Force Preparation - New Techniques for Developing Collective Training Environment Specifications

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ABSTRACT

Our Forces face operating environments of ever increasing complexity. In his opening address to ITEC 2010, Lt Gen Newton, Commander Force Development and Training in the British Army, characterised the complexity of contemporary warfare as a “wicked problem”. This complexity places ever increasing demands on the training environments within which our Forces train. At the same time, budgetary and environmental pressures necessitate increasing reliance being placed on synthetic training environments, with the reducing availability and viability of live training. This presents a significant challenge to the training community to ensure that training environments are correctly specified so that effective training environment options can be developed. Whilst the principles of Instructional Systems Design/the Systems Approach to Training have a well established tradition within NATO Forces, the underpinning analytical techniques are predominantly focused on individual training. In the published literature there are relatively few techniques that address the issues of collective training (the training of teams and teams of teams). This paper articulates a novel approach to the development of training environment specifications appropriate to collective training. The first part of the paper describes a novel model of team training which captures how teams perform tasks (derived from a synthesis of team performance models), and includes new representations of both team task environments, and of how training is overlaid onto team task performance. The second part of the paper demonstrates how analytical techniques from the human factors and software engineering domains can be adapted and integrated with some new representations to facilitate the analysis of collective training tasks within the framework of the team training model, such that a training environment specification can be incrementally developed and checked throughout the training analysis process.

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INTRODUCTION

Context

Our Forces face operating environments of ever increasing complexity. In his opening address to ITEC 2010, Lt Gen Newton, Commander Force Development and Training in the British Army, characterised the complexity of contemporary warfare as a "wicked problem". This complexity places ever increasing demands on the training environments within which our Forces train. At the same time, budgetary and environmental pressures necessitate increasing reliance being placed on synthetic training environments, with the reducing availability and viability of live training. This presents a significant challenge to the training community. We have to ensure that training environments are correctly specified so that effective training environment options can be developed such that the benefits of simulation are fully exploited without overlooking the key attributes of live environments that determine where live training is essential.

Team/Collective Training Needs Analysis

In Huddlestone and Pike (2009) we outlined a new analytical framework for Training Needs Analysis (TNA) suited to the analysis of training requirements and the specification of training solutions at scales ranging from small teams such aircraft crews up to large scale teams of teams such as armoured battle groups. We refer to this analytical process as Team/Collective Training Needs Analysis (TCTNA). The process is structured around the TNA Triangle Model (Huddlestone & Pike, 2009) shown in .

The essence of the model is that four inter-related analyses are conducted. Training task analysis is concerned not only with task analysis in the traditional sense, but also with developing a picture of the context of the task environment and its dynamics, including generic task scenarios. Training overlay analysis focuses on the identification of appropriate training methods and the range of instructional and other

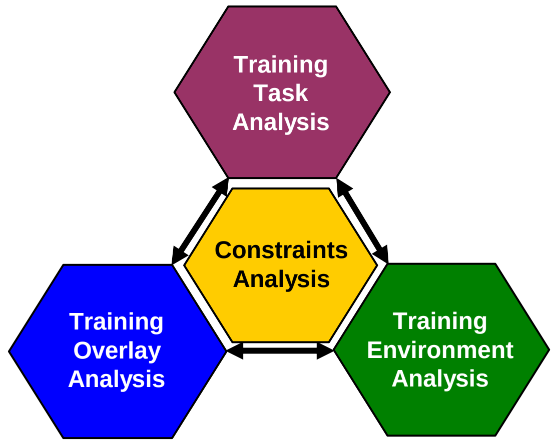

Figure 1 The TNA Triangle Model

supporting roles that have to be filled to deliver these methods. Training environment analysis is concerned with the specification of training environment requirements and the evaluation of the suitability of environment options. The purpose of constraints analysis is to identify factors that constraint he choice of training solution (such as cost, equipment availability and safety) as early as possible so that effort is not wasted in the evaluation of inappropriate solutions.

Aim of this Paper

This paper explains how the TCTNA work has been advanced to support the development of training environment specifications appropriate to collective training. The first part of the paper describes a novel model of team training which captures how teams perform tasks (derived from a synthesis of team performance models), and includes new representations of both team task environments, and of how training is overlaid onto team task performance. The second part of the paper demonstrates how analytical techniques from the human factors and software engineering domains can be adapted and integrated with some new representations to facilitate the analysis of collective training tasks within the framework of the team training

Table 1 Team Effectiveness Models

Model	Inputs	Process	Output	Feedback
Hackman and Morris (1975)	Individual level factors Goup-level factors Environmental level factors	Group Interaction Process	Performance Outcomes Other outcomes	Not shown diagrammatically
Tannenbaum et al (1992)	Task Characteristics Work Structure Individual Characteristics Team Characteristics	Team Process Team Interventions	Team Changes Team Performance Individual Changes	Team Performance into Task Characteristics and Individual Characteristics
NATO (2005)	Mission Framework, Task Organisation Leader, Team Member, Team	Task Focussed behaviours Team Focussed behaviours	Task Outcomes Team Outcomes	Outcomes to processes & conditions

model, such that a training environment specification can be incrementally developed and checked throughout the training analysis process

TEAM TRAINING MODEL

If you consider a set of analytical tools to be the means by which you can navigate an effective route through a territory of data potentially available describing a problem, then you could argue that it would be expedient to have a map of the territory in order to plan an efficient route. In the context of TCTNA, such a map would be a team training model. A review of the literature revealed that no suitable model existed and so a model had to be constructed. The first stage of the development of the model was to construct a team performance model. The second stage was to add a representation of the training overlay. These are described in turn.

Team Performance Model

The majority of published models concerning team performance have focussed on inputs, processes and outputs (also known as I-P-O models). A selection of typical models is shown in Table 1.

Team and individual characteristics show as common input elements to team processes. Team interactions (teamwork behaviours) are common process elements. Both task performance outcomes and effects on the team are common outputs of all the models. Also, all of the models describe the feedback of outputs to inputs. What is conspicuously absent from these models is a full consideration of the environment in so far as the purpose of team activity is to act on inputs from the environment in order to have some desired effect on the environment, otherwise there would be no requirement for the team undertake a task in the first place (although the Hackman and Morris (1975) model does refer to environmental stress as a factor that affects the team) . One of the few models concerning team or group activity that captures this is the rather obscurely named "Information Transduction Model" Roby (1968) which takes an information processing view relating the processing of environmental cues to action outputs from the team. The team performance model that we propose, shown in Figure 2, integrates the key elements of the team effectiveness models discussed with the information processing concept captured by Roby (1968). Each of the elements are discussed below.

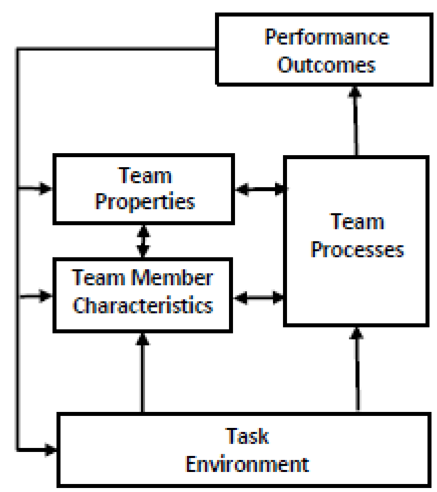

Figure 2 Team Performance Model

Team Processes

Team processes are the team's response to the environmental inputs and are composed of both teamwork and taskwork elements. Their purpose is to generate appropriate task outcomes to achieve the required goal. They also have the side effect of generating other outcomes. The conduct of team processes will be influenced by the characteristics of the team members (their KSAs) and the properties of the team both in terms of the organisational factors of the team (structure, roles etc) and attributes such as cohesion and adaptability.

Performance Outcomes

Team Processes generate "Task Products" and "Other Outcomes", both of which constitute a modification to the task environment. In the case of a field hospital example the principal task product is successfully treated casualties - this constitutes the achievement of the task goal. Other Outcomes are ancillary modifications to the task environment which are concomitant with task performance (though not necessarily goal achievement) i.e. what changes in the environment as a result of the task being performed which isn't directly goal related. These might include resources used such as bandages, dressings, syringes, units of blood etc, and human elements being affected such as untreated casualties worsening in condition. Other outcomes also include effects on individuals and the team as a whole. These might include team organisation having to be changed because of a team member being injured, team members becoming fatigued, knowledge gained by individuals from experiencing a new situation. Therefore, performance outcomes feed back to team properties and team member characteristics, as well as the environment.

Team Properties

Team properties include both organisational aspects, such as organisational structure, roles and role allocation, team size, and team attributes such as cohesion, adaptability and morale. These are affected by the conduct of team processes and the outcomes of the processes as well as by the characteristics of the individuals in the team. In the field hospital there may need to be an adjustment to role allocation to handle particularly demanding casualty levels or to deal with a casualty who has come into contact with a chemical agent. Replacement of a team member with another who does not have the same degree of team orientation as his predecessor may affect team cohesion and morale. Successful treatment of large numbers of casualties who arrived in a short space of time may boost team cohesion and morale.

Team Member Characteristics

Team member characteristics include their teamwork and taskwork KSAs and their emergent states. Emergent states reflect the dynamic nature of individual performance capabilities, influenced by the environment, the experience of carrying out the team processes including teamwork interactions, and the properties of the team. A senior surgeon coaching a junior surgeon may result in the junior surgeon extending his knowledge and skills and self-confidence. Similarly, working in a highly cohesive nursing team may engender greater team orientation in a newly trained nurse in the team. On the other hand, seeing severely injured young soldiers who have been victims of Improvised Explosive Devices may have a severe emotional impact on a team member, reducing their effectiveness in their task.

Task Environment

For the purposes of TNA, the task environment refers to all the features of the real world that are of significance from the perspective of task performance.

Task Environment Elements

In the absence of any established framework we suggest that elements of the environment can be characterised as falling into one of the following categories, each of which have different types of salient features that need to be captured, which are ultimately of significance from the perspective of fidelity specification:

- **Humans** are all the people outside of the team that the team interact with. In the field hospital case this category would include patients and personnel at field dressing stations that they communicate with. Salient features would include both physical properties (such as appearance) and behaviour (including language and cultural aspects).

- **Systems** are all the elements that have interfaces that the team use and would include medical systems such as Electrocardiograms (ECGs) and ventilators as well as such items as communication systems. Salient features would include interface characteristics and functional performance.

- **Manned systems** are those elements external to the team that they interact with. For a field hospital this might include field ambulances and support helicopters providing casualty evacuation. Salient features would include appearance, performance and behaviour – noting the element of human control (this would include tactics for friendly and enemy combat elements).

- **Resources** are all the other items that the team use including equipment, such as hospital trolleys and forceps, and consumables such as dressings, drugs and water. Salient features include their physical properties as well as quantities and location.

- **Physical environment** refers to the immediate environment(s) in which team members are operating (in the field hospital example this would include the tents that they work within) but may also include the land/sea/airspace in which the task is being conducted if relevant. Environmental characteristics such as extreme temperature would also fall into this category.

Environmental Task Demands

Analysis of the task environment using the above categories has the potential to produce a comprehensive model of the task environment. However, the view would be limited to a static description in that it would characterise what was there and how the dynamic elements could behave. Arguably, it is the dynamic and changing nature of the task environment that has the potential to put the team under stress. From observation of many US Navy exercises, Cannon-Bowers and Salas (1998) identified a set of factors which they termed environmental stressors which could impact on team performance. These stressors can be mapped on Orasanu's (1993) properties of naturalistic environments (Huddlestone and Pike, 2010). The following elements, which we term environmental task demands, are an amplification of that provided by Cannon-Bowers and Salas (1998): threat, performance pressure, time pressure, high workload, high information load, requirement for team co-ordination, rapidly changing evolving scenarios, incomplete, conflicting information, multiple information sources, adverse physical conditions, auditory overload/interference, visual overload and resource scarcity/depletion. Examples of environmental task demands from the field hospital example include **high workload** due to large numbers of casualties and **performance pressure** and **time pressure** caused by a critically ill patient requiring urgent, life-saving treatment.

The Training Overlay

The development of a team/collective training model necessitates consideration of how the training overlay, in particular the instructional and supporting functions, and the systems and resources required to facilitate them, are mapped onto the team/collective performance model. Tannenbaum, Smith-Jentsch and Behson (1998) identify key instructional functions in team training as briefing, monitoring, diagnosing performance (evaluation) and provision of feedback (after action review). To these we would add initial instruction and the requirement to manage the training environment in terms of configuring, monitoring and controlling it. The mapping of the training overlay onto the team performance model is shown in the Team Training Model shown in Figure 3.

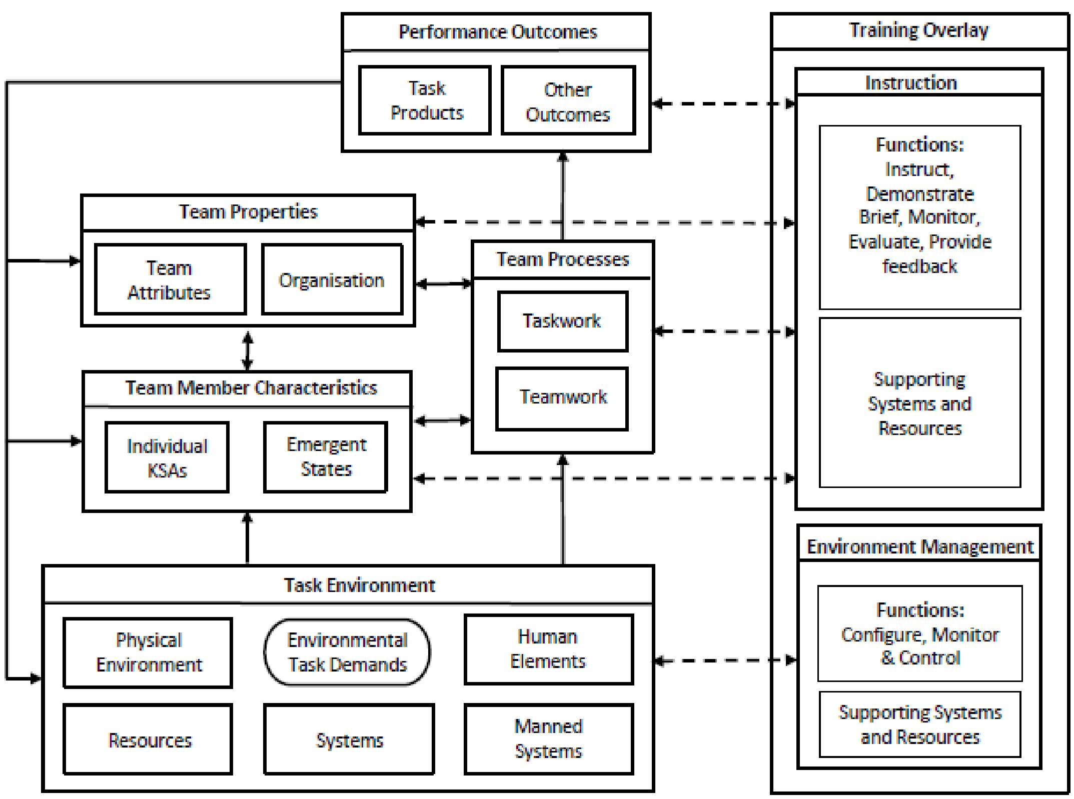

Figure 3 The Team Training Model

APPLICATION OF THE TEAM TRAINING MODEL IN TCTNA

Figure 4 Close range weapons - GPMG (left), Mini-gun (top right) and 30mm gun (bottom right)

This section demonstrates how the Team Training Model can be used to guide the application of the TCTNA method, focusing on the development of specifications for training environments. A case study is used to illustrate the method. The case study chosen is the use of close range weapons systems on board a warship, as shown in Figure 4, by the Local Area Surface Defence Team to conduct Local Area Surface Defence (LASD) in open waters.

Training Task Analysis

The purpose of the training task analysis is to gain a detailed understanding of the nature of the task to be trained and develop training objectives. In short it needs to determine what needs to be achieved, by whom, in what environment using what resources?

External Task Context Description

The first stage of the task analysis focuses on developing a description of the nature and context of the task

Generic Scenarios. **A useful starting point is to capture the nature of typical scenarios for the task. Scenarios may be captured as a simple narrative in a more structured way in a table**.

Table 2 shows an example of a scenario description. It captures the effect that has to be delivered, the environmental conditions, the various elements involved (such as Fast Inshore Attack Craft (FIAC) and jetskis), the initial conditions and typical events that might occur as the scenario unfolds. This data may be derived from documents such Concept of Operations (CONOPS) and doctrine and discussions with Subject Matter Experts (SMEs).

Table 2 Scenario Description for LASD.

Scenario Reference	**Local area surface defence in open waters**
Effect Required	Combat identification of unknown small craft entering the local area of responsibility and interception of enemy small craft to maintain local area surface defence of own ship.
Timing	Daytime
Location & Environment	Open water. Variable weather and sea state conditions
Enemy Forces	FIAC, Jet skis armed with small arms, RPG, and/or machine guns both individually, in multiples or as a swarm attack.
Friendly Forces	Other ships or helicopters within the task force.
Neutral Elements	Local vessels of various sizes
Initial Conditions	Ship in defence watch or cruising watch
Events	Intel report from another ship in the task force Intel report from maritime component command Possible radar contacts Neutral craft entering the local area Craft approaching with unknown intent Optical/IR sensors detecting incoming weapons threat Aggressive action from single, multiple or swarm attack craft. Attack from craft with small arms, RPGs and WBIED. Craft attempting to alter speed or course of own ship. Craft retreating (in response to escalation of force).

External Context Diagram. At the same time as developing the scenario description it is useful to construct a context diagram which portrays the external entities that the team interacts with. An example is shown in Figure 5. The notation is derived from that used by Ward & Mellor (1985) for describing systems contexts for real-time software design. The boxes indicate the external entities that the team interacts with and the arrow show the direction of the interactions.

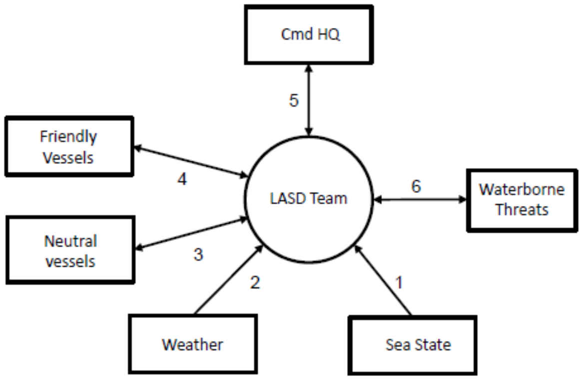

Figure 5 LASD Team External Context Diagram

Interaction Table. As there can be multiple types of interactions with each element, a supporting interaction table can be used to provide supporting descriptions of the interaction sets, cross referenced to numbers on the interaction arrows. Table 3 shows examples of interaction table entries.

Table 3 Example Interaction Table Entries

No	From	To	Nature	Mode
6	LASD Team	Waterborne threats	Monitoring of threat	Optical sensors Binos Radar
	Waterborne threats	LASD Team	Engage with the ship	RPG Small arms

At this stage, with only two tables and one diagram completed it is possible to start a discussion about what a training environment might look like, since we already know what entities need to be present, how the team interacts with them and what types of events need to be generated in a typical scenario.

Internal Task Context Description

Having established the external context, the next step is to characterise the internal context of the team which encompasses the team structure and the nature of its immediate environment, its interfaces to the outside world and its internal communications structure.

Organisational Chart. A first step in understanding the organisational structure is to either obtain (best case) or construct (worst case) an organisational chart. An organisational chart for the LASD team is shown in Figure 6.

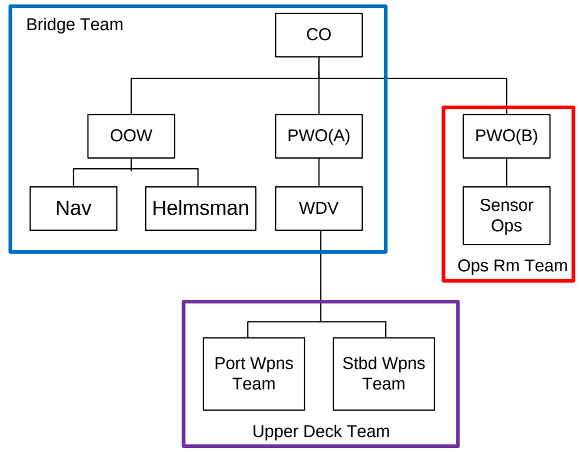

Figure 6 LASD Team Organisational Chart

The organisational chart is useful from a number of perspectives. Most obviously, it shows “who’s who in the zoo”. In this case it shows that LASD team is comprised of three sub-teams, the bridge team, the ops room team and the upper deck team. The bridge team comprises the CO, a Principle Warfare Officer (PWO) and the Surface Warfare Director (SWD). The ops room team is made up of another PWO and a group of sensor operators. The Upper decks team comprises port and starboard weapons teams. The other feature of significance is that it highlights that there are three different local environments, one for each team (the bridge, the ops room and the upper deck). We can therefore determine that a suitable training environment would have to replicate each of these team environments.

Team Internal Context Diagram. The nature of each of the team local environments can be captured using further context diagrams showing the equipment and interfaces that the teams use to interact with the outside world and each other. Figure 7 shows such an internal context diagram for the Bridge Team.

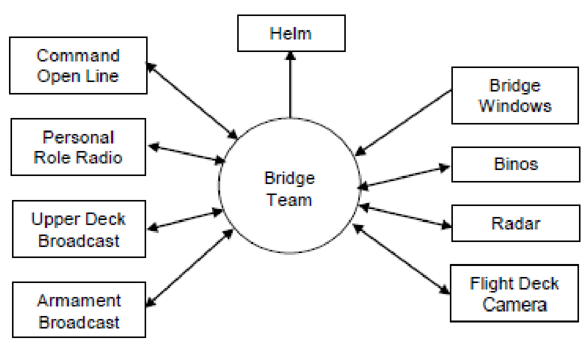

Figure 7 Bridge Team Internal Context Diagram

Again, the context diagram can be supported by an interaction table. Notable in this context diagram is the fact that the Bridge team have access to four different communications systems.

Communications Matrix. It is critical to understand how teams communicate both internally between team members, between teams and with external entities. A communications matrix can provide a concise summary of the communications networks (supported if appropriate by a suitable network diagram. Table 4 shows a communications matrix for the LASD team.

Table 4 LASD Communications Matrix

Role	Communications Channel				
	Face to Face	Personal Role Radio	Command Open Line	Upper Deck Broadcast	Armament Broadcast
CO	X		X		X
PWO (A)	X	X	X	X	X
OOW	X		X		X
NAV	X				X
Weapons Positions	X	X		X	X
Weapon Directors	X	X	X	X	X

The communications matrix is of particular significance, as it captures the communications systems that must be provided in the training environment.

Team Task Analysis

Having captured the external and internal team contexts it is possible to move onto the team task analysis. A suitable method for this is Hierarchical Task analysis for Teams (HTA(T)) developed by Annett, Cunningham and Mathias-Jones (2000). This extends traditional HTA notation by including the team members/teams involved in each task sub-component or goal. An example of the HTA (T) graphical notation is shown in Figure 8. The Goal statements in each box can be used to provide a hierarchy of training objective performance statements. Annett et al (2000) also suggested a tabular format that captures key information about each element such as a description of the teamwork involved and assessment criteria. We have extended the tabular notation further to capture task inputs and products, critical errors and consequences and data capture required for assessment. The capture of inputs and task products is critical as the training environment must be constructed such that these inputs and outputs can be supported. The critical errors and consequences can be used to inform a risk analysis to determine training priorities.

Environmental Task Demands. The final piece in the task analysis jigsaw puzzle is to identify the environmental task demands. These can be presented in a table stating the significance of each type of demand (high , medium or low) with a description of what generates the demand. Table 5 shows some sample entries for the LASD task. These serve to reinforce the key attributes the scenarios delivered in training must embrace.

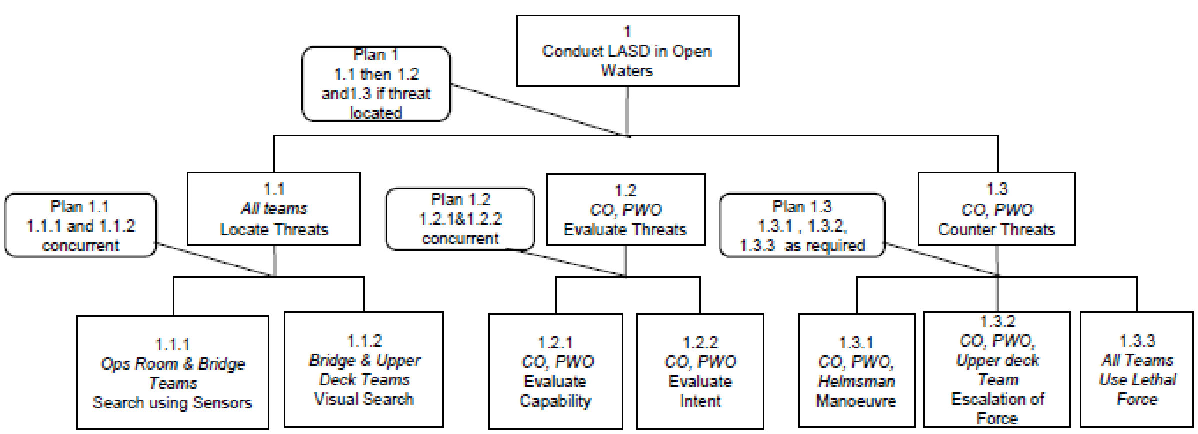

Figure 8 HTA(T) diagram for the LASD Task

Table 5 LASD Environmental Task Demands

Scenario: LASD in Open Waters		
Environmental demand	**Sig (H/M/L)**	**Description of how demand occurs**
Threat	H	Lethal threat posed
Performance pressure	H	Speed of events and actual speed of craft
Time pressure	H	Rapid movement of threat vessels
High workload	H	Many targets in a swarm attack
Rapidly changing, evolving scenarios	H	As intent established the threat level may change. Fast attack craft moving asymmetrically.
Requirement for team coordination	H	Communication between environments.

Constraints Analysis

Before conducting training overlay and environment analysis it is sensible to determine the constraints which will apply. The LASD task is typical of the many military tasks which require weapons effects to be included in training. The common major constraints are cost, safety and resource availability. Plainly, live rounds cannot be fired at manned targets – you wouldn't get many volunteers to helm a fast attack craft being fired at by selection of GPMGs, miniguns and 20 mm cannon! Similarly, there would be little appetite for firing machine guns and RPGs at one of Her Majesty's operational warships. The cost of live rounds precludes extensive live firing, and range availability is also a factor. Consequently, simulation will be required for weapons effects. Costs of providing swarms of 20 or more FIACs are also high.

Training Overlay Analysis

Training overlay analysis considers both training methods and instructor roles.

Training Methods

Perhaps the first consideration is whether LASD training should be provided to formed teams from specific ships or as generic professional training. Generic training would be problematic as it would required appropriate numbers of people in every role from CO downwards to be available at the same time. Therefore, training for specific ships crews would seem to be the only viable option. The next consideration is whether the whole team needs to be trained at once or whether some sub-team training would be advantageous. Given that tactical decision making requires not only initial scenarios to be presented but also the efficacy of tactical decisions to be established by seeing their effects and providing the opportunity for subsequent revision of tactics as required, whole team training in a suitable environment would seem to be the most appropriate option. Classroom teaching of key aspects such as rules of engagement and tactics would also seem appropriate.

Instructional Roles

The main instructional roles for the practical exercises would be setting up, monitoring and controlling the environment in order to deliver appropriate scenarios which are reactive to team actions, and briefing, monitoring and debriefing team performance. Significantly, these would require the facility to track vessel movements, both of the ship and the many FIACs in a swarm attack, as well as weapons effects both from and against the ship. The facility to monitor communications channels would also be required. Sufficient numbers of instructors would be required to monitor all the individuals in each of the sub-teams.

Training Environment Analysis

Training Environment Specification. Given the constraints related to live firing and weapons effects, at least two training environments will be required, one to support live firing and one to support full weapons effects from both FIACs to the ship and from the ship to the FIACs.

Arguably the whole of the analysis document can be treated as a specification for the training environments, since each section captures pertinent information. However, specific further information is required for each specific environment that is identified. Notably, fidelity requirements must be established for each element that is required in the environment. In the description of the task environment of the Team Training Model specific categories of environment elements were identified (physical environment, systems, manned systems, humans and resources). For each type of element we have developed a fidelity template which can be used to capture fidelity requirements. The template is divided into physical and functional fidelity requirements. There is also a need to capture training overlay requirements for each element. These can be combined with the fidelity requirements to form a specification table. An example of a specification table for a manned systems is shown in Table 6.

Training Environment Option Evaluation

It is probable that there will be a number of alternative technical solutions for the provision of each environment, particularly where simulation is an option. The specification table format can easily be extended to capture evaluation data as shown by the right-hand columns in Table 6. We suggest that a traffic light coding system provides an easy visual overview of the suitability of different options (red, non-compliant, amber – partially compliant, green – compliant) which can be backed up with written comments to support amber or red codings. It would also be necessary to provide a separate overall description of each option which would outline the option and detail how the instructor roles would be instantiated and the overall architecture of the system.

Table 6 Example of a Manned System Specification and Evaluation Table

FIAC Specification		**Option Evaluation**		
Physical Fidelity Requirements		**Options**		
Attribute	**Description**	**A**	**B**	**Comments**
Appearance	FIACs should have appearances representative of the current threat. It should be possible to identify the lead boa of a formation			
Sound	FIACs should emit representative engine sounds and weapons sounds			
Numbers	FIACs should be available in representative numbers for a swarm attack as indicated by current intelligence data.			
Functional Fidelity Requirements				
Attribute	**Description**			.
Armament	FIACS should be armed with representative weapons			
Behaviour	FIAC attack tactics should be consistent with current threat profiles, including swarm attacks. They should also be able to make a range of appropriate responses to escalation of force measures and to hits and near misses from ships weapons and ship manoeuvre. .			
Performance	FIAC speeds and rates of turn should be consistent with the assessed threat			
Interaction information requirements	FIACS should receive an indication of fall of shot including when by fire from the ship			
Knowledge and skills	The FIAC drivers should know what behaviours FIACs should exhibit when attacking and when in receipt of fire			
Appearance to other system elements	FIACS should have a representative radar cross section and appear at a representative size in visual displays			
Training Overlay Requirements				
Tracking	It should be possible to record the track of each FIAC for AAR purposes			
Weapons effects	It should be possible to record the effects of hits from ships weapons for AAR purposes.			
Control	It should be possible to direct the track and actions of the FIAC whilst an attack is in progress			

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SUMMARY

This paper has demonstrated how the Team Training Model can be used to guide TCTNA using the TNA triangle model. The systematic analysis of both the task and its context, and the training overlay requirements facilitates the comprehensive definition of the requirements for the training environment. We have also demonstrated how a range of diagrammatic representations and tables can be used facilitate these analyses and provide concise but full description of a training requirement and specifications for training environments. The representation selected are designed to be both efficient for recording appropriate data, but also easily readable by SMEs so that they can provide a stimulus for data capture and for review of the analysis.

A significant feature of the approach is that having identified which elements need to be present in the training environment, they are specified not only in terms of their fidelity, but also by how it should be possible to configure, control and capture data from them in order to be able to deliver the scenario requirements and provide feedback in after action review.

ONGOING RESEARCH

Research around the method continues and includes testing the method at different levels of complexity, evaluating its applicability to Joint Training and exploring its utility for analysis both in capability audit and early in the acquisition cycle.

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