Countering a Swarm Attack

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ABSTRACT

Ships transiting a choke point, such as the Strait of Hormuz, may face an asymmetric naval threat consisting of a swarm of 50+ knot, fast inshore attack craft (FIAC), armed with unguided rockets, anti-ship missiles (ASMs) or torpedoes. In such an environment, survival will depend on very close crew coordination and communication between the Combat Information Center (CIC), the bridge team, lookouts and crew-served weapon operators on board the vessel under attack, plus optimal tasking of supporting helicopters and armed unmanned aerial vehicles (UAVs). No single naval simulator provides adequate training for crews and their supporting air assets in such a swarm attack environment. Against a determined enemy, perhaps with little regard for their own survival, ships will require a carefully coordinated crew response to provide an acceptable chance of countering a swarm attack. This paper proposes a training methodology to prepare crews to counter a swarm attack that links conventional simulators to Serious Games utilities representing the target vessel's crew positions and associated air assets, opposed by multiple FIAC attacking in a swarm. The paper will consider the phases of a swarm attack and how simulators may be networked to train crews to survive. The training provided stresses the need for early recognition and identification of the threat; prioritizing FIAC to be engaged; tasking defensive weapon systems; and ordering initial maneuvers. As the attack develops, lookouts are trained to provide accurate information to the bridge and CIC, which will take evasive maneuvers and task the crew-served weapon operators. Having mastered self defense of their own ship, the trainer will allow crews to work with other vessels to improve situational awareness and multi-ship cooperation. The aim of the training is to ensure that crews facing a swarm attack are well coordinated and therefore best able to survive.

ABOUT THE AUTHORS

Morten Kolve is from Norway and is currently the Marketing and Business Development Manager for navy simulators and trainers at Kongsberg Defence Systems, a supplier of a wide range of military systems. His interest and work for more than twelve years has been systems design and development of naval team and task group level trainers with emphasis on enhancing team and task group level performance and coherency through new training capabilities. Prior to his current work in simulation and training, he worked for eight years as a systems engineer on naval combat management systems. He also served for ten years in the Royal Norwegian Navy (RNoN) as an underwater weapon systems officer and holds an engineering degree in computer science and electronics from Gjøvik University College.

Geoff Tompson is from the United Kingdom and served twenty years in the Royal Air Force (RAF). He flew as a navigator and Captain on Nimrod Maritime Patrol Aircraft, and as a navigator and Electronic Warfare Officer on Buccaneer strike/ attack aircraft. After attending the RAF's Aerosystems Course, he worked in the UK MoD, where he was responsible for anti-ship and several cruise missile projects. After retiring from the RAF, he took a three year sabbatical running a commercial diving boat, before working in Saudi Arabia as the Senior Training and Planning Coordinator at the Royal Saudi Air Force Electronic Warfare School. After four years there, he returned to the UK where he became the Vice Principal of GEC Marconi's Dundridge College. In 2000, he and two colleagues set up a simulation and training business in the UK and, as its Managing Director, he played a key role in the development of training tools now in service with more than twenty five users, including the US Air Force. After two years back in uniform as a naval adviser in the UAE, he started Decisive Encounters Limited, which is working with Kongsberg Defence Systems to develop new naval training systems.

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INTRODUCTION

Ships transiting a choke point, such as the Strait of Hormuz, may face an asymmetric naval threat consisting of a swarm of 50+ knot fast inshore attack craft armed with unguided rockets or torpedoes, supported by 'Silver Bullet' craft armed with beyond visual range radar or infrared-guided anti-ship missiles (ASMs). Countering a determined swarm attack, perhaps by an enemy with little regard for their own survival, requires a carefully coordinated crew response. However, analysis of the training needs to counter swarm attacks showed us that no existing naval simulator provided adequate training to bring the key crew members together as a well integrated team, and that a new training approach was needed.

We determined that all the building blocks needed to create an effective counter-swarm trainer existed, so we devised a 'system of systems' to combine the strengths of each component into our swarm trainer. Having created our ideal swarm trainer, we devised a pedagogy that would develop an understanding of *offensive* swarm tactics as a key to building defensive skills. A key feature of our swarm trainer was therefore to teach crews to 'Think Swarm'.

After studying the capabilities of the potential threat, and conducting counter-swarm training in existing simulators, we found that surviving an attack by such a swarm and its supporting 'Silver Bullets', would depend on having a well-coordinated, layered defense. We assumed the layered defense would have an outer defensive ring where armed helicopters and unmanned aerial vehicles (UAVs) would operate; a middle ring, where targets would be engaged by own ship weapons aimed using over-the-horizon targeting provided by a third party; and an inner ring where direct fire could be used against visually identified targets. To be effective this layered defense required the following:

- Optimal tasking of on-board sensors, supporting helicopters and armed unmanned aerial vehicles (UAVs) to ensure early detection of the swarm and its supporting 'Silver Bullet' craft.

- A timely and appropriate response to each phase of the attack, from initial detection to the close-in, end game, battle.
- Identification and destruction of the enemy's high threat 'Silver Bullet' vessels, before they can launch their attack.
- Very close crew coordination between the Combat Information Center (CIC), the bridge team, lookouts and crew-served weapon operators on board the vessel under attack.

The Swarm Trainer has been created and will undergo further user trials by the Royal Norwegian Navy and others during 2012. Earlier trials using an action speed tactical trainer established the value of experiential training and demonstrated an ability to improve survival rate against swarm attacks. Albeit in these early trials, only the ship's Captain and Combat Information Center team benefitted from the training. Early trials with the new 'system of systems' swarm trainer have shown the potential for further significant improvements in overall crew performance and survival rates against swarm attacks.

This paper initially considers the training need and the training options currently available. We then describe what we considered to be the optimum counter-swarm trainer, which we created by linking together existing trainers in a 'system of systems' using a high-level architecture (HLA) federation. However, our 'optimum' trainer would have been worthless without employing the 'optimum' training pedagogy, which involved creating experiential training in a competitive training environment.

THE TRAINING NEED

The earlier the presence of a swarm can be detected, the greater the probability of mounting an effective defense. It is therefore essential that reconnaissance assets, be they manned helicopters or maritime aircraft, UAV sensor operators, picket ships or submarines, recognize and identify all potentially hostile vessels within at least 30 nautical miles (nm) of the vessel or task force they are supporting.

To complicate the tactical picture, smugglers using very high speed boats ply their trade between Iran and Oman, so not every group of high speed vessels in the Strait of Hormuz is a swarm. Therefore, we determined it is imperative when countering a swarm attack to train personnel to recognize, identify and prioritize potential threat vessels. For example, in the Persian Gulf, Iranian Naval and Revolutionary Guard vessels overtly practice attacking in swarms. The threat such forces might pose ranges from a suicide bomber on a jet ski to 50+ knot fast inshore attack craft armed with radar or infrared (IR) guided ASMs.

Figure 1. Prioritizing Potential Threats

Correct identification of threat vessels is necessary so layered defenses can concentrate their weapons on destroying swarm attackers in order of their lethality. For example, Figure 1 shows three potential fast inshore attack craft threats. The middle one is an example of a 'Silver Bullet' threat with its guided ASMs that can be fired from beyond visual range, making it the highest threat of those shown in figure 1; the craft in the background, armed with torpedoes, is probably the next highest threat; whilst the fast inshore attack craft in the foreground, armed with unguided rockets fired from an unstabilized launcher, must close to well within 8km before firing. Accordingly, it can be engaged later in the swarm attack.

Having located, identified and prioritized the threats for destruction, we decided the keys to repelling a swarm attack lie in sound tactics, command and control, and excellent crew cooperation – a view subsequently validated in discussions with naval personnel and others. Weakness in any of these areas is likely to be exploited by the swarm, with potentially devastating results.

Training must address all the aspects of countering such a threat thoroughly and in depth, with the result that in a real scenario the crew works together seamlessly and effectively as though on automatic pilot. The training should cover two main thrusts:

- Realistic tactical and crew training.
- Timely and accurate threat recognition and identification.

The Value of Realistic Tactical Training

Perhaps one of the best examples of how realistic tactical training can affect the outcome of combat is the experience of USN crews against North Vietnamese pilots during the Vietnam War. Between 1965 and 1967 the USN's kill-to-loss ratio against North Vietnamese pilots was 3.7:1. During a lull in the air campaign, the USN concluded that the poor kill-to-loss ratio was due to inadequate crew training and created the USN Fighter Weapons School (Topgun). When aerial combat resumed in the early 1970s, the USN's kill-to-loss ratio improved to 13:1, whilst that of the US Air Force, which hadn't adopted Topgun-like training, actually worsened for a while after the resumption of bombing (Lambeth, 2000).

Naval crews encountering a swarm for the first time are unlikely to have received any realistic training, yet the history of swarming in warfare suggests that the initiative lies with the swarm, and a poorly executed defense usually results in defeat. As described above, the USN's own experience in setting up Topgun was that realistic training significantly improved performance in combat (Lambeth, 2000). Given this success, coupled with the fact that live 'on-the-job training' against swarm attacks could not replicate the likely size of a swarm or the effect on radars of hundreds of inbound rockets, the driving force for developing a swarm trainer was to simulate the vital experience crews require to successfully survive their first (and any subsequent) swarm attack. Simulation was seen as the most cost-effective counter-swarm training solution.

Tactical and Crew Training

Vessels transiting an area where a swarm might be encountered, especially when passing through a choke point such as the Strait of Hormuz, often use high speed to complicate an attacker's options. However, this could potentially result in a closing speed against a swarm of 80 knots or more. At such a speed, the reaction time for the vessel or task force being attacked would be very short. In such circumstances, crews must be well trained and work efficiently together. To maximize the probability of surviving a swarm attack, we determined that the following skills had to be honed to perfection:

- Early prioritizing of targets for destruction of the most lethal 'Silver Bullet' threats by

supporting helicopters, armed UAVs and the ship's own layered defenses.

- Tactical maneuvering of the ship or task force.
- Airspace management, in particular, maintaining safe separation between supporting helicopters, UAVs, other air assets and gunnery engagement areas.
- Accurate third-party targeting and correct interpretation of the Rules of Engagement (RoE) to allow own ship guns to engage the 'Silver Bullets' beyond visual range.
- Crew coordination between the Combat Information Center, the bridge, lookouts and crew-served weapon operators.

Threat Recognition and Identification Training

From our previous operational experience, we knew that the key to threat recognition and identification against swarm threats was a comprehensive database of accurate 3D models of potential threats, plus regional and Coalition vessels (the latter to reduce the risk of fratricide). Since correct threat identification was essential, using a common 3D models database in both the recognition trainer and the swarm trainer maintained the recognition and identification skills of swarm trainer users. Further benefits of using high fidelity models were that they enhanced the immersive nature of the training; and they improved the application of the Rules of Engagement (RoE) by training crews to recognize hostile actions, such as opening weapon launchers prior to firing a weapon.

REVIEW OF EXISTING TRAINING OPTIONS

When searching for the optimum counter-swarm trainer solution, we considered a number of existing training options.

Stand-Alone Bridge Simulator

A stand-alone bridge trainer would have provided a good solution for maneuver and navigation training, particularly in confined waters. It is possible to have up to a 360° field-of-view visual display and to integrate sight inject binoculars and head-mounted displays (HMDs). However, we had determined that an effective counter-swarm trainer needed to provide a layered defense out to at least 30 nm from own ship, and bridge trainers were only suited to operations within the radar and visual detection range against fast inshore attack craft. As 'Silver Bullet' fast inshore attack craft could fire their ASMs from beyond the detection range of lookouts and shipboard radars, a conventional bridge trainer could not provide the

necessary full layered defense training environment. In favor of a conventional bridge trainer, it would provide excellent ship maneuver training should the swarm close within 5 nm. However, in reality, if the 'Silver Bullet' fast inshore attack craft fired their ASMs from beyond radar detection range and timed the impact of their missiles to coincide with a hail of unguided rockets fired from the less capable fast inshore attack craft, ship defenses could be swamped and significant damage would most likely be sustained. Consequently, we decided that defense in depth was essential to defeat a swarm attack. In summary, we did not consider a conventional bridge trainer to be a viable counter-swarm trainer.

Stand-Alone or Networked Tabletop Trainer

In recent years, a number of simulation companies have developed desktop trainers that provide individual training in ship handling, navigation and visual signaling. These trainers are excellent in providing such training but they lack the interaction that would normally take place on the bridge of a vessel. By networking multiple desktop trainers together, it is possible to practice fleet maneuvers and visual signaling, and some navies have found them to be excellent for developing situational awareness skills. Most desktop trainers are installed with a limited field-of-view display, though an HMD could be readily integrated to provide 360° coverage. However, like the conventional bridge trainer, a desktop trainer is limited by the visual and radar horizon, thus severely limiting its effectiveness for practicing defense in depth. Furthermore, a core skill in counter swarm operations is crew cooperation and this would be difficult to develop using individual desktop trainers.

Action Speed Tactical Trainer

Action speed tactical trainers provide the sensors, tactical displays, weapons, countermeasures, and command, control and communications necessary to conduct a layered defense. In the case of an action speed tactical trainer with multiple cubicles, it is possible to assign cubicles to be the Combat Information Center (CIC) on the various ships in the friendly force, or to represent other platforms, such as picket ships, maritime helicopters or aircraft and UAVs. However, due to their normally designated training role, action speed tactical trainers do not provide a wide field-of-view visual display of the world outside the CIC. At best, an action speed tactical trainer might have an emulation of an IR Search and Track or other narrow field-of-view electro-optical or IR system. Although an action speed tactical trainer would provide a layered defense, it would not be ideal

should the swarm close to within 5nm, when visual maneuvering would probably become the key to survival.

Crew-Served Weapons Trainer

Crew-served weapon trainers are designed to fulfill a focused training need, that of firing a specific weapon against targets at relatively close range. They are not appropriate for use as the basis of a swarm trainer. However, the crew-served weapon trainer has a visual system covering out to the horizon. Long before targets come within range of the weapon, the gunner would provide another pair of eyes to supplement those on the bridge and the lookouts. For this reason, gunners should have a secondary role as members of the lookout team. As the swarm comes within range of the crew-served weapon, engaging targets in order of their lethality is of paramount importance. Accordingly, whilst a crew-served weapon trainer would not provide the sole basis of a swarm trainer, it would provide both longer-range lookout training and simulate engaging threats with crew-served weapons as attacking vessels come within range.

Lookout Trainer

A lookout trainer has the same visual horizon limitations as some of the other trainers already considered. A lookout trainer's primary use is for training lookouts in visual search techniques and vessel or aircraft recognition. That said, when a swarm closes to within visual range, lookouts take on a very important role. They are likely to be well placed to identify high threat vessels attempting to hide within the swarm. Furthermore, a torpedo firing fast inshore attack craft may have to open doors protecting the torpedo tubes and a lookout might thus see a torpedo actually being launched, or see the telltale puff of condensation as the high pressure gas used to eject the torpedo from its tube meets the warmer moist air outside of the tube. A timely warning of a torpedo launch to the bridge and CIC might make the winning difference in initiating an effective maneuver and/or deploying countermeasures. Most warship bridges do not have a 360° field-of-view so lookouts become the eyes covering blind arcs from the bridge, with whom they must work seamlessly.

Limitations of Existing Trainers

After considering the existing training options, we concluded that none provided an adequate stand-alone counter-swarm training solution. Whilst some promoted individual team training, such as the bridge and Combat Information Center teams, none brought together all elements of the crew that need to work in perfect harmony to successfully counter a fast-moving swarm attack. Clearly, we needed to create a solution that encompassed each of the ideal characteristics of the separate trainers. We were aware that existing trainers operating independently didn't involve all the vital crew members in a common communications network. A major challenge during a swarm attack will be maintaining clear, concise and timely communications. Without adequate training, inter-crew communications while under stress could become very confused as individuals compete to report the approaching threats. The time when the CIC and bridge require clear and concise threat information is precisely when untrained personnel could let the team down through poor intercom discipline. Another communications issue we addressed was enabling junior crew members to build their confidence to speak when they have the vital information that could save their ship. It is a Captain's prerogative to act or not on their input, but without a full picture of the threat to the ship, a Captain cannot make reasoned and timely tactical decisions.

OPTIMUM SWARM TRAINER

Our analysis showed that each of the existing trainers incorporated some of the requisite characteristics of a counter-swarm trainer. We decided that a combination of these proven trainers, linked together as a high-level architecture (HLA) federation, would reduce development time and risk. These benefits notwithstanding, some new development was required, which included using a games engine to provide some enhanced visual displays.
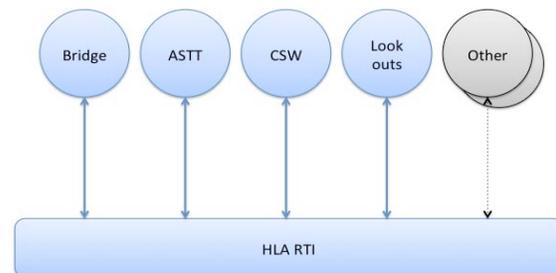

Figure 2. Swarm trainer HLA federation

The optimum system-of-systems swarm trainer configuration (Figure 2) combined an HLA federation of the following:

- Bridge trainer; if required, more than one bridge trainer could be connected to the HLA federation.

- An action speed tactical trainer.
- A crew-served weapons (CSW) trainer for each crew-served weapon station.
- A lookout trainer for each lookout position.
- Other swarm trainer functions, such as attacking swarm vessels.

A key aspect of the swarm trainer was the provision of realistic communications links between the various roles, positions and 'players', which allowed the crew to practice the crucial coordination between the team members so vital to their survival.

TRAINER DESCRIPTION

As previously described, our concept was to develop a new 'system of systems' by creating an HLA federation combining existing naval trainers as federates in our counter-swarm training system, all connected in a common scenario – Figure 3. Where new training capabilities were required, we used a games engine with a high quality visual system and serious games development tools. By adopting such an HLA federation, our counter-swarm trainer became scalable, thereby allowing users to fit the trainer to their operational needs. It also meant that users who already had HLA-compliant naval trainers could create a swarm training capability merely by adding the required federates. Given the current maturity of HLA and the wealth of information available as a means of providing simulator interoperability, only functional descriptions of the various HLA federates will be given in this paper.

The trainer HLA federation is described with reference to Figure 3.

Bridge Trainer. The bridge trainer federate provided functionality appropriate to the bridge of a warship, including detection of swarm threats out to the visual and radar horizons, as shown in Figure 3. Bridge trainer functionality included:

- The ability to maneuver the vessel being attacked (ownship) using an accurate hydrodynamic model to ensure maneuver characteristics represented those of the real vessel.
- A wide field-of-view visual display representative of the view from the bridge of the users' own ship, with high fidelity target, traffic ship and airborne models, plus weapons and weapon effects, such as missiles, rockets and their exhaust trails, and the splash from fall of shot. The visual display also had to accurately display visibility, time of day, the position of the Sun, sea state and weather conditions.
- Standard bridge communications, controls, displays and sensors, including radar and, if appropriate, a warship electronic chart display and information system (WECDIS).
- A binocular function, either using sight inject binoculars, or dedicated displays that simulated binoculars.

Action Speed Tactical Trainer. Our concept is that a layered defense is essential to prevent 'Silver Bullet' craft getting to their ASM firing point. We therefore needed an action speed tactical trainer to provide a Combat Information Center to control all platforms, sensors and weapons out to at least 30 nautical miles (nm) from own ship (Figure 3). The action speed tactical trainer also provided cubicles for other friendly
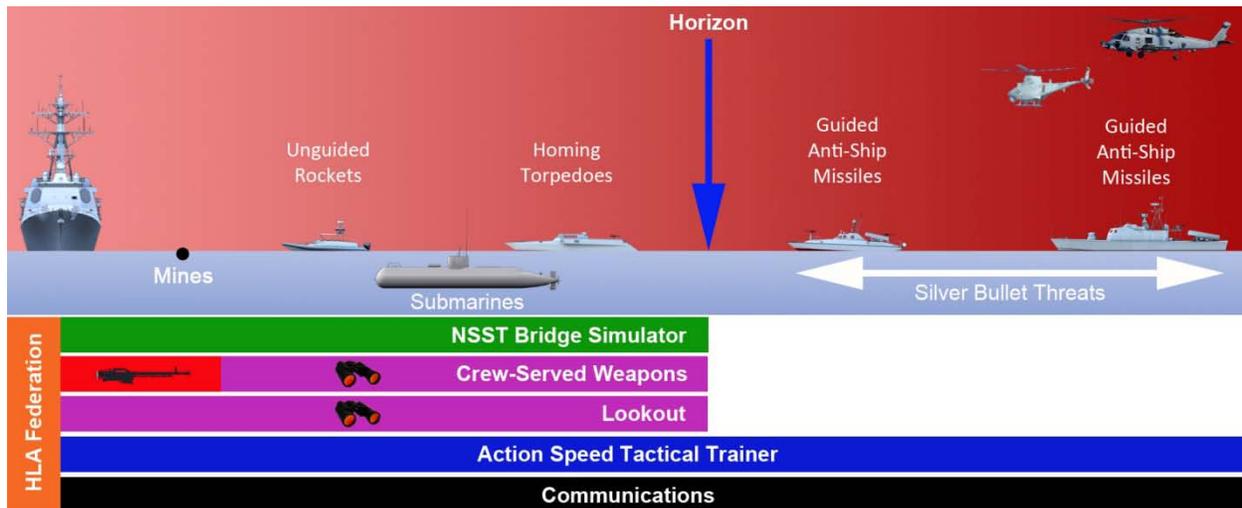

Figure 3. Swarm Threats and Swarm Trainer Federate Areas of Interest

vessels, helicopters, aircraft and UAV control consoles. The action speed tactical trainer federate had to provide the following:

- Tactical displays and warship electronic chart display and information system (WECDIS).
- Sensor displays, including radar, electronic warfare support measures, electro-optical / infrared, or infrared search and track, missile approach warning systems, and communications intercept and direction finding systems. Additionally, as a swarm might merely be a distraction to cover a submarine attack, sonar sensor displays were also required.
- Secure, jam-resistant voice, data and datalink communications.
- Countermeasures, including active jammers (against radar and communications), chaff, infrared flares and other decoys.
- Controls for self-defense guns and missile systems.

Crew-Served Weapon Trainer(s). In addition to the weapons controlled from the Combat Information Center, most naval vessels are now armed with a number of crew-served weapon (CSW) systems. Such systems are relatively short range (Figure 3) and are mostly used to provide close-in defense against suicide attacks, such as the one that severely damaged the USS Cole in Aden in October 2000. Such weapons might also deter fast inshore attack craft armed with unguided rockets or rocket-propelled grenade (RPG) launchers from closing to an effective range. In addition to simulating crew-served weapons, the crew-served weapon trainer federate also provided an additional lookout function beyond the range of the crew-served weapon (Figure 3). This federate thereby augmented the lookouts and bridge team monitoring approaching fast inshore attack craft and, if detected visually, crew-served weapon operators could report the position of vessels preparing to fire weapons, as well as reporting inbound missiles and rockets detected visually. The crew-served weapon federate provides the following:

- A simulated crew-served weapon system, preferably mounted on a motion platform linked to ownship dynamics, in particular roll, pitch, heave, yaw and acceleration vectors.
- A high fidelity visual system, with at least a 180° horizontal field-of-view. Like the bridge trainer federate, the CSW visual system required the same high fidelity target, traffic ship and airborne models, plus weapons and weapon effects, such as missiles, rockets and

their exhaust trails, and the splash from fall of shot.
- Accurate display of visibility, time of day, the Sun, sea state and weather conditions.
- Appropriate communications with the bridge, Combat Information Center, other crew-served weapon stations and lookouts.

A key aim of the counter-swarm trainer was to involve all appropriate personnel in the threat reporting network. CSW operators were therefore provided with access to appropriate communications and trained to use them correctly.

Lookout Trainer. From the lookout position on the deck of a warship, fast inshore attack craft will become visible at about 8 to 10 nautical miles (nm), at which range, in the real world, a lookout with good eyesight should be able to recognize the approaching vessel as a potential threat, and may be able to identify it by type using binoculars. Unfortunately due to the limitations of simulator displays, even high fidelity models will be heavily pixilated at such a range and it is unlikely that fast inshore attack craft will be recognized and identified without the use of sight inject binoculars. Accepting this limitation of digital displays, the lookout federate still provided important training for lookouts in terms of recognition skills (using sight inject binoculars) and intercom reporting procedures. Lookout federates used the games engine and the same high fidelity 3D models as those used in the bridge and crew-served weapon federates. The position of target vessels and traffic ships seen on radar and visually by the bridge, Combat Information Center, crew-served weapon operators and other lookout federates was correlated by the federation object model, thereby ensuring that reporting appeared logical to all participants, irrespective of which federate they were using. Lookouts were therefore able to assist the Combat Information Center in prioritizing threats within visual range. As with the crew-served weapon federate, a key function of the lookout federate was to train lookouts in correct inter-crew communications procedures during a swarm attack.

Voice Communications. As previously emphasized, a key function of the swarm trainer was to bring together all key crew members with a reporting or decision-making responsibility into a representative voice communications network. Inevitably in a fast developing swarm attack, there would be an element of uncertainty that could be clarified or compounded depending on the quality of intra-crew communications. The communications provided in the swarm trainer were therefore as representative as possible of real-world systems. For ship-to-ship and

ship-to-air communications, we provided secure jam-resistant radios where appropriate, together with standard marine band, VHF and UHF radios.

Federation Object Model. The federation was largely built using existing trainers having the requisite Protocol Data Units using industry standard Real-Time Platform Reference – Federation Object Model 2.0, thus requiring no additional extensions. We defined the federation agreement with a basic set of Protocol Data Units to provide a common dataset across the federation and to ensure correct mapping of models between the trainers. Likewise we defined Simulation Object Models for each trainer's communications with the Run-Time Infrastructure.

Common Data and Synthetic Environment. To minimize the risk of confusing crew members assigned to the various federates, it was imperative that we correlated all visual and sensor contacts across the HLA federation. We achieved this using a federation object model and the action speed tactical trainer acting as the scenario controller. The action speed tactical trainer controlled all entities, allowed the injection of new entities, and was the controlling federate for starting and stopping the exercise.

Modeling

We compiled and modeled all the entities making up the complete swarm scenario, together with their equipment and capabilities, using open source unclassified data. The data was then distributed to the various federates. 3D models of targets included correct articulation of key features such as: missile and torpedo launcher doors (important for training correct use of the Rules of Engagement); elevating masts, radars and communications antennas; and, for semi-submersible fast inshore attack craft, such as the one shown in Figure 4, and submarines, the ability to partially or completely submerge. We included appropriate Digital Terrain Elevation Data (DTED)

terrain data in the federation agreement and distributed it to each trainer where required.

TRAINING SCENARIOS

The swarm trainer provided a number of training scenarios, including:

- **Ownship v Swarm**. In these scenarios, a single friendly vessel would be attacked by a swarm, either in a choke point or in open water.
- **Escorts and High Value Unit (HVU) v Swarm.** In these scenarios, while a number of friendly vessels were escorting a HVU, either through a choke point or in open water, they would come under attack by a swarm.

Scenario development followed. An example of one is that shown in Figure 5 on the following page. In this scenario, the swarm adopted either a predetermined attack plan, irrespective of the reaction of the vessel or vessels under attack, or the swarm vessels adapted their attack plan in response to defensive actions by the vessel, or vessels, they were attacking. If the swarm tactics involved the use of radar or radio communications to coordinate the attack, the vessel, or vessels, under attack could use jamming or other countermeasures to confound the swarm. Neither side was given an unrealistic advantage. As crews became more adept at countering a swarm, shore-based or air-launched ASMs, and submarines, added to the complexity of coordinated attacks. The addition of minefields raised the bar again as they limited maneuver options and forced vessels into pre-determined 'kill zones'. Experience with the scenarios highlighted the importance of correct intra-crew communications and reporting procedures, whilst clear, concise and timely tasking and communications between ships and their supporting helicopters, aircraft and UAV operators proved to be vital.

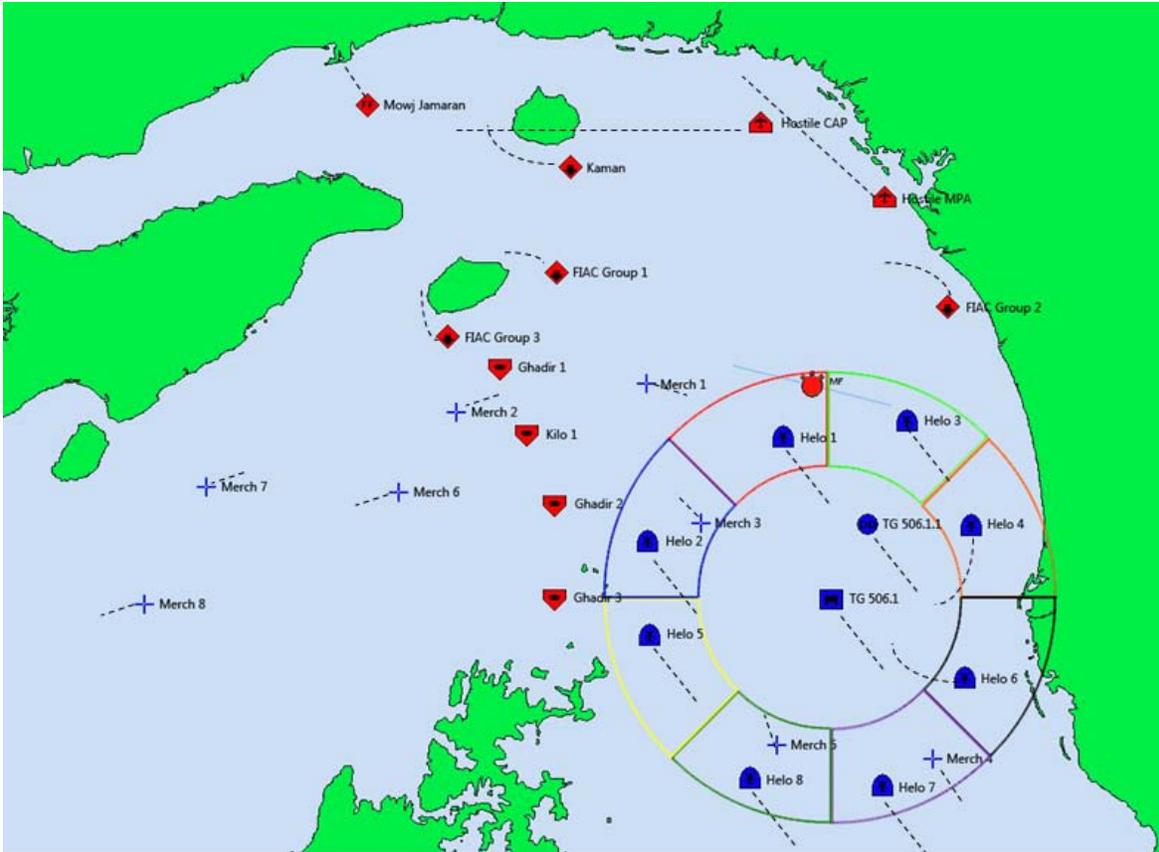**Figure 4. Semi Submersible Fast Inshore Attack Craft**

Figure 5. Typical Choke Point Scenario

PEDAGOGY

The swarm trainer was developed to train both new and established crews how to defend themselves against a swarm attack. When deciding how best to prepare crews to face a swarm threat, we assumed that the bridge and Combat Information Center teams, and their various operators, were already competent to fight their vessel in 'normal' naval warfare. Yet, swarm attacks should not be considered as 'normal' naval warfare. The essence of a successful defense to swarm attacks is speed of threat recognition; prioritization of its lethal 'Silver Bullet' vessels; and a crew whose communication and coordination are honed to perfection. In 1944, as the USN demonstrated at the Battle of Surigao Strait, a swarming attack by PT (Patrol Torpedo) boats distracted a powerful Japanese force and broke up its formation. Further swarm attacks by USN destroyers resulted in the battleship Fuso and two Japanese destroyers sinking, whilst another destroyer was hit and subsequently sank. Shortly thereafter the survivors of the Japanese formation came within range of the guns of six US battleships (Tully, 2009). The Battle of Surigao Strait is possibly best remembered as being the last time a battleship fired a salvo against another heavy ship. However, it should

also be remembered that up to 75% of the Japanese losses in that battle resulted from the USN's swarm attacks prior to the US battleships firing their first salvo. The USN's own experience has shown that swarm tactics can defeat even a very powerful and well-equipped opponent. Thus, we concluded that building an understanding of swarm tactics was crucial when training to counter a swarm attack.

Training Methodologies

We next considered a number of training methodologies.

- **Operator Training v Team Training**. Part Task Trainers (PTTs) provide a valuable means of teaching individual operator skills. Of course, once operators become competent using their equipment, it is more challenging to put them into a realistic working environment. Before radar operators can take responsibility for conducting a surface radar search in a busy shipping lane, they must first learn the function of each radar control and how to interpret the radar display. Learning these basic operator skills is best done in

isolation using a PTT. Once they have mastered the basic operator skills, the next step in their training might be to move them into a bridge simulator or action speed tactical trainer, where they can learn their role as part of a team. When they move to the bridge simulator or action speed tactical trainer, a careful choice of training scenarios will gradually improve their operator skills along with their interactions with other team members. We believe that building team skills is a key goal of the swarm trainer.

- **Experiential and Team Learning**. As the USN demonstrated when it set up Topgun, learning by experiencing a realistic combat environment was highly effective. For the same reason, the naval simulation world widely adopted team training simulators for bridge and Command Information Center teams. As already considered, counter-swarm training requires a number of teams to work together and we found no adequate solutions available that met all of our requirements.

- **Scripted v Competitive Scenarios**. The final part of the training pedagogy was to decide how best to run training exercises. In most naval simulators, instructors plan scenarios in advance to bring out specific training goals. Based on our experience instructing in naval simulators, we felt that such scripting was too restrictive in a counter-swarm scenario and, in some respects, wasted training opportunities. When tracking Soviet submarines during the Cold War, I recall there was a sign over the operations desk on my squadron that instructed us to 'Think Submarine.' By understanding the constraints affecting the navigation and safe operation of a submarine, it became easier to track or reacquire it if contact were lost. Given this experience, we decided that scripting swarm attacks could inhibit innovation and defeat the objective of encouraging crews to 'Think Swarm'. More than 2,000 years ago, Alexander the Great demonstrated that swarms can be defeated by understanding their strengths and exploiting their weaknesses. In early battles with Bactrian horse archers, Alexander's army suffered defeats as the Bactrian archers avoided close combat, where the Macedonians' melee weapons gave them a significant tactical advantage. Alexander reorganized his forces into five columns that isolated the Bactrians from re-supply. Once

their horse archers ran out of arrows, they had no alternative but to engage the Macedonian phalanx in close combat and were defeated (Edwards, 2000). Put in a modern context, the guided-missile armed 'Silver Bullet' craft equate to the Bactrian horse archers gaining a tactical advantage by using stand-off weapons.

We decided that our trainer should encourage crews to 'Think Swarm'. We achieved this by taking two watches from the same crew and made one watch the defenders, and the other the swarm. In this way the counter-swarm trainer built defensive skills by increasing the understanding of how a swarm would *attack*. To ensure the success of a swarm attack against a well-defended target, the attack itself must be meticulously planned and executed. It would be extremely unwise to assume a swarming opponent will rely merely on rushing at their target in an uncoordinated, numerically superior attack. Introducing a competitive nature into the counter-swarm training encouraged watches to develop a thorough understanding of effective defensive strategies by fully understanding the opponent's attacking strengths and weaknesses. When facing a swarm attack there is little room for error and timely defensive measures are vital.

CONCLUSION

Swarm threats are not new and the lessons of history are clear: a well-executed swarm attack has a high probability of success, even against the most powerful opponent. More than 2,000 years ago, Alexander the Great demonstrated that swarms can be defeated by understanding their strengths and exploiting their weaknesses. However, modern naval warfare mostly relies on possessing superior technology and has neglected to train effectively against swarming tactics.

Live training in the naval environment against swarm threats is not a realistic option as few navies can justify the expense of maintaining their own 'swarm' of fast inshore attack craft, merely as a training capability. On-the-job training is not an option as the average swarm attack will last no more than 20 minutes, so there is no time to develop defensive capabilities before the swarm launches its weapons. Without adequate counter-swarm training, a crew's first encounter with a swarm could well be their last. At best, they are likely to suffer serious damage or, worse still, many ships will be sunk and lives lost.

As described in this paper, the USN used swarm tactics to disrupt a serious Japanese threat during the Battle of

Surigao Strait in 1944. Furthermore, during a lull in the air war over Vietnam, the USN developed Topgun. The experiential training pilots gained at Topgun resulted in a significant improvement in their kill ratio when the air war resumed. These examples highlight two key points: that a well-executed swarm attack against a powerful enemy can succeed; and effective experiential training prior to live combat can make a significant difference to the outcome.

When considering the threat, we concluded it was more complex than many appreciated and that defense in depth, well beyond the visual and radar horizon, would be crucial. Our assumption was later validated in discussions with those charged with countering swarm threats in various naval forces. Against this background, we looked at what training systems were available to counter swarm attacks in the naval environment and it was apparent that none trained all the aspects of defense in depth.

When considering the training needs to counter the factors of a swarm threat, we realized that all of the building blocks either existed or were in development, though they had not previously been federated together. We decided that a key element was training crews to recognize and identify the threat, as well as giving them the skills to prioritize engaging the 'Silver Bullet' threats before they could launch their guided weapons. An added benefit of using high fidelity models with correct articulation of weapon systems was that crews could familiarize themselves with the correct use of their Rules of Engagement (RoE).

For training defense in depth, we decided to use a multi-cubicle action speed tactical trainer, with its accurate simulation of sensors, communications and countermeasures. For ship maneuver, a bridge simulator provided the ship-handling controls and wide field-of-view visual display. We required this wide field-of-view visual display to counter by maneuver any close-in swarm threats that leaked through the outer defenses. Lookout trainers – augmented by off-line recognition training using CBT – provided training in visual search techniques, threat recognition and identification and, perhaps most importantly, effective reporting to the Combat Information Center and bridge. Additionally, crew-served weapons trainers provided crew-served weapons training, and also trained operators to supplement the bridge and lookouts with threat recognition, identification and reporting.

To link the various trainers together we used a high-level architecture (HLA) federation, with each of the trainers being federates within the overall swarm trainer. We correlated all visual and sensor contacts across the HLA federation. This provided a single coherent view and minimized the risk of confusing crew members assigned to the various federates. We used a federation object model to achieve this and used the action speed tactical trainer as the scenario controller.

The synergy achieved by bringing the various trainers together in a single HLA federation created highly effective training in a fully stressed environment. Having created the swarm trainer, we addressed the training pedagogy to be used. We rejected scripted training as being predictable and, dare we say, too boring. Instead, we decided to adopt experiential training and pit crew members defending their own ship against other members of their crew acting as the swarm. This introduced an element of competition and enabled users to anticipate likely enemy tactics, in effect to 'Think Swarm'.

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