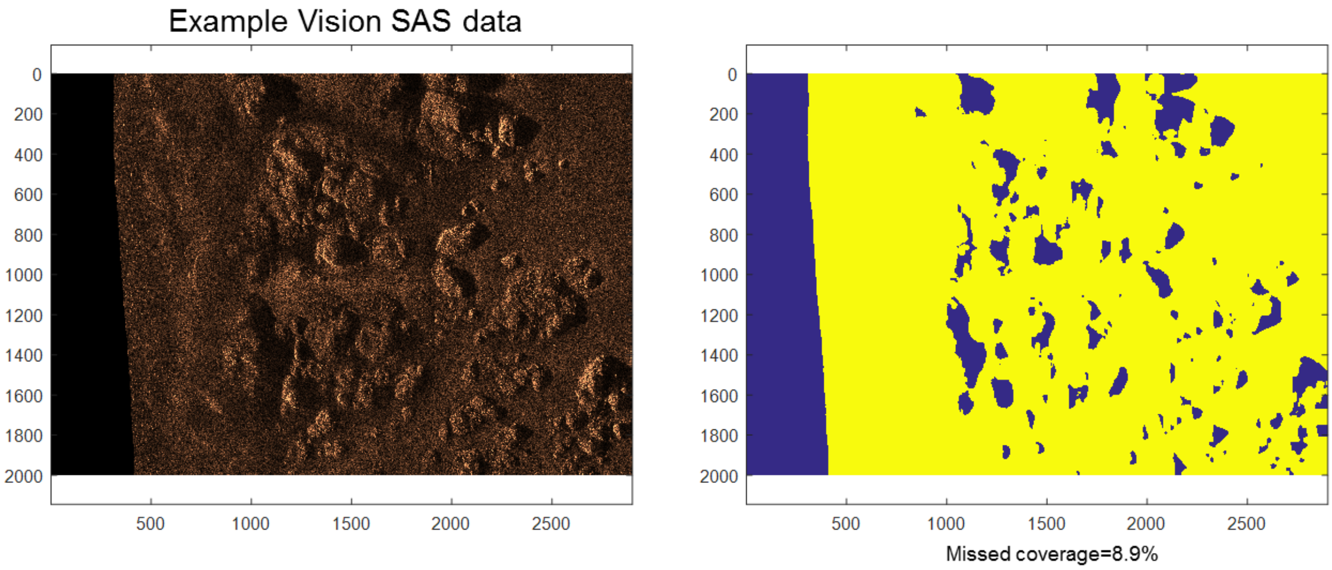

**Figure 4. Example Vision SAS data (left), and results of the auto-shadow detect algorithm (right). Missed coverage in shadow zones can be included in overall MCM planning.**

It is worth pointing out that the 2D coverage approach suits new, more flexible doctrine. It can incorporate single coverage P(y) data from traditional MCM evaluation and can be combined with intelligence data to produce spatial risk. In dealing with MCM coverage, it also enables the combined effects of mine hunting and mine sweeping in the same mission, opening up a range of tactics to the user.

## 3 DISCUSSION

A number of organisations are procuring UxV systems for MCM, covering a range of budgets and capability. All have MCM utility, but may differ in terms of operational performance, swath width and/or coverage rate. The key to the customer is that they understand the capability (possibly mixed) they have procured, and can implement it intelligently to best MCM effect. The proposed 2D coverage mapping approach to P&E presented here enables them to do so.

AEUK have a developed a 2D coverage mapping process that can form the basis of an end-to-end P&E process for MCM UxV toolboxes, by including the following features:

- The P&E process is based on mine and environment intelligence (modern GEOINT products)
- The process accounts for UxV manoeuvrability;
- As mapping is based on “% clearance” the process can account for mine hunting + mine sweeping – opening up a range of MCM tactics to the modern user;
- The process accounts for through-the-sensor missed coverage in evaluation.

## Author/Speaker Biography

Richard is a consultant working in numerous aspects of the Mine Countermeasures (MCM) and Hydrographic domains. He has over 23 years of experience working in operational analysis modelling and system design, sensor performance modelling, novel sensor processing techniques, and the exploitation of geospatial information.