The Advanced Air Defence Simulator for the Australian Army

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Abstract. The Advanced Air Defence Simulator (AADS) constructed in South Australia during 2004 provides the Australian Army with a collective training capability for Ground Based Air Defence (GBAD) Detachments. The Detachment enters the AADS, takes post at a realistic facsimile of a Short Range Air Defence (SHORAD) Missile Weapon System and is immersed into the simulated training environment, projected on a 12.2m diameter dome. Upon completing the tactical scenario, which may take minutes or hours, the Detachment moves to the debriefing room, where the full complement of audio and visual recordings, computer generated replays, accuracy scoring, event and action logs are available.

As background to this paper, the previous training assets for GBAD detachments are outlined so that the capability gap (pre AADS) may be appreciated. A description of the AADS is then provided, briefly detailing functionality and characteristics. It will become evident that the most significant development challenge was the integration of two simulators to form a collective trainer. Much consideration is given to the 3D graphics techniques used to ensure that aircraft, missiles, terrain, weather etc would appear correlated and without delay on all display devices: the dome, internal weapon site, the hand-held binoculars, the Target Data Receiver and the debrief sub-system.

Further to the acceptance of the graphics techniques is the agreement between the Project Office Teams (Government and Contractor) to adopt a unique development approach, justified by the short period of development (less than 20 months) and motivated by the desire for the best possible solution. Having presented technical challenges, unique solutions and then the results, this paper is a testimony to the success of adaptive graphics techniques and an interactive development approach. Visions for likely enhancements are briefly outlined.

1. GBAD SKILLS, DRILLS AND C3 TRAINING

Many SHORAD systems can be deployed in tens of seconds. A skilled soldier can 'maintain track' on a fast moving target while the missile takes ten seconds of flight and then the detachment is ready to engage another target in less than ten seconds. Every performance focused training consideration for an effective GBAD detachment is based on destroying or deterring the incoming platform before it completes its mission. Performance is, of course, improved with practice. This is why GBAD soldiers in the Australian Army spend many days deploying the SAAB Bofors RBS 70 MANPAD from trucks, helicopters, armoured vehicles and their own backs. Many days are also spent on simulators keeping the 'cross hairs' on the target.

Simulation in its many forms has been used for decades to teach, improve and test the drills and skills of Australia's GBAD soldiers. From a cement-filled replica of the weapon, which saves damage to the expensive authentic item, to the visual aircraft recognition software used in the classroom.

Confident in the drills and skills of his detachment, during the heat of the battle the Commander is attentive to the orders promulgated through his radio ear piece and the symbols appearing on the visual display of his Target Data Receiver (TDR). Both are being fed live and in real-time from the Command Post.

So back in the barracks, while a Gunner is 'tracker training' on the 'green dot' simulator, the Detachment Commander is on the LAN with a PC replicating a TDR, and speakerphone replicating a radio. Scattered through the barracks are other participants in the same CPX (Command Post Exercise), monitored and assessed by a higher level Commander.

2. TACTICAL DECISION-MAKING TRAINING

With slick drills, a high level of skill, well-practised command, control and communication procedures, a GBAD detachment is ready for the culmination of its training on a field exercise. Many Army units come together, with support from the Air Force, to practice their trades with and against each other, in the final preparation for military operations.

Although field exercises are very effective, enormous logistic effort and funding is required to practise and assess a Detachment commander in tactical decision-making. Consider alone the cost of using real fighter jets to fly multiple sorties against the detachment, using various profiles to test the Detachment Commander's application of the Rules of Engagement (ROEs). It is also only by chance that the Detachment Commander is challenged in all aspects. For example, consider the influence of weather on the range of the weapon and radar.

There is no doubt that any missile system is capable of inflicting expensive, devastating and embarrassing loss if it is guided towards a friendly military or even worse, a civilian aircraft. Mandated procedures and C3 do prevent this from occurring, but the distraction and diversion from a potential target is difficult to replicate without considerably more resources.

In order to frequently conduct affordable collective training of the GBAD Detachment and tactical decision-making of the Commander, simulation is necessary.

3. THE ADVANCED AIR DEFENCE SIMULATOR (AADS)

In June 2003, Tenix Systems Pty Ltd entered a contract to deliver a simulator that would provide collective training and objective assessment of a GBAD detachment. The facility is now complete at the 16th Air Defence Regiment, Woodside Barracks, South Australia.

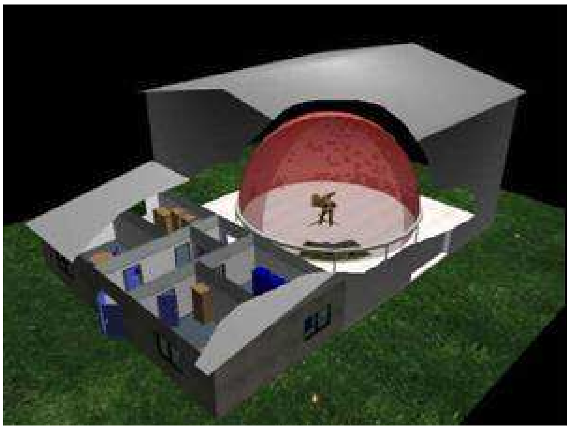

Figure 1: Depiction of the AADS

The AADS acquired under DMO Project Land 19 Phase 2B will enhance the operational effectiveness of in service RBS 70 equipped SHORAD batteries by providing an efficient training mechanism. The AADS: simulates multiple aerial targets; simulates weapon system missile flight; allows a full engagement sequence to be assessed; and recreates a simulated battlefield environment with noise, obscuration, weather and ambient light effects.

The capability obviously complements other collective training normally conducted in the field with real aircraft and live missile firings. But now the Australian Army can frequently exercise the Detachment Commander in C3 and tactical decision-making functions in a simulated environment.

3.1 Weapon Facsimile

At the centre of the simulator sits a SAAB Bofors facsimile of their RBS 70 weapon system. Originally designed by SAAB to operate as a stand-alone simulator, the facsimile is usually fitted with an external 14” LCD providing the coarse aiming view, which the operator would normally see through the open sight (or bore sight). When a target is acquired and centred through the open site, the operator then peers down into the monocular lens. Where the x7 magnification optics would normally be (inside the actual weapon system) is another LCD providing the x7 magnification view and the cross hairs, which must be centred on the target.

3.2 Advanced Moving Target Simulator

The external LCD has been removed from this RBS 70 facsimile and the coarse aiming view has become a 12.2m diameter dome. Above the weapon detachment is a column on which 27 projectors (Christie DS30W DLP) are mounted.

Also mounted on the column are the SoniStrips that provide and receive the sonic triangulation signal for the two sets of simulation binoculars held by the Tactical Commander and Air Sentry.

3D objects are positioned, in accordance with their scripted path and realistic performance parameters, by the Advance Moving Target Simulator (AMTS) (from AAI Corporation, USA). As well as providing a correlated and identical view to all visual devices, the AMTS was integrated (by Tenix) with the RBS 70 facsimile, so that operator inputs, such as missile guidance, can be appropriately handled.

An example series of events in the AADS during an AMTS and RBS 70 Facsimile scenario is:

- A target enters radar range (20km) and the TDR shows a symbol and alerts the Detachment Commander with a tone.
- The Detachment concentrates on the sector of the field of view (on the dome) that the TDR indicates, until one member visually detects the target and provides an indication to the others.
- Depending on the range, the binoculars and RBS 70 facsimile may then be used to commence identification.
- If ordered, the RBS 70 operator engages the target. The launch is heard on the surround sound system and a glimpse of the missile is seen on the dome as it accelerates to Mach 2.2. A wisp of smoke trail indicates the missile’s path, which is controlled by the operator.
- By script or on demand of the instructor, the target may perform an evasive manoeuvre to further challenge the operator. While the AMTS is realistically portraying the target’s movement, it is awaiting data from the RBS 70 facsimile on tracking accuracy and the final result.
- Hopefully (for the detachment under training) an explosion will occur, the aircraft will fall from view and the aircraft symbol will disappear from the TDR display.

3.3 Image Generators (IGs)

To appreciate the challenge of developing visuals for so many integrated and correlated devices, it is worth stating the types of IGs in the AADS.

The *Debrief IG* produces views such as the Situation Awareness Display (SAD) – which is a low fidelity ‘God’s eye view’ of the scene. Simple 3D models move through a low-resolution scene in real time, or in replay mode for instructional or debrief purposes. This view and other debriefing tools are projected onto a flat panel display in the debrief room, or the rear quadrant of the dome in the training room.

27 *Dome Projection* IGs (one per projector) are combined to provide the 270^{o} x 75^{o} image on the dome during training or during dome replay mode.

The *Target Data Receiver* (TDR) is the hand-held ruggedised terminal providing the radar view for the Detachment Commander. This field unit was provided as Government Furnished Materiel (GFM) to Tenix for interfacing to the AADS. The TDR is normally used in the field with the Portable Surveillance and Target Acquisition Radar (PSTAR) (from BAE Australia).

Two *Bino IGs* provide the images to the LCDs within the simulation binoculars. The image is provided on the internal LCDs in accordance with the bino position and pointing direction (6 degrees of freedom). The binos provide a x7 magnification view or x1 Night Vision Goggle (NVG) view.

Within the *Weapon Facsimile* is the LCD providing the view of the scene in accordance with the axis of elevation and azimuth of the weapon direction. With the exception of the x7 magnification the view must be precisely aligned and correlated so that the operator can acquire the target (on the dome) through the bore site and then peer directly down onto the narrow field of view (NFOV) on the LCD. For night scenarios the RBS 70 weapon facsimile IG must also simulate the Clip On Night Device (COND) by providing a simulation of an 8-12μm thermal image.

4. KEY CHALLENGE – VISUAL DEVELOPMENT

Creating terrain databases and entities for a single type of image generator (IG) is a common process but the complexities of completing the same task for multiple types of IGs have not been widely recognised. Integrating five different IGs from two international subcontractors was the key challenge for this project. The next part of the paper describes the technical approach taken to meet this challenge.

4.1 Technical Implementation

Site visits were planned for the Visuals Team to the sub-contractors during the development of databases for their respective IGs. Following the preliminary analysis on interoperability of the systems, the Visuals Team then examined each IG type to verify latency, and establish the methods used to import and convert source data and display the terrains and entities.

The most challenging IGs to visually integrate were the dome projection IGs and the weapon facsimile IG. Much consideration was given to the techniques available that would ensure aircraft and terrain would appear correlated.

It was also recognised that the characteristics of each IG merge to form an overall level of fidelity for the entire system. This became the key factor in the conversion of source data into terrains and entities. Hence a thorough understanding of these IGs was critical before acquiring source data for the entities and scenes.

The project team recognised that there would be a need to develop terrains and entities to suit each type of IG. Rapid development was planned to find the optimum level of fidelity and a multi-IG terrain optimisation process was created.

The terrain optimisation process started with the highest fidelity IGs, which were dome projection IGs, and created complementary highly detailed terrain. Then this terrain was converted into optimised versions for each of the other IGs. The terrain fidelity for each IG was then tested and documented. It was found that the Bino IGs had the same fidelity as the dome project IGs so there was no optimisation needed. The debrief IG did not need a high level of detail so all the trees were deleted to improve performance. The TDR only needed the terrain for "line of sight" calculations so the trees and textures were deleted to achieve a high fidelity of radar performance.

The weapon IG was found to be the IG most significantly impacted by the number of polygons in the terrain and a process of performance improvement was developed. The weapon IG had the advantage of having only a single viewpoint, that of the gunner. The other IGs needed the complete terrain model since they could depict a 'God's eye view'. This insight allowed a non-visible polygon culling approach to be developed just for the weapon IG, using intervisibility. All polygons visible from the gunner's viewpoint were saved. All others were deleted and the end results of this process can be seen in Figure 2. This solved the fidelity challenge for the terrains and represented the end of research and the start of production of all terrains and entities.

Figure 2: Non-visible polygon culling

Having established and tested the terrain optimisation process, the Visuals Team commenced the arduous task of creating nine databases, 20 background scenes, 50 airborne entities and 5 ground entities. 15 of these airborne entities were to have three variants each, bringing the total number of airborne entities to 80. In total, 105 objects needed to be converted to suit 5 types of IGs.

4.2 Evaluation of Implementation

To evaluate the effectiveness of the visuals in a training environment and the accuracy of the visuals as compared to a real world environment, we conducted "Database Working Groups" (DBWGs) concurrently with the rapid development.

Regular feedback on the product is essential to rapid development and implementation. If any visual output was not satisfactory, the Visuals Team needed to be made aware, before substantial rework was incurred. The DBWGs between the customer and the Visuals Team performed the evaluation and provided subsequent feedback to the visuals development and implementation.

Five DBWGs were convened over the course of the project. These activities constituted User Evaluation Testing (UET), and solicited feedback from members of the Commonwealth Project Team and invited subject matter experts.

5. RESULTS OF IMPLEMENTATION

The results present project findings that support successful multiple IG visuals development and successful technical CoA/contractor interaction. However, alongside these results, anecdotal evidence, including Database Working Group minutes, suggest that the subjective nature of visuals development was managed successfully over the course of the working groups. Although this conclusion is not empirically based it is believed that the successful outcome was due to the technical interaction, knowledge transfer and transparency of the process-based development.

5.1 DBWG #1

The focus of the first DBWG was to define common terminology and explain the proposed terrain and entity development process.

The entity requirements were presented at this working group. They were reviewed and an approach for modifying them was discussed.

The terrain development process was presented, demonstrating the ability to generate multiple 30km radius "background scenes" from 200 – 400km^2 terrain databases and database themes. Individual background scenes are generated from specific points on the terrain database. These specific points became the location of the RBS70 MANPAD. The two circles displayed in Figure 3 represent different background scenes generated from the same terrain database. The background scenes are then converted for use in the IGs. Using this approach, a large number of background scenes can be created from a single terrain database.

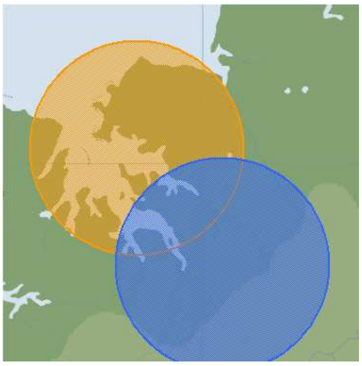

Figure 3: Background Scenes created from one terrain database

In addition, as each background scene is created a database theme is applied. A database theme is a collection of related surface textures and feature models that represent natural and man-made terrain characteristics within a typical geographical environment. For example, a tropical theme may contain palms and rainforest trees; a bushland theme may contain grass textures and eucalypts; and a desert theme may contain sand textures, rocks and scrub trees.

The customer wanted to choose the locations of the terrain databases for maximum training variation. The availability of terrain source data was identified as a possible constraint during the meeting and became part of the focus of the second iteration of the working groups.

5.2 DBWG #2

The focus of the second working group was to confirm source data on entities and select background scenes from terrain databases.

The entity list was reviewed, and reference images were used to identify the correct entities, eliminating any points of confusion. This finalised which entities would be provided. The next stage of discussions determined the correct ordnance layout for the entities, i.e. the placement of weapons or ancillaries on the correct location of the 3D airframe.

The source data available for the terrain databases was reviewed. There was a combination of high and low detail source data available for each of the 9 databases. The use and availability of Digital Terrain Elevation Data (DTED) and the overlaying vector map (VMap) level 2 (approx 1:50,000 detail) data was discussed. The background scenes were then chosen from the terrain databases.

The development of one background scene commenced immediately. This occurred whilst the customer sought and delivered the source data for the remaining scenes. The early development of a single scene allowed the Visual Team Leader to visit both sub contractors with a database for conversion into their IGs.

5.3 DBWG #3

The focus of the third working group was to visually demonstrate the progress of entity development and to effect knowledge transfer of the improvements in background scene creation after the sub-contractor visits.

The entity development process was visualised as shown in Figure 4. This depiction benefited the project in providing transparency so that any conflicting expectations could be resolved. The primary challenge for entity development was to combine the Dome IG and Weapon IG entity requirements to achieve a high-level of fidelity in both IGs.

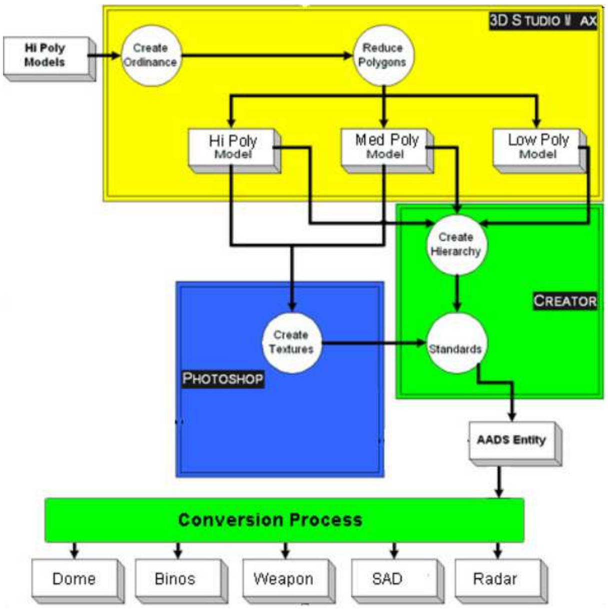

Figure 4: Entity creation process

Prior experience provided best practice, which was to produce one complete flight model, and then run it though a conversion process to output an entity for each IG. Developing the same model concurrently for each IG would have meant that changes would have to be made to each instance of the model, whereas the best practice approach allowed changes to be made to the base model and then optimised through the conversion process for each IG. The only handraulic activity was the creation of collision and proximity boxes around the entities and they only had to be recorded once for each entity. Destroyed, major damage, and minor damage boxes were created for collision and proximity detonation around the entities.

Figure 5 shows a high poly entity in the early stages of the production process. Figure 6 shows a low poly model almost ready for the conversion process. Figure 7 shows an entity in a scene. Each of the 80 entities was shown in at least one of these states.

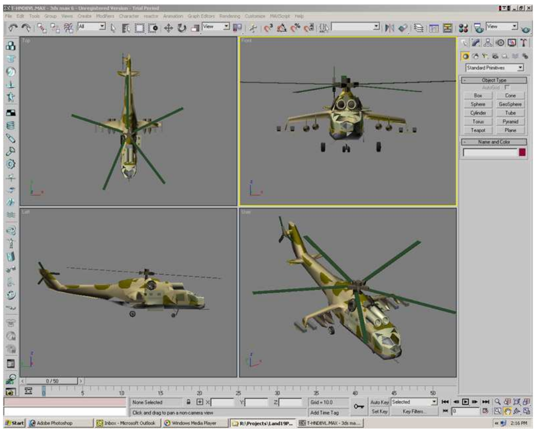

Figure 5: High Poly Model

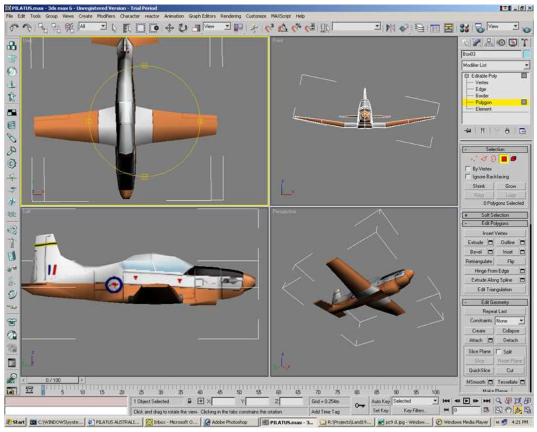

Figure 6: Low Poly Model

The decision to demonstrate a complete set of entities this early in the project was made to increase confidence and reduce risk. It was only possible to show entities at different states of development after the entity creation process was explained. Previous experience had demonstrated a loss of confidence when clients have been shown work in progress. Having a customer who understood the complete process eliminated this risk. Comments and discussion between the contractor and customer confirmed a common understanding and increased the confidence of both customer and contractor.

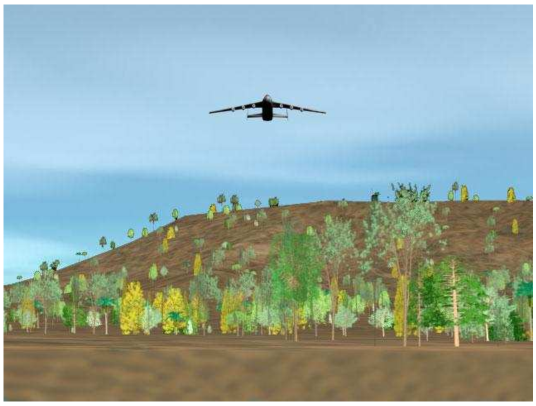

Figure 7: In Scene Model

5.4 DBWG #4

The focus of the fourth working group was to achieve confirmation of the "look and feel" of all of the entities, and to review the progress of terrain creation. This working group was critical to moving forward with the conversion process for the entities. Converting entities across to the different IG formats commenced as soon as we were satisfied that all of the entities looked correct.

Subject matter experts completed an aircraft identification test. Their results were over 90%. This outcome proved to be critical, and the approach should be factored into every subjective deliverable process where possible. Feedback from the test was solicited. The subject matter experts concentrated on correcting ordnance loads and suggesting slight colour changes. The corrections required were relatively minor; an outcome attributable to the high level of exposure the customer had to the entities in DBWG#3.

DBWG#2 had finalised the locations of the background scenes to be used in the terrain development process. The development of these background scenes was well underway. This working group exposed the customer to the "look and feel" of the terrains.

The fidelity levels of each of the IGs were demonstrated on the test-rig environment. Discussions on what the end result would look like and how that would meet expectations ensued. These discussions provided further direction and supported a results based final working group.

5.5 DBWG #5

The focus of the fifth working group was to achieve visual confirmation of terrain databases and background scene locations. The terrain databases were confirmed with a visual demonstration and correlation with military maps. Discussions on the derived fidelity ensued when differences between VMap data and topographical map data were first observed. This resulted in an increased understanding of the rapid development process, and the subsequent end product, by the customer. This understanding was further enhanced with the demonstration of background scenes and entities on the RBS 70 facsimile. DBWG #5 was also used for the conduct of introductory training and live firing on the AADS test rig to confirm the expectation of fidelity in terrains and entities.

5.6 Into the dome

Integration of the entities and terrains on-site was successful in terms of achieving customer expectations for the visuals and their level of fidelity. Providing transparent processes and a high level of technical interaction proved to be successful in decreasing the risk of subjectivity in the development of the visuals for this project.

6. CONCLUSION

The AADS is more than a visual feat. It provides the type of immersive simulation necessary to train GBAD Detachment Commanders in the art of rapid tactical decision making, the faultless application of ROEs and of course their ability to command and control their detachment while receiving commands and situational awareness information from the higher level Command Post.

The most significant development challenge was the integration of the RBS 70 facsimile from SAAB and the Advanced Moving Target Simulator from AAI. Not to mention the other visual devices used by the Detachment. The 3D graphics techniques used to ensure that aircraft, missiles, terrain, weather appear correlated and without delay on all display devices are now proven.

Key to the success of the rapid development process was the close working relationship between the customer and the contractor. The DBWGs were vehicles for the customer to gain an appreciation of the challenges and then provide constructive feedback on the results. They were also a vehicle for the contractor to gain timely feedback on the results so that development could be redirected and corrections made with minimal redundant effort and rework.

It is known that realistic and detailed requirements are essential for the production of visuals. This case study is a testimony to the fact that close and regular interaction, not bound by normal project management constraints, is essential for the rapid development of visuals for a complex environment.

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