

## **A Paradigm Shift in the Test and Evaluation of Terrain Databases**

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### **ABSTRACT**

The Synthetic Environment Core (SE Core) program is a primary provider of Terrain Databases (TDB) for the US Army's training and simulation systems. Through an open format, non-proprietary, image generator independent TDB generation process, SE Core produces terrain and models to link Live, Virtual, and Constructive domains into a common operating environment. The test and evaluation processes of these Terrain Databases for US Army virtual simulators have taken many forms over time. Until recently, this process has been disjointed and often far removed from the system level testing of the major database consumers. As a primary TDB provider for the US Army simulation and training, the SE Core program has taken steps to improve the testing process by developing the Major Evaluation of Geospatial Areas (MEGA) Review. By incorporating the test procedures of SE Core's primary virtual customers, the Close Combat Tactical Trainer (CCTT) and the Aviation Combined Arms Tactical Trainer (AVCATT), SE Core has developed an efficient test process that incorporates incremental system-level testing early on in the TDB test schedule. The new process also involves a series of set milestone review events designed to gather input from Subject Matter Experts (SMEs) and site representatives. To better understand the new process, this paper will first provide a brief historical background on test and evaluation of Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI) virtual TDBs followed by its evolution into the current MEGA Review process. Additionally, the paper will present lessons learned throughout the development of this process along with the cost, schedule and performance benefits realized.

### **ABOUT THE AUTHORS**

**Thomas Kehr** is the Government Integration and Test (I&T) Lead Engineer for the Synthetic Environment Core (SE Core) program at the US Army PEO STRI. Thomas is responsible for overseeing the day-to-day testing for SE Core terrain databases as well as managing the overarching database test schedule in both the virtual and constructive system laboratories. Thomas currently holds a Masters Degree in Electrical Engineering from the University of Central Florida and is currently pursuing his PhD in Modeling and Simulation there as well.

**Trey Godwin** is a Visual Systems Engineer for the for the Synthetic Environment Core (SE Core) program at the US Army PEO STRI. Trey is responsible for the execution of SE Core terrain database productions and is the advocate for aviation training programs, with an emphasis on the Longbow Crew Trainer (LCT) and the Aviation Combined Arms Tactical Trainer (AVCATT). Trey holds a Bachelor of Science in Geography and Environmental Science from Stetson University. Prior to joining the SE Core program, Trey accumulated nearly ten years of experience with industry partners developing virtual terrain databases.

**Ryan McIntire** serves as the contractor Integration & Test (I&T) Lead for the SE Core CVEM program. Ryan oversees all testing functions for the program including system level testing of virtual, constructive and gaming formats against database content & confederate requirements as well as the testing of all SE Core software tools against functional software requirements. Ryan holds a Bachelor of Science Degree in Computer Graphics Technology from Purdue University. Ryan has almost 15 years of experience in database content creation, systems integration and providing both technical and managerial expertise toward the development and delivery of visual simulation and training solutions.

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### INTRODUCTION

The process of Terrain Database (TDB) generation for the military's virtual and constructive simulation systems is not in itself a new idea; however the process can often be disjointed, confusing, and chaotic. There are often many moving parts to consider, including both hardware and software, as well as a large number of programmatic and system stakeholders with their own requirements and objectives. As a result, the true training objectives and requirements of the TDB can be lost in the convolution. Additionally, the testing and evaluation of the terrain database to verify requirements is often overlooked or underutilized as a secondary or tertiary process to the whole TDB generation process. As one of the largest providers of terrain databases to the United States Army, the Synthetic Environment Core (SE Core) program, under the Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI) has worked to develop a process to better streamline the test and evaluation of terrain databases by unifying all database stakeholders through a singular test process with several key milestone events that lead up to a culminating final acceptance test event. This paper will first provide a background on several test and evaluation processes from the past in order to illustrate the need for a greatly improved process.

Throughout this paper reference is made to the SE Core confederate system programs of record. Currently, SE Core provides TDB deliveries to over fourteen confederate program systems within the Live, Virtual, and Constructive simulation communities. These confederate program systems each require a separate unique format of the SE Core TDB. Due to the historical background of SE Core, the primary focus of this paper is on the virtual confederate programs, to include the Close Combat Tactical Trainer (CCTT) family of systems, the Aviation Combined Arms Tactical Trainer (AVCATT), and the Games for Training program. The paper does, however, cover the latest developments in the SE Core test and evaluation process for Constructive TDB formats, including the Warrior Simulation (WARSIM), One Semi-Automated Force (OneSAF), Joint Conflict and Tactical Simulation (JCATS), FIRESIM, and the remainder of the Live, Virtual, and Constructive Integrating Architecture (LVC-IA) Constructive confederate systems.

### BACKGROUND

The Integration and Test (I&T) process for both virtual and constructive TDBs has evolved significantly over time. This section will briefly highlight legacy approaches to TDB testing as well as discuss the early stages of SE Core TDB testing in an effort to illustrate the need for a paradigm shift for a more robust test and evaluation process.

#### Legacy Terrain Database Testing

Database development and testing prior to SE Core generally consisted of a collaborative effort between prime and subcontractors. Prime contractor responsibilities generally encompassed the integration of database products, software and fielding while the development of the various database products (visual database, SAF database) fell to the subcontractors. The involvement of multiple contractors developing their products at locations across the United States (and across the world) as well as dependencies on the products of other partners could only support a linear process as opposed to parallel development.

Product testing often focused on one aspect of the system at a time, occurring at the location of the developer. This approach called for multiple test events and travel; interim testing could only be conducted through frequent travel or when developers shared offices in the same location. As a result, user involvement was limited due to the frequent time required to travel and the multiple test events conducted.

Testing of one product at a time presented challenges as well. While the visual database product formed the foundation of the remaining correlated databases, testing was limited to what could be demonstrated on the Image Generator in a standalone environment. Negative impacts on products generated downstream or during integration would not be realized until a later date, resulting in rework and additional regression testing. If a solution could only be made fixing the visual database early in the process, all work and testing up to that point would not have to be conducted again until final acceptance was achieved.

### **Early SE Core Test Process**

The inception of the SE Core program brought upon several improvements to legacy TDB test processes. While the early SE Core test process was still previously decoupled from confederate system testing, several milestone review events were established to enhance TDB content quality and ensure requirements were being met. Through coordination with Program Manager (PM) Field Operations at PEO STRI, subject matter expertise was requested from virtual simulation system operators from the Warfighter Training Alliance (WTA), through the Warfighter Focus Contract, at each TDB Home Station installation. These SMEs provided their input to the look-and-feel of the database content through three established review events throughout the course of the TDB development cycle based on their knowledge and experience at the training sites.

Similar to the legacy testing approach, regression testing of TDBs in the early days of the SE Core program was predominantly accomplished internally through stand-alone Image Generators (IGs) in the SE Core contractor facility. The confederate program's I&T laboratories were utilized on an as-needed basis and were not scheduled as part of a formal TDB test process. Additionally, confederate program engineering personnel were not leveraged by SE Core during TDB testing, either internally or at the respective system I&T laboratories. Thus, first major exposure the confederate systems (or customer) had to the SE Core TDB was the final delivery hand-off to the respective program. The confederate program I&T staff would then conduct their own test of the TDB which often duplicated test procedures already conducted by SE Core, leading to increased cost and schedule associated with redundant testing and review. Additionally, the results of testing from the confederate program I&T staff had the potential to vary from the results captured internally on stand-alone IGs due to difference in hardware as well as software baselines. This disparity often caused rework based on findings captured on the final fielding hardware.

### **Reason for Process Change**

Ultimately, the TRADOC Capability Manager for Virtual systems (TCM-V) and the TRADOC Program Office for Terrain (TPO-Terrain) determined that SE Core TDBs were taking too long to reach the end-users in the field, due to the amount of rework that resulted from the original testing process. Based on this input, SE Core performed an analysis of current I&T efforts accomplished both internally and by the SE Core confederate programs of record. This analysis indicated that there were redundant test efforts being performed by both entities. In an effort to reduce cost and schedule associated with these redundant I&T efforts, SE Core proposed a new paradigm for the integration, test, and evaluation of terrain databases, known as the Major Evaluation of Geospatial Areas (MEGA) Review process.

### **MEGA REVIEW PROCESS**

The Major Evaluation of Geospatial Areas (MEGA) Review is a system-agnostic, comprehensive, and iterative Integration and Test (I&T) process designed to efficiently verify and validate SE Core TDBs. The primary objective of the MEGA Review is to reduce TDB integration and test time by overlapping terrain database testing with confederate program system testing. Through close coupling of SE Core TDB I&T with confederate system testing, we are able to identify issues upfront in the TDB generation process as opposed to potentially waiting several months until the confederate system testing has begun to occur. The MEGA Review process also relies heavily on Subject Matter Expert (SME) support from multiple TDB stakeholders. Representatives from the TDB installation are utilized to evaluate terrain content to insure proper look-and-feel of the required AOIs. Representatives from the Fort Rucker Directorate of Simulation (DoS) are enlisted to evaluate the system performance of the aviation TDB formats and representatives from the Maneuver Center of Excellence (MCoE) are requested to evaluate the ground maneuver TDB formats. There are two primary improvements that separate the MEGA review process from other legacy or industry test approaches. First, SE Core is able to engage all stakeholders early and often to mitigate the

risk of a TDB failing final acceptance testing due to unforeseen deficiencies. This includes multiple confederates that may be using a single database. Legacy contract vehicles or program schedules have typically precluded engagement of multiple customers in a single test event. Second, SE Core is able to take a system testing approach early and often to avoid duplication and program schedule delay from issues that typically arise during later phases of integration.

The system-agnostic nature of the MEGA Review process allows it to be applied across all the various TDB formats that are developed in support of the Army LVC-IA and ITE efforts. As such, this methodology can also be adopted by other members of Industry or Government organizations for the test and evaluation of their own terrain database products.

### Requirements Management and Pre-Test Activities

The SE Core End-to-End process is a construct that defines every milestone of the terrain database generation process from requirement solicitation to final delivery. The first milestone event in this process is requirements collection and approval. TDB requirements are provided to SE Core by TPO-Terrain based on input and feedback from the respective TDB installation site. These requirements are provided in the form of Areas of Interest (AOIs) with an accompanying one-to-N priority rating defined by the installation. These AOIs are typically training ranges, flight routes, maneuver areas, and airfields, but can be any area deemed as training areas by the installation receiving the TDB as well as Outside [the] contiguous United States (OCONUS) to support additional Army training scenarios (i.e. Hawaii, Alaska, etc.)

SE Core will then take this AOI list and generate a Database Content Requirements (DCR) document that defines the fidelity level of each AOI, the database extents, and the TDB formats to be delivered. The DCR is developed in the form of a Google Earth '.kml' file to provide maximum readability across TDB stakeholders. Each AOI receives a color code or symbol based on the requested fidelity. Figure 1 illustrates several AOIs represented in the DCR for Hawaii. Table 1 provides a legend for the color code and symbols used in the DCR. Upon completion of the DCR, it is submitted back to TPO-Terrain for final approval. Once approved, the DCR is used to generate the TDB test procedures for each required TDB format. These test procedures are directly tied to each requirement outlined in the DCR.

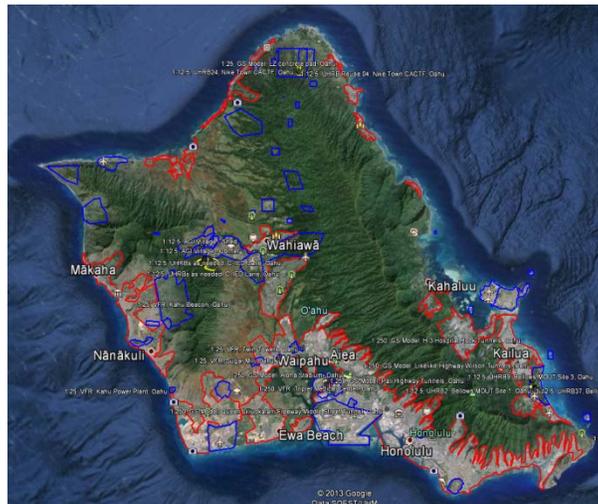


Figure 1. SE Core DCR Example – Hawaii DCR Subset

**Table 1. SE Core Scale Specification Definitions**

<b>Scale</b>	<b>Description</b>
1:250K	The 1:250,000 scale is the ancillary area not covered by the other higher fidelity areas. This scale is not considered directly relevant to training.
1:50K	The 1:50 scale is an area with notable landmarks and navigationally significant features. This is typically a city or built up area surrounding a military facility or along a known route between military facilities or training areas. It can also be a corridor or path along a planned operational route as well.
1:25K	The 1:25 scale represents the military areas of operation that are deemed important to training. This is intended to be military installations, training areas, airfields or other designated areas of operations. In general, this scale will not extend out to the boundaries of the Government installation or training area.
1:12.5K	The 1:12.5 scale is defined as the high resolution urban inset for dismounted training. In this scale, every feature recognizable in the satellite image will be represented in the vector data.

### Test Procedures

A set of test procedures are created for each TDB format generated as part of the database development effort. These MEGA Review test procedures are jointly developed with the confederate programs through peer-review and integration with the program's stand-alone test procedures. For example, the AVCATT Integration Readiness Evaluation (IRE) document was utilized to develop the set of SE Core test procedures for the AVCATT TDB. Through close coordination with the confederate programs on test procedures, we can insure that the primary objective of the MEGA Review, overlapping TDB and system testing, is being accomplished.

The MEGA Review test procedures are broken down into various sub-sections to allow for a modular and iterative approach for regression testing. Table 2 and 3 provide examples of these sub-sections for a virtual and constructive based test procedure document.

**Table 2. Virtual (AVCATT) MEGA Review Test Procedure Example**

<b>Sub-Section Title</b>	<b>Description</b>
Deliverable Data Verification	Demonstrate that the expected output products have been provided on the deliverable media and that they are formatted in accordance with the AVCATT Deliverable Training Database Components Media Format Specification document.
Database Boundaries	Demonstrate that the deliverable database meets the overall extent requirements specified in the Database Request.
Database Specific Content	Demonstrate the presence and accuracy of the features and zones specified in the <Database Name> Database Content Requirements documents.
Scene Management	Demonstrate that scene management settings are appropriate for the AVCATT Training System. Visibility ranges, switch distances, and transition ranges will be thoroughly tested for prominent terrain features in order to verify that LODs blend smoothly with acceptable fade transition, terrain tiles blend correctly, and cultural features do not pop in/out of the scene.
SAF Interactions	Demonstrate the capability of OneSAF entities to interact with delivered terrain database. It is not intended to test all OneSAF entity types within the terrain.
Manned Module Interactions	Demonstrate that the ability of the AVCATT Manned Module to perform some basic functions has not been compromised when using the delivered database.
Database Free Play	This evaluation will be used to further test and identify visual anomalies or performance issues that may have been missed in other portions of the test procedure.
Airfield Lighting	Demonstrate the Airfield Lighting Control functionality using the BMC. The Airfield Lighting Checklist below will be utilized to verify the presence and thoroughly test the functionality of the lighting controls on all of the included airfields.
Moving Maps	Demonstrate that the Manned Module CIB, CADRG, and DTED moving maps are functional and properly correlated with the visuals (and therefore each other). The

	DRLMS radar database will also be tested.
Radio Communications	Demonstrate that the TIREM (radio) database is compatible with AVCATT's pre-existing radio database format. It will be verified that it supports radio propagation effects within the AVCATT System by utilizing two AVCATT Manned Modules with communications capabilities.
Seasons and Views	Demonstrate that the seasons and views are appropriate for the AVCATT Training System. The general appearance of the rendered OTW database terrain will be evaluated at different times of day and using various MM views (OTW, FLIR, and DayTV).
Database Performance	Demonstrate that the performance of the database is not negatively impacted when running an exercise with a reasonable number of SAF entities and activity.

**Table 3. Constructive (WARSIM) MEGA Review Test Procedure Example**

<b>Sub-Section Title</b>	<b>Description</b>
Startup and Configuration	Demonstrate the capability of SAF entities to interact with delivered terrain database. It is not intended to test all SAF entity types within the terrain.
Deliverable Data Verification	Used to verify receipt of all output products and other supporting files associated with the SAF database in preparation for testing.
Database Extents	The objective of this test case is to verify that each database extent is contained within the database boundary.
Linear Features	The objective of this test case is to verify that each requested database linear feature is present.
Point Features	The objective of this test case is to verify that each requested database point feature is present.
SAF Interactions	Demonstrate the capability of SAF entities to interact with delivered terrain database. It is not intended to test all SAF entity types within the terrain.

### **Phased Regression Testing**

The MEGA Review broken down into three major phases, with each phase having multiple I&T efforts associated with it. Phase one constitutes the initial SE Core testing of TDB formats using the developed MEGA Review test procedures. Phase two releases the TDB to the confederate programs for joint testing and provides SMEs a first look at the terrain for feedback and input. Phase three corrects the issues identified by confederate programs and SMEs and includes the final culminating terrain validation event prior to TDB delivery.

### **Phase One - Initial Internal I&T Testing**

During this early stage of the MEGA Review process, SE Core I&T personnel evaluate the state of the TDB against the jointly developed test procedures. As much as possible of this testing occurs in the TDB target simulation system in the respective I&T laboratory environments. The SE Core I&T team schedules weekly time at confederate system I&T laboratories. Confederate program visual engineering and I&T staff are invited to these lab times to witness TDB testing on the systems and provide feedback if necessary. If confederate laboratory time is not available, visual TDB tests are conducted on stand-alone IGs at the SE Core contractor facility. During this phase, SE Core visual engineering and I&T personnel also run automated terrain validation and test tools to check for global TDB errors. Traditionally this phase occurs over a five to six week time period.

### **Phase Two - System Test Delivery**

Once SE Core I&T and TDB engineering personnel determine the TDB to be at an acceptable level for more rigorous review, a System Test Delivery (STD) is released to the confederate programs to conduct their own system testing if desired. The STD typically represents the TDB at between a 70-80% completion level. Most AOIs will be at a nearly finished state, while ancillary areas outside AOIs may still require additional work before final release.

### **Phase Two - Confederate System Testing**

Once the confederate programs receive the STD release, they are allocated two weeks (more if requested) for their own stand-alone system testing. This testing often reveals issues associated with training scenarios that the confederate programs may execute that are outside of the expected use-case therefore not encountered during typical SE Core testing. When such issues are encountered, they are documented so that test procedures can appropriately be updated to reflect any oversights.

During these two weeks, the confederate programs are also encouraged to obtain TDB feedback from their respective simulation platform accreditation/SME bodies (i.e. Directorate of Simulation – AVCATT, Maneuver Center of Excellence – CCTT, etc.). This feedback from system SMEs allows issues to be identified in areas where SE Core I&T personnel do not have authority to properly test, such as Infrared and Thermal tuning and certain physics characteristics associated with terrain features.

### **Phase Two - Site Review**

During the scheduled confederate system testing timeline, SE Core will invite representatives from the TDB installation to the SE Core facility to evaluate the visual content of the TDB. This week-long visual evaluation milestone is known as the Site Review. During this event, installation SMEs evaluate the visual look-and-feel of the TDB training areas and provide feedback on current TDB status against the original list of required AOIs. This event gives the end user and opportunity to view the product before final delivery and provide small tweaks that may be missing from the TDB in its current state.

In order to obtain comprehensive feedback on the TDB, both an aviation SME and ground SME are requested from the respective installation to attend the Site Review. This ensures that both aviation and ground requirements will properly be evaluated. While the required minimum SME count is two, an installation may send as many representatives as desired to participate in the Site Review event.

### **Phase Three - Interim Internal I&T Testing**

Directly following the Confederate System Testing and Site Review, TDB engineering personnel start working to fix the issues generated during these respective events. This process requires iterative TDB builds to verify that issues are corrected as desired. The SE Core I&T team tests each successive TDB build against the original test procedures used in the Initial Internal I&T Test phase to ensure that issue fixes do not affect other working aspects of the TDB. This iterative regression testing effort typically lasts around six weeks or until SE Core Government representatives feel the TDB is at an acceptable level for final acceptance testing.

### **Phase Three – Release Candidate Delivery**

Once SE Core Government, SE Core contractor, and confederate system personnel feel the database is at a sufficient level for acceptance testing, the Release Candidate Delivery of the TDB is generated and delivered to the confederate programs for integration. The Release Candidate Delivery is for all intents and purposes the final TDB delivery pending any major issues generated during the final acceptance testing that would require a TDB return and rebuild.

### **Phase Three - MEGA Review Preparation**

Prior to final acceptance testing (known from herein out as the MEGA Review), SE Core I&T personnel conduct several administrative tasks and final checks to ensure the MEGA Review runs as smoothly as possible. Instead of running the complete set of test procedures during the MEGA Review event, a more streamlined version of the TDB test procedures are generated, known as the Acceptance Test Procedures. These procedures contain the major steps to validate and verify all TDB requirements and AOIs. Certain derived requirements and lengthier test steps are removed to allow for all requirements to be verified in the allotted time. Additionally, all test documentation and notes from the previous test phases are made public for added reference.

A Test Readiness Review (TRR) is conducted two weeks prior to the execution of the MEGA review to present the outcome of final regression testing that occurs prior to leading into this event. After the TRR occurs, the SE Core Government team will determine whether or not the database products are ready to proceed to the MEGA review test event. The week before the MEGA Review a dry-run is conducted using the acceptance test procedures to ensure that all AOIs in the TDB look correct and the system functions as expected. The dry-run also verifies that the TDB loads on the confederate system correctly and will be available for the final MEGA Review event.

### **Phase Three - MEGA Review (Virtual)**

The MEGA Review represents the culminating verification and validation event for a TDB before it is delivered to confederate programs. Currently the MEGA Review is only held against the virtual TDB formats (AVCATT, CCTT, Games for training, etc.) due to lead time to develop the constructive TDB formats (seen in future sections). This, typically, week-long event an effort is made to involve all TDB stakeholders. An important characteristic of this event is that all final testing and review occurs on the real-world TDB simulation systems in their respective I&T laboratory environments. This provides SE Core and confederate programs confidence that the TDB will perform as it will in the real-world on fielded simulation platforms.

Like the Site Review, representatives from the TDB installation attend the final MEGA Review event. As a risk mitigation effort, it is highly recommended that the installations send the same representatives to the MEGA Review as they did with the Site Review. This ensures that major new issues associated with TDB content, outside those identified during the site review, are not identified. Outside of the official site SMEs that the installations provide, SE Core also reaches out to PEO STRI PM Field Operations (PM Field Ops) to identify installation-specific simulation operators from the WTA program under the Warfighter Focus Contract. Since the MEGA Review occurs on actual simulation system platforms, we leverage these simulation operators to help run the test scenarios while also receiving their feedback on the operator/battle master controller (BMC) aspect of the TDB.

Outside of the installation site-specific SMEs, the expertise of confederate simulation system SMEs is also requested. In keeping with the theme of a joint test event between SE Core and confederate programs, SE Core defaults to the confederate program recommendation from simulation system SME support. During the MEGA Review, SE Core enlists support from both the Directorate of Simulation (DoS) from Fort Rucker and the Maneuver Center of Excellence (MCoE) from Fort Benning. DoS's expertise is used to evaluate the TDB from an aviation perspective to identify any performance or negative training impacts to the current status of the TDB. MCoE provides input and feedback on the TDB from a ground training perspective.

Outside of SME support, SE Core also requests direct support from the confederate simulation system engineering personnel during the MEGA Review event. Confederate engineering simulation is extremely valuable during this review as they are able to provide insight into any issues that arise from SME feedback that SE Core I&T personnel may be unable to answer. Confederate engineering personnel also serve as a witness for all SE Core I&T efforts during the MEGA Review.

Finally, the combat developers for all confederate programs, including SE Core, are requested to attend the MEGA Review. The TRADOC Capability Managers for Virtual (TCM-V) and the TRADOC Program Office for Terrain (TPO-Terrain) are the primary attendees. While TPO-Terrain is the primary deciding entity for TDB delivery acceptance, TCM-V and the other TDB SME's input is heavily weighted in the decision.

Prior to the end of each day of testing during the MEGA Review, a Deficiency Review Board (DRB) is held to set the severity of each issue recorded during that day's testing efforts. Issues, or Deficiency Reports (DRs) as they are known by SE Core, can be assigned to one of five severity levels based upon the impediment they impose on Soldier training. Table 4 provides a description of each severity level recognized by the SE Core program and confederate programs. It is important to note that only a Severity level 1 DR will immediately halt testing and result in a TDB return and rebuild. A TDB can still be delivered to confederate programs for integration with Severity 2-5 DRs; however, depending upon the location (training areas and required AOIs) and proliferation of the issue, it may cause a TDB return. A Deficiency Report is assigned a severity from a collective committee consisting of TDB stakeholders involved with MEGA Review testing. A DR requires a consensus agreement from the DRB committee for a severity to be assigned to it.

**Table 4. Deficiency Report Severity Definitions**

<b>Severity Level</b>	<b>Definition</b>
1	Safety issue or prevents continuation of an operational or mission essential capability or testing
2	Adversely affects the accomplishment of an operational or mission essential capability and no work-around solution acceptable to the government is known
3	Adversely affects the accomplishment of an operational or mission essential capability but a work-around solution is known
4	Results in user/operator inconvenience or annoyance but does not affect a required operational or mission essential capability
5	Any other effect (e.g. documentation error)

### **Phase Three - Terrain Database Acceptance**

As stated earlier, TPO-Terrain is the primary acceptance authority to determine TDB delivery to the confederate program systems; however, due to the joint mission of the MEGA Review paradigm, all TDB stakeholders are surveyed for their delivery acceptance recommendation. By eliciting the stakeholder input at this state, redundant testing and review can be eliminated from programs who might otherwise return the TDB due to an issue identified by their system accreditation organization.

In the event that a TDB is not accepted for delivery to the confederate programs, it is imperative that a full list of issues preventing the delivery of the TDB is defined. Due to the tight schedule allotted between TDB deliveries, a TDB return can cause a cascading schedule slip in future TDB deliveries. Thus, the only the outstanding issues preventing TDB acceptance will be corrected in order to maintain schedule.

### **Constructive Format Review Event**

The current primary focus of Phase Three of the SE Core MEGA Review is on visual TDB formats. Constructive TDB formats are iteratively tested by I&T personnel during the first two phases of the process, but they are not officially part of the final MEGA Review acceptance event. The SE Core Constructive TDB formats currently have a lead time of about four-weeks after the delivery of the virtual TDB formats. Since the virtual TDB formats require more effort to get the visual scene correct, in order to maintain correlation across all TDB formats, the Constructive formats cannot be fully generated until the virtual product is complete; otherwise a change in the virtual TDB would require the Constructive TDB to also be changed.

Currently, TPO-Terrain has allocated resources at the National Simulation Center (NSC) at Fort Leavenworth for the validation of SE Core Constructive TDB formats. SE Core I&T Government and contractor personnel are working closely with TPO-Terrain and the NSC to fully develop these Constructive TDB validation processes with the intention of rolling them back into the SE Core MEGA Review process.

### **Interim Government Database Review**

Throughout all phases of the MEGA Review process, SE Core Government representatives conduct two weekly TDB review efforts. The first is a weekly Interim Progress Review (IPR) between SE Core Government, SE Core contractor, and confederate system personnel. The purpose of the IPR is to discuss weekly status of the current TDB in the development queue. Topics covered in the IPR are typically the previous week's test results, future availability of confederate laboratory and personnel assets, and administrative items to prepare for the final MEGA Review event.

The second regularly scheduled event is a bi-weekly TDB visual review. This event is a stand-alone informal review of the visual TDB content on an IG at the SE Core contractor's facility. It serves as a weekly sanity check for SE Core Government to make sure the TDB is ready to proceed into the next MEGA Review milestone phase. Early on in the SE Core End-to-End process, both SE Core Government and contractor participate in a site survey of the installation to be built as a TDB to collect source data. The source data and experience of the site personnel is utilized to review against the visual database content during these bi-weekly database reviews. As with all MEGA

Review events, this event is open to all confederate program personnel so that they may view the TDB if they aren't available to participate in the regularly scheduled I&T laboratory times.

## RESULTS/OBSERVATIONS

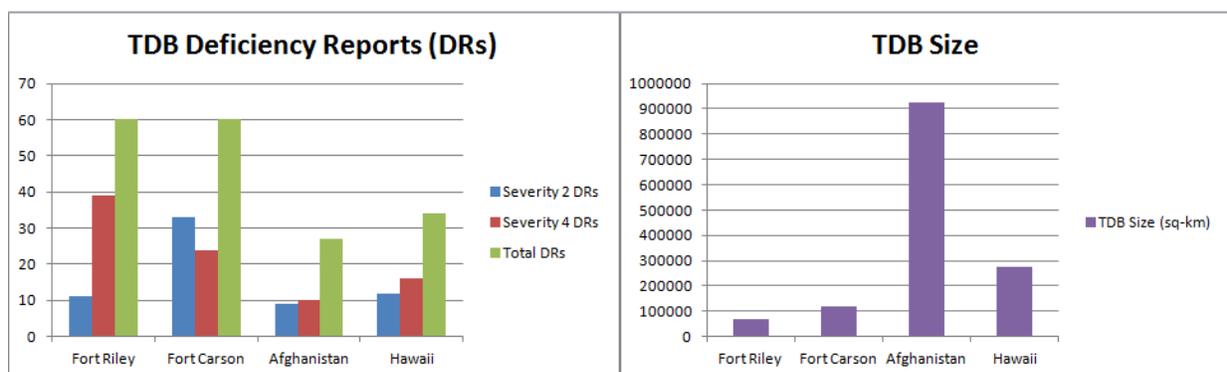
Terrain database generation can often be regarded as both a science and an art form. As a result, the validation and verification of TDB products can be very subjective from one SME to another; therefore it can be hard to generate metrics due to high variability of validation SME personnel utilized between TDB MEGA Reviews. The SE Core standardized DR severity definitions and the ability to trace test procedures back to requirements helps offset this difficulty.

In order to evaluate the success of the MEGA Review I&T paradigm, valid quantitative metrics must be chosen. The number of DRs generated during the final MEGA Review (Post-MEGA Review) event can be a strong metric since this will determine if issues become less prevalent over time across TDB testing. Severity level 2 and 4 DRs are the most encountered during TDB I&T, therefore these were chosen as metrics for this evaluation. The number of DRs remaining open prior to the final MEGA Review (Pre-MEGA Review) event is also a valid metric to determine how well the Initial Internal I&T Testing is capturing TDB issues. Additionally, DRs tend to fall into certain categories based on what part of the TDB they affect. Experience shows several common issue types encountered are those that deal with the tuning of Infrared (IR) and Thermal sensors, issues related to the physical content accuracy of the TDB, and issues related to road/transportation networks. Thus the number of DRs that fall into each of these categories was also chosen as an evaluation metric. The size of the TDB can also be valid metric when comparing number of DRs across multiple TDBs.

The MEGA Review test and evaluation paradigm has thus far been applied to four SE Core terrain databases: Fort Riley, Fort Carson, US Army Hawaii garrisons, and the country of Afghanistan. Table 5 provides a results summary of the final MEGA Review event for each of these TDBs with the above defined metrics.

**Table 5. Historical MEGA Review Issue Summary**

Metric	Fort Riley	Fort Carson	Afghanistan	Hawaii
TDB Size (square-kilometers)	67, 255	120, 143	925, 780	276, 347
Severity 2 DRs: Pre-MEGA Review	6	14	2	1
Severity 4 DRs: Pre-MEGA Review	N/A	N/A	N/A	N/A
Severity 2 DRs: Post-MEGA Review	11	33	9	12
Severity 4 DRs: Post-MEGA Review	39	24	10	16
Total DRs (including Sev 3 and 5)	60	60	27	34
IR Tuning Related DRs	2	0	0	0
TDB Content Accuracy DRs	29	37	5	4
TDB Transportation Network DRs	1	1	1	1
TDB accepted for delivery?	No	No	No	Yes



**Figure 2. MEGA Review Graphical Summary**

The metrics show that, with the exception of the Afghanistan TDB, there are less DRs being generated for each new TDB in relation to the size of the terrain database extents. Additionally, the common issues of IR Tuning and site-specific content accuracy DRs are also declining across new TDBs. These results indicate that the MEGA Review process is working to appropriately update test process so that the regression testing done during the Internal I&T phases of the MEGA Review are capturing important issues identified by Subject Matter Experts and the SE Core confederate system programs. The metrics also show that across there is a constant issue with Transportation Networks across all TDBs. This issue has been a systemic issue within the SE Core program and is attributed to TDB generation tools. As a result, system engineering initiatives have been put in place to fix this issue across future SE Core TDBs.

An additional indication that highlights the success of the MEGA Review process is reflected in the TDB delivery acceptance status. Prior to the Hawaii DB delivery, each TDB that went through the MEGA Review process was not accepted for delivery due to DRs remaining in the database that limited training in an Area of Interest of the TDB, thus requiring a TDB rebuild. While Hawaii still had DRs generated during the MEGA Review, ultimately these DRs were not deemed severe enough by TPO-Terrain and TDB stakeholders to limit training. This indicates that the MEGA Review process caught all significant issues that would have prevented TDB delivery seen in past terrain databases.

The Afghanistan TDB can be seen as an outlier to these metrics for several reasons. The first is that it is significantly larger than any TDB previously built by SE Core. In addition, this database was only built and delivered to the AVCATT program instead of the full gamut of SE Core confederate programs, thus not receiving the traditional level of test and evaluation from other confederate programs that would normally generate DRs. Finally, while the Afghanistan database was significantly larger than other TDBs, it was ultimately less complex, in terms of feature content, than a traditional SE Core TDB. Currently, SE Core does not have a metric to test TDB quality or complexity due to the qualitative and subjective nature of these measurements; however, the SE Core program, based on feedback from fielded TDB sites and the confederate programs, believe that each subsequent database is of higher quality than the next. Since the numbers of issues are also being reduced across new TDBs, the SE Core program can focus on increasing the complexity of these terrain databases, such as the use of higher fidelity terrain elevation insets and the implementation of Ultra-High Resolution Buildings (UHRBs; models that can be entered by SAF and player entities). As an example, the Fort Riley TDB did not contain any UHRBs, while the Hawaii TDB contained over 100 unique UHRB models.

## **PROCESS IMPROVEMENTS AND FUTURES**

The MEGA Review test and evaluation paradigm is a living process and is constantly evolving to address changing TDB requirements and confederate simulation system TDB formats. Following each MEGA Review cycle, SE Core and the confederate programs work to generate a lessons learned document that is used to shape current iterations of the MEGA Review process.

One area of improvement that has been identified is in the validation of data contained within the SE Core Master Database (MDB). The MDB is the master repository of cleaned source data from which all TDBs are generated from. SE Core database engineers found that the MDB often contained erroneous data which led to issues in terrain database generation which could have been completely avoided if it was caught in the early stages of MDB data population. In order to mitigate this inherent problem, a new process prior to the MEGA Review has been established, known as the MDB Acceptance Test Procedure (MDB ATP). This multi-part process involves milestone review events to verify all the inputs to the MDB including raw GIS source data (elevation, imagery, vector layers), cleaned GIS vector data, three-dimensional static models and procedurally generated airfields. This MDB ATP process provides SE Core TDB engineers and Government representatives a chance to approve MDB content before the TDB enters the system level I&T phases.

Additionally, as the SE Core mission for the Army grows, so too must the capability to generate and test new TDB products and formats. The most recent example of this is the development of Constructive TDB test procedures and processes for the MEGA Review. While still not included in the final MEGA Review event, test procedures for these formats were developed and are actively tested by the SE Core I&T team during the Internal I&T phases of the MEGA Review with the eventual intention to hold a single validation event for both Constructive and Virtual TDB

products. The SE Core program is also anticipating the eventual requirements for the generation of Army and Department of Defense (DoD) Mission Command TDB formats. This will require the SE Core I&T team to integrate innovative and improved test procedures into the MEGA Review process to account for the highly advanced and sensitive Mission Command systems.

### **Challenges**

The benefit of involving all the major TDB stakeholders in the MEGA Review comes with the challenge of coordination across multiple areas. SE Core TDB testing efforts are rarely the only activity occurring in the confederate program I&T laboratories. These facilities are often extremely limited in both hardware and personnel assets, thus close coordination must be made on a weekly basis with confederate programs to reserve time for SE Core personnel to execute MEGA Review test procedures.

The timely development and approval of MEGA Review test procedures also provides a unique challenge to the MEGA Review paradigm. Since the primary mission of the MEGA Review is overlapping test and evaluation with confederate programs of record, close coordination must be maintained to receive appropriate feedback during peer reviews of the test documents. In order to receive buy-in from confederate programs on the MEGA Review process for each TDB, a consensus must be reached on the MEGA Review test procedures. Since TDB performance is often tightly coupled to system hardware and configuration it is often necessary to perform basic system testing to fully evaluate TDB performance, even if it may be out of scope of the official SE Core requirements.

From a high-level schedule perspective, the SE Core TDB development and delivery schedule is directly coupled to the LVC-IA program's fielding schedule which is in-turn based on the Army's Integrated Training Environment (ITE) event schedule. Current SE Core practice is to provide the TDB to the confederate programs for integration between six and eight months before the installation's ITE date; however, this date may fluctuate to the left or right based on current Army training priorities. If this happens, SE Core must be flexible to support the new date which may put a strain on TDB I&T resources. As a second order effect of this, since SME personnel support is often coordinated far in advance of the actual review event milestones, changes in review dates can lead to SME schedule conflicts that must be properly adjudicated to ensure consistent SME representation.

### **CONCLUSION**

This paper highlighted a new paradigm used by the SE Core program for the test, evaluation, and integration of terrain databases used by the Live, Virtual, and Constructive Integrating Architecture confederate simulation systems. This new process was developed out of necessity to reduce the cost and schedule of terrain database testing seen through redundant test efforts across all the LVC-IA confederate programs. Through close coordination with these confederate simulation system programs, SE Core has implemented a successful process, known as the MEGA Review, which has significantly reduced the number of issues identified during test efforts and has ultimately led to higher quality terrain database deliveries for the Soldier.

The MEGA Review is a living process and is constantly being updated and improved by both SE Core and the SE Core confederate programs to account for lessons learned across each terrain database I&T cycle. In the future the SE Core program hopes to develop more robust metrics to better track the success of the MEGA Review process for future terrain database products.

The MEGA Review process was ultimately designed to be a system-agnostic approach due to the multiple TDB formats and simulation systems. Since this process is not tied to any one specific system or TDB format, all or part of this methodology can be adopted by other members of Industry or Government to test and evaluate their own terrain database products.

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