

An Innovative Approach to Weapon Performance Assessment

Dominic Cernis and Graham Halsall

Defence Science and Technology Laboratory (Dstl)
Air and Weapons Systems Department
A2 Building, Ively Road
Farnborough, GU14 0LX
England

dccernis@dstl.gov.uk / grhalsall@dstl.gov.uk

ABSTRACT

Until recently, software models for weapon system assessment were dedicated to particular systems and were very difficult to modify to meet changing requirements. Therefore more flexible modelling and simulation tools were required to ensure a coherent and efficient capability to rapidly assess the performance of increasingly diverse and complex modern weapon systems. The Unified Weapon Model (UWM) is a novel solution to this problem and this approach addresses all aspects within the subject of this NMSG conference.

The UWM uses the latest software engineering techniques to develop an integrated framework that can exploit existing software models in a “plug and play” fashion. All aspects of the engagement between the weapon and its target are included from launch to consequence. Furthermore, the UWM has facilitated a repository of flexible and expandable software models that encompass legacy assessment models. The creation of this modelling environment has also acted as a catalyst for the innovative design and development of future systems and sub-systems.

This paper outlines the approach taken and the benefits achieved in developing a UWM capability. It also shows how the UWM meets the objectives outlined in the MOD Defence Technology Strategy (DTS) for a national capability which exploits collaboration between MOD, Industry and our International partners.

1.0 INTRODUCTION

The aim of the UWM initiative is to provide an integrated set of flexible and expandable software models that represent the various aspects of the ‘Launch-to-Effect’ timeline for a Guided Weapon operating in the land, sea and air environments. It is principally a generic, flexible, physics based framework supporting component models of varying fidelity and functionality, that can be configured as required. The starting point for the UWM consisted of a range of legacy tools, many of which have elements that are suitable for re-use. These have been brought together within new modelling and simulation environments that comply with a well defined interface specification and provide a high degree of flexibility.

The UWM capability is a set of interface standards, simulation frameworks and model development methodologies intended to facilitate model sharing and reduce model development and integration times. It is important to stress that the UWM is NOT a model, but a way of implementing and developing models. The development of the UWM draws from experiences in model development, model integration and model sharing in simulation frameworks.

The UWM is a significant feature within the UK MOD Defence Technology Strategy (DTS) document and directly addresses the requirement to ‘develop shared models and test environments to maximise the options for Through Life Capability Management and reduce costs’. The UWM is being created in conjunction with UK Industry and with international partners to share a common engineering model framework for unified weapon modelling. This collaboration will allow a coherent “cradle to grave” modelling and simulation toolset, used consistently by stakeholders across MOD, industry and academia.

1.1 Background

The UWM initiative consists of four main development activities:

- **Simulation environment** – The simulation environment provides a global, spatial and temporal framework in which the weapon(s) and target(s) component models can interact and exchange information. A generic component based simulation architecture called SimFramework5, created by the Defence Science and Technology Organisation (DSTO) in Australia, is used within the UWM.
- **Weapon system fly-out** – This is achieved with a generic 6 degree-of-freedom weapon fly-out model called SALEM. The model has been designed using the principles of flexibility and code re-use and utilises an internationally recognised weapon interface specification known as MIST, which was generated through The Technical Cooperation Panel (TTCP). Development of SALEM was conducted jointly by Dstl and DSTO.
- **Sensors (Fuzing)** – In order to develop a launch to consequence capability it was necessary to include weapon fuzing, this element of the UWM programme concentrated on the development of a MIST like interface specification for fuzes.
- **Weapon/Target Interaction (WTI)** – This area of work addresses the unification of the vulnerability and lethality modelling capability currently used within Dstl, namely the air target model; INTAVAL and the mobile/re-locatable land target model; MAVKILL. The future growth path for the WTI encompasses the fixed land target model; PALETTE, the sub-surface model; SUBKILL and the above water model; SURVIVE. Incorporation of the functionality of these three models is, however, outside the scope of the current work programme and is subject to further programmes.

1.2 Uses of the UWM

The primary use of the UWM within Dstl is the development of modelling and simulation tools and applications to, for example:

- Undertake weapon system concept generation / technology assessments;
- Determine the optimal use of a munition;
- Support Operation Analysis (OA) activities;
- Provide/Support procurement advice;
- Address Urgent Operational Requirements (UOR);
- Support Hardware in the Loop (HWIL) based studies;
- Integrate with Man-in-the-Loop (MIL) Simulators.

Note: this is not an exhaustive list, and the application of the UWM changes depending on the type of studies being undertaken.

2.0 REQUIREMENTS OF THE UWM

2.1 Overview

The UWM addresses the weaknesses that are evident and growing in UK MOD's ability to conceive and assess future and existing weapon and target systems.

The aim of the UWM is to provide a unified and truly tri-service 'Launch-to-Effect' modelling capability that encompasses the current and future requirements of the, land, sea and air, target vulnerability and weapon lethality assessment communities. The construction of such a capability required the software to be fully expandable and as much as is currently possible, interchangeable with industry and other international partner's models.

In short, the UWM programme required extensive discussions and interactions between technical teams involved in all areas of weapon system modelling e.g. weapon system fly-out, fuzing, vulnerability/lethality and any other consequence modelling within the three operating environments. The precise definition of the UWM includes code developers (within Dstl, industry and other international Government departments) and ultimate users of the tools and their output.

2.2 UWM - an integrated tool and a set of standalone tools

One of the aims of the UWM was to generate an integrated environment in which the various aspects of weapon system fly-out, fuzing and weapon target interactions (V/L) can interact.

Each aspect of the UWM is represented by one or more alternative software components. The purpose of allowing alternative pieces of software within a specific class of component is intended to allow flexibility (for future enhancements) and customisation. For example, fuzing components could be developed to represent the different types of fuzes that exist in weapon systems.

However there are many occasions where the users will want to focus on a limited area of the engagement and investigate some of the effects:

- In great detail;
- Over a large number of engagements;
- Where detailed data required to represent all aspects of the engagement (i.e. fly-out and/or fuzing) is not available.

In order to facilitate such circumstances each of the core models are able to operate as a standalone tool instead of having to be part of the integrated UWM environment.

2.3 Modular Approach to the UWM

The UWM consists of three activities and the 'glue' which will allow them to interact:

- Weapon System Fly-out (including guidance, propulsion, sensors, aerodynamics and actuation);
- Fuzing;
- Weapon target interactions (including damage).

Each of these components exchange data via a software framework (i.e. the 'glue') named the UWM simulation environment, which also defines the format of the data sets that will be exchanged.

By precisely defining the data interfaces for each UWM component it is possible to provide alternative solutions (possibly at different levels of detail or classification). Thus weapons specific components could be created (possibly by industry) that would operate with the rest of UWM.

3.0 DEVELOPMENT OVERVIEW

3.1 Introduction

Traditionally, Modelling and Simulation (M&S) of weapon systems has been carried out such that the existing tools and resources dictated the way particular weapons analysis problems were solved. Complexity of scenarios and fidelity of models were, to a large extent, fixed at the beginning of a project due to the architecture and procedural computing languages used to write the tools and analysis methods. The weapon models were typically closely coupled to the environment they ran in and the opportunity to reuse existing models was limited.

Component based modelling however, aims to have all parts of the simulation and models as removable ‘blocks’ such that a scenario can be built up from only the components that are needed. Component based modelling also seeks to reuse as many of these elements as possible between different areas of the model. This is prudent in a model where many of the common elements are interchangeable such as data logging and visualisation. The UWM is based on this type of component architecture.

Figure 1 and the following sections describe the process, environment and approach that have been adopted to create the UWM:

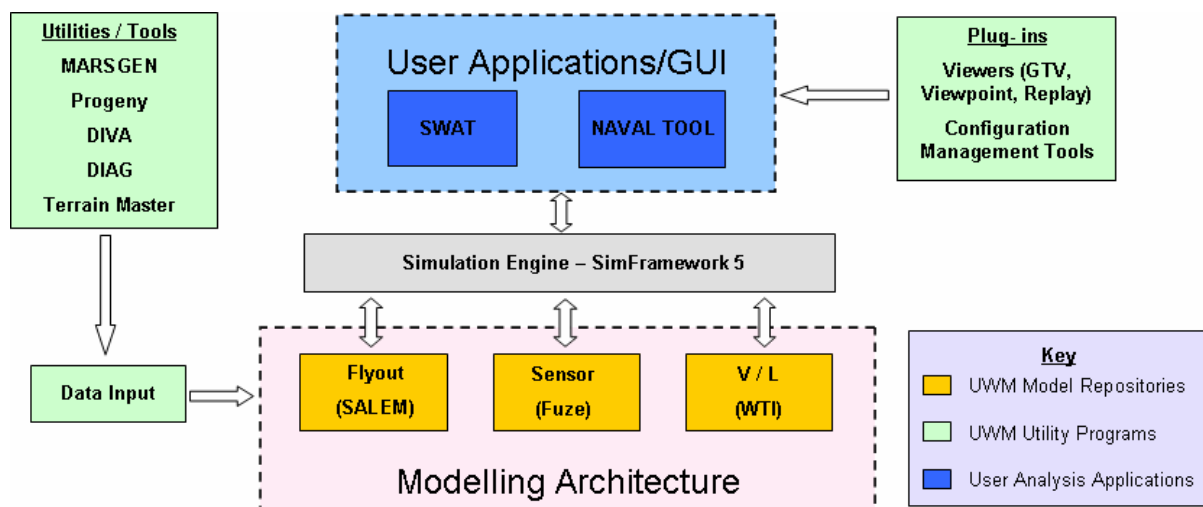


Figure 1: UWM functional diagram

3.2 Approach

3.2.1 Underlying Principles and Philosophy

The implementation of a component based model in software requires the definition of an interface between that model and the simulation architecture that integrates its execution with the other components of the simulation. However it is impossible to define one complete interface specification that is valid for implementations of all model types, for all simulation architectures and programming languages.

The fundamental principle is that models should have interfaces that tell a user/developer/reader exactly what the model needs, and how to make it run. In order to build component model implementations that are portable there must be some specification of the software aspects of component model interfaces. For models written in different languages to be portable to different simulation architectures, a set of “minimum criteria for a full interface specification” needs to be defined. This ‘minimum criteria’ is called the specification-blueprint and any language-specific modelling architecture specifications are derived from this specification-blueprint, for example MIST.

3.2.1.1 Muniton Interface Specification for TTCP (MIST) [1]

The MIST specification has been developed through TTCP and captures the accumulated knowledge and expertise from each participating nation, i.e. UK, US, Canada and Australia. Its aim is to “Improve modelling of real systems, more quickly, leading to better advice to customers with less risk”. The MIST specification is specific to the Weapon System Flyout however the philosophy has been applied throughout the UWM. Other TTCP technical areas are currently drafting MIST-like specifications for the fuzing and WTI.

The MIST specification is a statement of how reuse, interoperability and commonality are likely to happen in practice. The specification reflects the conclusion that it is unrealistic to agree on a single common modelling architecture since each nation has its own methodologies, resource libraries, frameworks and policies. Future collaboration environments are more likely to be composites with higher level agreements on interfaces, guidelines and best practices. MIST is the result of negotiating an acceptable level of commonality to allow efficient collaboration. In summary:

- **MIST improves joint and coalition interoperability.** The generic conceptual weapon model allows the sharing of model development time and cost between joint and coalition organisations. It also allows sharing of weapon performance information in the intelligence and procurement communities. Moreover, it can contribute to joint and coalition capability development such as improved precision weapons, integrating the best sub-systems from each nation, new multi-purpose weapon concepts, network-enabled weapon tactics, doctrines or training.
- **MIST improves the reusability of weapon models,** since model interfaces are well defined, documented and independent of any simulation architecture. MIST also improves model availability through the compilation of MIST-compliant assets and the sharing of resource repositories between nations, organisations and teams.
- **MIST improves the extensive usage of M&S** throughout the capability life cycle in a seamless fashion to reduce time, costs and risks. Models developed according to the specified interfaces are applicable to support concept development and experimentation, acquisition, rehearsal, training and upgrade. The specification can also be used as a significant part of the requirements for weapon model acquisition from the industry.
- **MIST improves the quality of weapon models** through the use of robust interfaces between munition model components (see Figure 2) and through multi-user verification and validation. An example of these interface names can be seen in Table 1 below. These names are built up from certain parts to which conventions apply related to system, quantity, type and co-ordinate system. For example, the state of the launcher in Earth axis becomes LchStateE.

Table 1: Example MIST naming convention for the Dynamics module

Name	Type	Units	Description
LchStateE	DynamicState	SI	Pos, Vel, Acc, Ang Vel(B), DCM of Launcher, Earth coordinate system.
BodyForceB	Vector3	N	Total Force acting on body at CG, Body coordinate system.
BodyMomentB	Vector3	N.m	Total Moment acting on body at CG, Body coordinate system.
BodyMass	double	kg	Current total mass of Body.
BodyMoIB	Matrix(3x3)	Kg.m ²	Moment of Inertia matrix of Body, at the CG.
LaunchTriggerCmd	int	event	Commanded trigger of launch, increment-from-zero triggered.

- **MIST approach has been leveraged to other TTCP domains** to develop similar advanced modelling and simulation capabilities, for example Terminal Effects, Seekers and Fuzing and Fuzing and Network Enabled Warfare.

The MIST philosophy of specifications, rules and guidelines lie at the heart of the UWM.

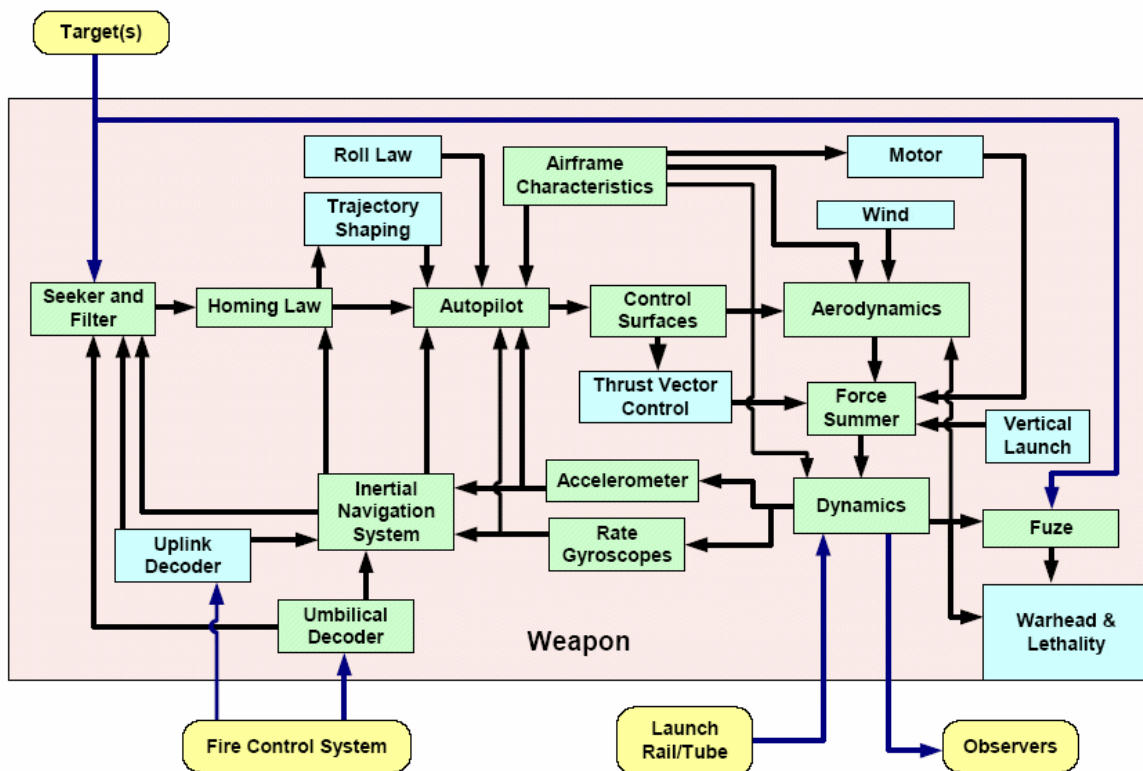


Figure 2: Baseline MIST Compatible Weapon Components

3.2.1.2 Model Development Process

Following on from the effort undertaken with MIST a well defined process is now adhered to for all model development, as shown in Figure 3. Before any development begins a model is defined by producing the Function and Signal Specification (FaSS). Separate documentation is also produced defining the mathematical equations to be used in the model. These are then used in the implementation of the model following the MIST philosophy and rules. Under the UWM this would lead to an architecture independent model which can then be adapted if necessary to be used with any other Simulation Engine by using a technique to map the inputs/outputs and then wrap the model to be accepted by the receiving architecture.

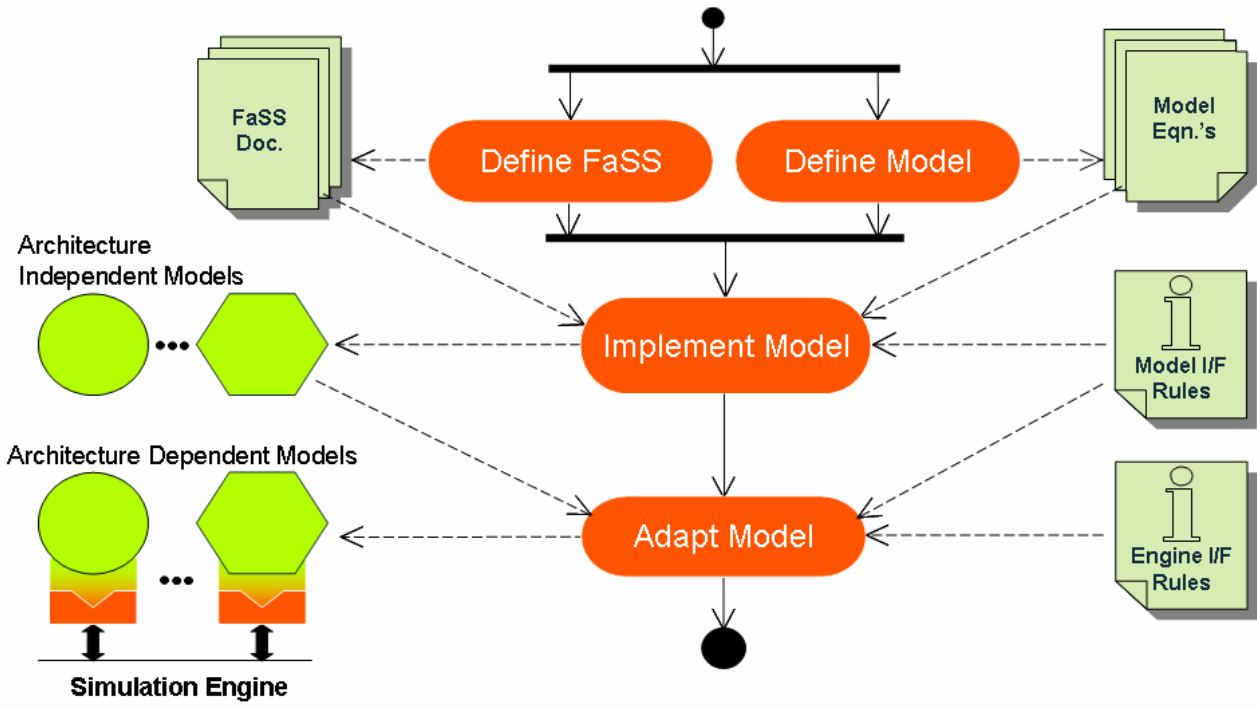


Figure 3: Simulation Development Process

3.2.2 Current UWM Compatible Models

3.2.2.1 SALEM

SALEM is a generic and highly flexible 6 degree of freedom weapon system flyout simulation tool. SALEM has been designed using the principles of flexibility and code reuse and utilises an internationally recognised weapon interface specification known as MIST. SALEM is an evolution of the Hittile Air Defence Engagement Simulation (HADES) missile engagement model and has been created jointly by Dstl and DSTO.

SALEM can represent almost any weapon (usually a missile) system engagement from launch to interception of the target. It does not consider warhead effects or fuzing, these are handled by different UWM compatible models.

SALEM contains detailed representations of the individual subsystem components of a weapon and the surrounding environment; from actuators and autopilots to aerodynamics and gusting wind effects. It also incorporates a complex target aircraft manoeuvre program and is currently receiving a suite of upgraded modules, including Imaging Infra Red (IIR) seeker models and IR scene generators such as CAMEOSIM (Camouflage Electro Optic Simulation).

SALEM is not a missile model. A SALEM model is created from a selection of weapon sub-system representations (all based on the MIST specification) and is configured using a set of data files to describe a specific missile. These configuration files can either be written from scratch or selected from a growing library of generic systems. SALEM cannot run itself, to run it needs a top level analysis application such as SWAT, see section 3.2.2.4.

3.2.2.2 *Fuze*

The Fuze model will be used to perform the high fidelity passive IR, active IR and RF fuze trigger point calculations. Low fidelity geometric fuze modelling, first point seen and closest point of approach are also available thus providing a mix of modelling fidelities.

The fuze modelling capability has reused the functions/technologies available within the legacy suite of codes including PIRATES (Predictor for Infra-red and Radar Air Target Engagement Simulations) and WISADS (Warhead Interactions And Simulation Display Suite). All fuze models can be used as standalone applications or as part of the UWM.

The current capability covers a broad range of fuze technologies largely based on the air-to-air weapon environment. The scope of the fuze modelling activity will need to be broadened to other domains to bring it in line with the tri-service aspiration.

3.2.2.3 *WTI*

The WTI is the latest generation of vulnerability and lethality models. The modelling capability has been extended to enable more complex interactions to be handled whilst allowing reuse of existing UK and international models.

The WTI supports weapon effectiveness/performance analysis (including subsystem analysis) conducted at engagement level using multiple or single weapons. It uses various measures of effectiveness to assess performance. The WTI also supports target vulnerability/survivability analysis again conducted at the engagement level examining the ability of a single target to survive single and multiple weapon engagements. The subcomponents have all been based on a 'MIST-like' specification developed under TTCP.

The WTI currently has the capability to analyse the effect of traditional weapon/target types and physical phenomena in a flexible and more integrated fashion.

Further enhancement of the WTI to cover other environments, specifically those included within the current functionality of PALETTE, SUBKILL and SURVIVE will be the subject of potential follow on work. This would provide wider links across MOD and increase the potential for exploitation of work in areas not traditionally supported.

3.2.2.3 *User Analysis Application*

The launch to consequence suite of models requires a scenario manager to execute them. The current scenario manager called SWAT (Standard Weapon Analysis Tool) allows the user to add various elements to a scenario by selecting them from a 'toolbox' of components. The toolbox contains the SALEM flyout model, the multi functional UWM fuze model and the WTI; it also contains generic reusable models that can be used as targets, launchers, terrain etc.

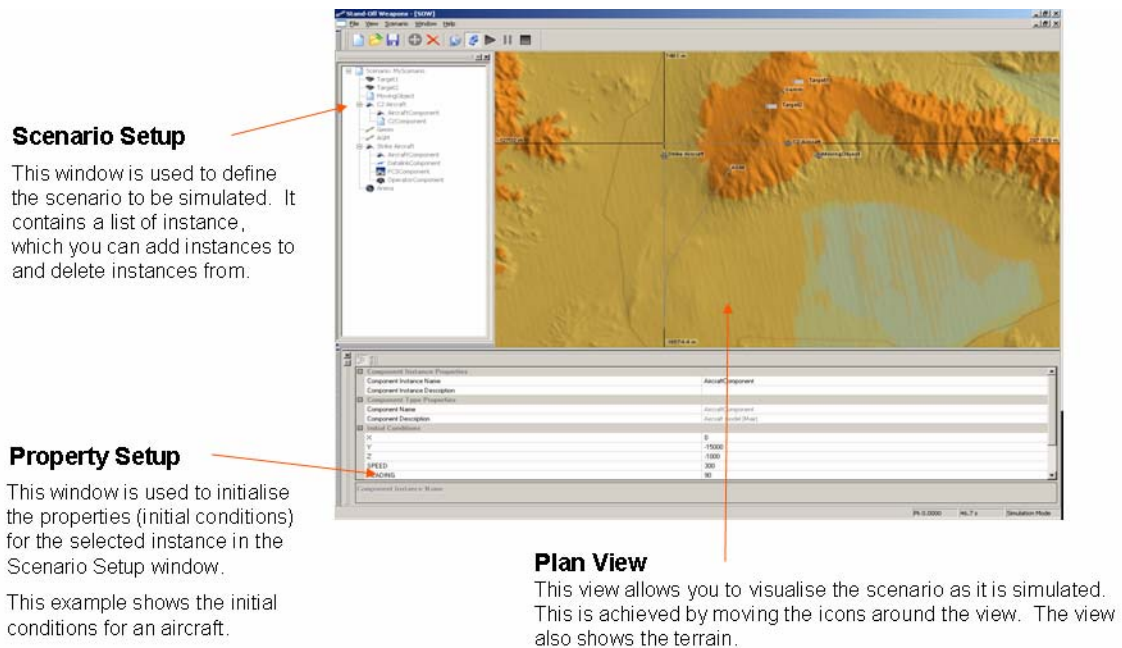


Figure 4: Example SWAT Screenshot

The toolbox provides for the use of lower fidelity missile/lethality models that can be used if a high fidelity model is not required. Due to the nature of this component based toolbox any of the models (including the key models specified earlier) can be used multiple times in the same scenario and even against each other in a single engagement. The toolbox is expandable and as new models are configured to work within the UWM framework so the capability of the UWM will expand.

Since SWAT is only the scenario generator, each key model is currently set up using an external program called Mogwai. This collates all the various data tables and attributes associated with each model into a visual tree structure based on XML that the user can interact with to populate attribute files. Plans are underway to add a further plug-in layer into SWAT that will allow users to set up each key model. This will reuse many of the elements of Mogwai but will incorporate specific elements so that the users of the models are not restrained to just data tables.

3.2.2.5 UWM Simulation Engine

The simulation engine adopted for UWM is called SimFramework 5 and is provided by the developers, DSTO. A simulation engine can be thought of as the glue that binds the models together and is invisible to the user but provides services for communication between models. It is a generic kernel that is customised through layers to perform model executions and is therefore infinitely expandable and thus can provide for the modelling of all types of models and simulation.

Other models may become UWM compatible by writing custom wrappers that allow SimFramework 5 to execute these external models; the framework then handles the interactions in the same way as it would for a specifically written model. The adoption of this simulation engine as a solution does not necessarily preclude the use of other simulation engines executing the models, for example SALEM can be run from within the Matlab Simulink environment if required.

3.2.2.6 *Modelling Architecture Definition*

A modelling architecture provides a structure for models – it defines a manner in which they behave and communicate.

MARS is an implementation of the modelling architecture specified in MIST and hence itself is a modelling architecture. It was created within the Weapons Systems Division, DSTO.

To facilitate the implementation and use of these standard interfaces and architectures, various tools and auto code generators have been developed.

3.2.2.7 *MARSGen*

The utility MarsGen has been used to define and record the interfaces for the UWM component models, generate template C++ classes, create design documentation and generate SimFramework 5 wrappers for the models. This tool automates these processes, making it easy for developers to modify and create new models and document/integrate them into a simulation environment.

3.2.2.8 *Verification and Validation*

Due to its flexibility the UWM and its component based models pose a challenge with regards to configuration management and verification and validation. Work is underway to firstly develop and implement a strategy to overcome these issues, and secondly to create a Verification and Validation toolbox which could be applied to the various UWM compatible models and includes:

- Definition of a process for the configuration management of modelling components/systems/tools;
- Definition of a Verification and Validation process to cover new and legacy component models;
- Identify Verification and Validation test metrics;
- The creation of a Verification and Validation toolbox for use with the UWM.

4.0 CONCLUSION

The most powerful aspects of the UWM philosophy is not the concept of a super model, but rather the creation of an underlying framework and the use of interface standards to enable model and tool reuse with a minimum of overheads.

The UWM has encouraged developers and users to adopt model sharing, tool sharing and general collaboration with industry, other Dstl departments and with our international partners.

Within UK MOD the UWM underpins weapon performance assessment and research conducted across the Land, Sea and Air environments. Future weapon system related research within the Equipment Capability areas, e.g. Theatre Airspace (TA), Deep Target Attack (DTA), Ground Manoeuvre (GM), Above Water Effectors (AWE), Under Water Engagements (UWE) will be supported, addressing many of the issues outlined in the Defence Technology Strategy (DTS). In addition, the UWM provides support to DE&S (Defence Equipment and Support) and the warfare centres regarding the performance of blue weapons against red targets and the vulnerabilities of blue platforms to attack by red/blue weapons.

4.1 Further Development

Further work is currently underway to look into developing component models to enhance SALEM and SWAT's maritime capability. The area identified for enhancement will be the Fire Control System (FCS) which is currently under developed as SALEM has traditionally been an air to air model (which involved minimal FCS). Maritime engagements will rely heavily on pre-launch and track formation, so it is important that these aspects are addressed should we wish to adequately model the naval environment.

5.0 REFERENCES

- [1] The Technical Co-operation Program, Subgroup WPN, Technical Panel 7 (May 2006). *MIST Interface Specification Version 1.0*, TR-WPN-7/1-2006.
- [2] Halsall G.R., Cork M.S., Cernis D.C. (August 2007). *Unified Weapon Modelling (UWM) Final Report*, DSTL/CR26126 v1.0.

6.0 ACKNOWLEDGEMENTS

The UWM has been developed by Dstl Air & Weapons Systems Department in collaboration with our international partners at DSTO Weapon Systems Division, and UK industry through the Guided Weapons (GW) Tower of Excellence. The collaborative development is sponsored by:

- Weapons Platforms & Effectors (WPE);
- Directorate of Analysis Experimentation & Simulation (DAES);
- Directorate of Equipment Capability (Theatre Airspace) DEC(TA).

The UK industry development includes the following companies:

- LMUK INSYS, MBDA, QinetiQ, Atkins Defence, Cardinal Consultants, Thales.

7.0 GLOSSARY OF TERMS

CAMEOSIM	MOD model used for Infra RED scene generation
DIAG	UWM software used to generate data logging. Provided by DSTO
DIVA	UWM software used to generate visualisation. Provided by DSTO
GTV	UWM software tool for viewing data logs from the UWM and real telemetry data. Provided by DSTO
HADES	Legacy Dstl 6 Degree of Freedom Flyout model. Code now reused in SALEM
INTAVAL	Legacy Dstl model for the calculation of aircraft vulnerability
MARSGen	UWM software tool used to auto generate MIST compliant code templates and documentation. Provided by DSTO
MAVKILL	Legacy Dstl model for the calculation of land vehicle vulnerability
Mogwai	UWM software tool for setting up data files through the UWM. Provided by DSTO
PALETTE	Current Dstl model for the calculation of fixed land target vulnerability
Progeny	UWM software tool used to auto generate consistent Visual Studio workspaces. Provided by DSTO
Replay	UWM software tool to show basic visualisation of a SALEM engagement. Provided by DSTO
SALEM	Current Dstl 6 Degree of Freedom model that forms the weapon system flyout section of the UWM
SimFramework 5	UWM software tool that forms the underlying Simulation Engine. Provided by DSTO
SUBKILL	Current Dstl model for the calculation of below water vulnerability
SURVIVE	Current MOD above water vulnerability model
SWAT	Scenario generator model used currently to demonstrate the UWM
Terrain Master	UWM software tool used to convert standard DTED terrain data so it can be used in SWAT. Provided by DSTO
Viewpoint	UWM software tool used to visualise WTI events and SALEM engagements elements of which are reused in SWAT. Provided by DSTO
WTI	Current Dstl model that forms the lethality/vulnerability section of the UWM incorporating legacy code from previous Dstl models