Operation Blended Warrior 2017
Terrain Database Interoperability Lessons Learned

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ABSTRACT

This paper explores the lessons learned from using a high-resolution terrain database, and the establishment of an on-line repository for its distribution, in order to support Operation Blended Warrior (OBW) 2017. OBW has been a multi-year, annual Live, Virtual, & Constructive (LVC) special event, conducted during the Inter-service/Industry Training, Simulation, and Education Conference, focused on exploring the challenges in using LVC simulations for training. To support OBW 2017, baseline terrain databases, runtime formats, and 3D models were shared with OBW participants via a common online repository. This proved to be extremely valuable, as previous OBW exercises required participants to access multiple disparate and often ad hoc repositories to locate terrain source data and database products. Despite using a single terrain distribution source, there were still clear difficulties in terrain interoperability: multiple systems used by various organizations – both government and industry – resulted in variations in appearance and quality of the terrain and models displayed; some hardware was insufficient for processing or displaying the high-density database; and anomalies such as floating buildings, broken roads, avatars walking in air, vehicles driving through trees, and avatars on ship remaining stationary while the ship was moving up and down (ankle deep in steel!). We explore the causes of the problems – whether hardware-related system problems, terrain development glitches, interoperability standards or compatibility issues, or software configuration settings. These problem areas are evaluated from a technical perspective and also from the perspectives of several OBW participants. Finally, we explore the impact on "fair fight" interoperability vice purely visual anomalies and highlight how to avoid them.

ABOUT THE AUTHORS

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INTRODUCTION

With the growing demands for the use of Live, Virtual, & Constructive (LVC) systems in training applications, the successful interoperability of heterogeneous networked simulation systems continues to pose significant challenges in the modeling, simulation, & training (MS&T) community. One of the contributing factors to these interoperability challenges is the coordinated use of data within the Synthetic Environment – composed of the Synthetic Natural Environment, Physical Models (fixed and moving), and Behavior Models (Cross, Woodman, & Vierling, 2011) – in a consistent and standardized fashion. Depending on the MS&T application, the data may include oceanographic, atmospheric, geospatial, and urban content, at a variety of resolutions and qualities, representing both natural and man-made objects. Another contributing factor is the ability to easily and seamlessly share and find such data. Users must be able to discover, access, and obtain the content from others, as well as publish and disseminate their own data. The MS&T community is far from having solved these challenges but progress, although slow, is being made in addressing the contributing factors to the interoperability problems.

This paper explores the lessons learned from using a high-resolution terrain database and the establishment of an on-line repository for its distribution in order to support Operation Blended Warrior (OBW) 2017. Baseline terrain databases, runtime formats, and 3D models were shared with OBW participants via a common online repository. This proved to be extremely valuable, as previous OBW exercises required participants to access multiple disparate and often ad hoc repositories to locate terrain source data and database products. Despite using a single terrain distribution source, there were still clear difficulties in terrain interoperability: multiple systems used by various organizations–both government and industry–resulted in variations in appearance and quality of the terrain and models displayed; some hardware was insufficient for processing or displaying the database; and anomalies such as: floating buildings, broken roads, avatars walking in air, vehicles driving through trees, and avatars on ship remaining stationary while the ship was moving up and down (ankle deep in steel!). We explore the causes of the problems – whether hardware-related system problems, terrain development glitches, interoperability standards or compatibility issues, or software configuration settings. These problem areas are evaluated from a technical perspective and also from the perspectives of several OBW participants. Finally, we explore the impact on “fair fight” interoperability vice purely visual anomalies and highlight how to avoid them.

BACKGROUND

OBW, an annual LVC special event conducted during the Inter-service/Industry Training, Simulation, and Education Conference (I/ITSEC) in 2015, 2016, and 2017, has been a collaboration between the U.S. military Services (Army, Marine Corps, Navy, and Air Force) and Industry for the purpose of uncovering and documenting the challenges accompanying the rapid development and integration of training LVC environments, including an open mix of government and industry simulation assets. Capitalizing on the phenomenal capabilities demonstrated at I/ITSEC by industry partners, OBW has implemented a network architecture to allow those capabilities to be integrated in a fashion representative of their real-life intended purpose. In this manner, I/ITSEC attendees are not only able to see industry’s capabilities in a highly representative environment but engage with LVC experts about the challenges (and potential solutions) associated with integrating the various capabilities. Whether the challenge to LVC is standards, database interoperability, cyber, performance measurement, cross-domain solutions, or distributed After Action Review, OBW has developed a construct to better understand and demonstrate those challenges. For an exposition of these challenges, additional background on previous OBW events, and a comprehensive overview of OBW 2017 initiatives and lessons learned, we recommend the paper "Operation Blended Warrior 2017 – Behind the Curtain!" (Matthews, Mamaghani, Gritton, Fraas, Kotick, & Gay, 2018), also presented at I/ITSEC 2018.

Each year, one of the U.S. military Services hosts I/ITSEC and in so doing, has acted as the lead Service for OBW. During OBW 2017, Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI) took the lead role on behalf of the U.S. Army and identified six critical MS&T objectives as focus areas to highlight and address emerging Army LVC challenges. Two of these objectives specifically dealt with the development, distribution, and interoperability of the terrain databases as part of the Synthetic Environment. One of the critical areas for the interoperability of disparate simulation systems is the correlation of their Synthetic Environments. Appropriate representation and use of dense urban areas for various training tasks was also identified as a critical topic for the U.S. Army. The two questions posed by the U.S. Army as objectives for OBW 2017 which were directly related to the subject of this paper were:

- **Multiple terrain providers/formats; integration of dense urban areas**: One of the critical areas for the interoperability of heterogeneous simulation systems is the correlation of their terrain/environment data. Appropriate representation and use of dense urban areas for various training tasks is a critical topic for the U.S. Army.
    - How can correlation and interoperability be improved, especially across the Services who currently utilize various terrain formats and standards?
    - For dense urban areas, how can current and emerging terrain standards, formats, and technologies be used to rapidly generate models, features, and attributes?
    - Analyze how well multiple providers of terrain data and various formats can meet Army terrain requirements and how inclusion of dense urban areas affect these providers and formats.
    - What capabilities (technologies, ontology [data and behaviors], others) exist and are needed that can dynamically provide multi-resolution terrain in the synthetic environment?
    - Identify gaps related to future Army terrain/environment requirements.
- **Centralized distribution of authoritative data:** Maintaining data correlation is critical in a distributed simulation/computing environment. Use of a centralized network/cloud-based distributor of appropriate/authoritative data (e.g., Operational Environment (OE)) can facilitate wider application of operational training and improve data sharing and subsequently data correlation across the board. During some LVC events updates to specific data are required at run-time.
    - Test how having a central mechanism to find, access, and retrieve data prior to an exercise can facilitate the LVC event for the participants.
    - Evaluate how centralized capabilities can broker data updates during exercises by providing discovery and access, then streaming and loading the new data as needed (on-demand).
    - Evaluate how centralized access to tools (e.g., entity mappings) can improve, or at least reduce the barriers to, correlation and interoperability.

MULTIPLE TERRAIN PROVIDERS/FORMATS; INTEGRATION OF DENSE URBAN AREAS

OBW 2017 saw the introduction of a diverse range of U.S. and international simulation and training systems, including cyber capabilities, a wide range of visual systems with varying capabilities and resolutions, a variety of military platform simulations (from ships to fixed and rotary wing aircraft to ground vehicles to dismounted soldiers) with different sensor capabilities, semi-automated forces (SAF), and constructive systems. To highlight the wide range of capabilities and training scenarios showcased at the 2017 event, three unique terrain databases were made available to all OBW participants: Southwest United States (SWUS), Pacific Northwest (PacNW), and the Emerald City Inset (ECI), a dense urban terrain. For details on ECI, we recommend the paper "The OBW Emerald City Inset Experience" (Moore, Kehr, Sedlak, & Boyd, 2018), also presented at I/ITSEC 2018.

The OBW 2016 SWUS database product was carried through to 2017. This allowed Industry members to participate without expending resources to integrate new terrain database products into their demonstrated systems, since many had a version from the previous year. SWUS was primarily used for the Air vignettes in OBW 2017. PacNW and ECI were new terrain database products, provided by the U.S. Army PEO STRI's Synthetic Environment Core (SE Core) program for OBW 2017. In most Ground vignettes, the new dense urban terrain of the ECI database was used. This database was distributed as 'Distribution A' ("Approved for public release: distribution unlimited.") and was a smaller footprint, yet very high-density urban subset, of the larger PacNW database. PacNW was provided as 'Distribution C' ("Distribution authorized to U.S. Government Agencies and their contractors."). In some Maritime, Air, and Ground vignettes both databases were used; however, most scenarios used either the ECI or the SWUS databases. Providing an unrestricted high-quality and high-resolution dense urban terrain database product to participants was seen not only as a significant contribution to the OBW effort, but also to the broader MS&T community. The use of the ECI database product beyond OBW can further enable future research in data correlation and interoperability. A summary of each of the three databases is provided in Table 1.

Table 1. OBW 2017 Terrain Database Summary

	SWUS	PacNW	ECI
Provider	NAVAIR Portable Source Initiative (NPSI); various	U.S. Army SE Core	U.S. Army SE Core
Extents	644 km X 869 km	406 km X 362 km	10 km X 10 km
Size	559,636 sq-km	146,972 sq-km	100 sq-km
MOUT Sites	2	23	0
Dense Urban Terrain (DUT) Sites	0	3	1
Elevation	• U.S. Geological Survey (USGS): 1m & 10m Digital Elevation Models (DEM) • NOAA: 1 arc second (arcsec) & 1/3 arcsec	• Digital Terrain Elevation Data (DTED) Level 2 (30m)	• USGS National Elevation Dataset (NED) 1/9 arcsec (processed to 5 meters)
Imagery	• USGS: 1ft High Resolution Orthoimagery (HRO) • 1m National Agriculture Imagery Program (NAIP)	• U.S. Department of Agriculture (1m) • Digital Globe and Buckeye • SE Core Procedurally Generated Imagery	• 1m SE Core Procedurally Generated Imagery
Feature Data	• Open Street Map (OSM)	• OSM with unlimited distribution • National Hydrography Dataset (NHD) with unlimited distribution • Hand edited data created in the vector editing of the original Joint Base Lewis-McChord (JBLM) dataset • Hand edited data created during the Homeland Security Infrastructure Program (HSIP) removal from the PacNW dataset	• OSM with unlimited distribution • NHD with unlimited distribution • Hand edited data created in the vector editing of the original JBLM dataset • Hand edited data created during the HSIP removal from the PacNW dataset.
Simulation Formats	• OpenFlight® • Virtual Battlespace 3 (VBS®3) • MASA SWORD	• Topographical Line Maps* • Joint Operations Graphic-Air*	• Common Database (CDB) • VBS®3 • OneSAF Terrain Format • MetaVR® • Unreal® Engine 4 (UE4) • Unity® • OpenFlight® • VR-Vantage™

* Not simulation formats. These are tactical map formats for Army mission command systems.

In addition to terrain databases, existing 3D models (static and moving) from OBW 2016 were provided along with the addition of new 3D models, in multiple formats and resolutions, by SE Core. All of these terrain database products were housed in a single repository, which was based on the Enterprise Data Service (EDS) capability, specifically tailored for use by OBW 2017 participants. This new process of a central repository was driven by OBW 2016's use of a decentralized data distribution process, which caused coordination and integration challenges. A major lesson learned and recommendation made after OBW 2016 was to emphasize "the importance of a uniform and centralized distribution of authoritative data" (Hoke, Townsend, Giambarberee, & Schatz, 2017).

CENTRALIZED DISTRIBUTION OF AUTHORITATIVE DATA

Old Process: Decentralized Data Distribution Process

OBW 2016 demonstrated several state-of-the-art enhancements for LVC capabilities, including multi-level security, cross-domain solutions, long-haul feeds, and performance measurement. OBW 2016 also saw the enhancement of the previous year's terrain data solution, which was largely based on the NAVAIR Portable Source Initiative (NPSI) product. In order to support a growing number of OBW participants and scenarios, OBW 2016 added additional data products, including source data, 3D models, and runtime terrain formats. These additional terrain data products were collected and/or developed by different OBW government and industry participants and were distributed on an as-needed ad-hoc basis. Figure 1 provides an illustration of the OBW 16 decentralized data distribution process.

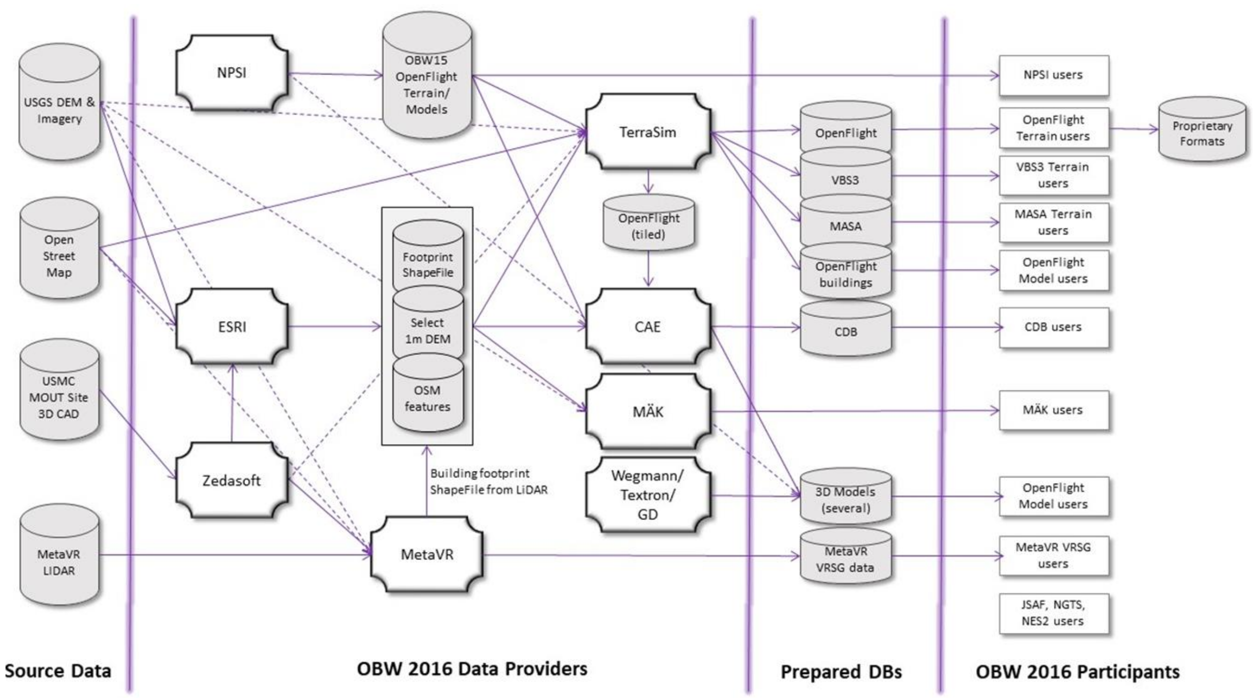

Figure 1. OBW 2016 Decentralized Data Distribution Process

Several open-source and/or publicly available source data formats were obtained by a handful of Data Providers to generate the runtime terrain formats and models used by OBW participants. Some of these Data Providers acted only as an intermediary to convert or process data prior to the final database generation. Some added further attribution to existing OSM feature data and generated shapefiles (geospatial vector data format) from architectural design files. After processing source data, content was distributed to the respective OBW participants by several Data Providers. The primary mechanism for distribution of the OBW 2016 data was through the use of the storage facilities hosted by a few of the industry organizations, as well as at the National Training and Simulation Association (NTSA) share site. Some data providers distributed the data in their specific runtime formats directly to a select few participants, who were their customers. In some cases, the same source data went through different paths, with different value-adding, change, and revision processes, before reaching an end target system. Some of these differences contributed to data inconsistency and in some cases to lack of data and system interoperability.

While OBW 2016 was ultimately successful in demonstrating LVC advancements, this ad hoc data distribution process added to the complications during the planning, integration, and execution phases of OBW 2016. Often, there was confusion on where specific data was located (or even existed), as well as persistent configuration management challenges, especially as OBW Data Providers continually refined their terrain data products. Therefore, one of the critical recommendations after OBW 2016 was to implement a centralized repository for authoritative data that could be shared and accessible by all participants.

New Process: Unified Repository

As the service lead for OBW 2017, the U.S. Army took the initiative to provide a centralized solution to address data distribution challenges highlighted in previous OBW events. Through collaboration and close coordination with the SE Core program, a centralized data repository was developed and deployed for OBW 2017. This new repository provided a single storage location for all OBW data, including all of the database products from previous years' events, existing 3D models, and previously used geospatial source data, as well as new products of varying distribution levels provided by SE Core. This process also provided inherent configuration management and discovery capabilities present in a proven software tool (EDS), from which this solution was derived. This included added capabilities for data access, based on user credentials and access control for specific data product restrictions. This new process is illustrated in Figure 2.

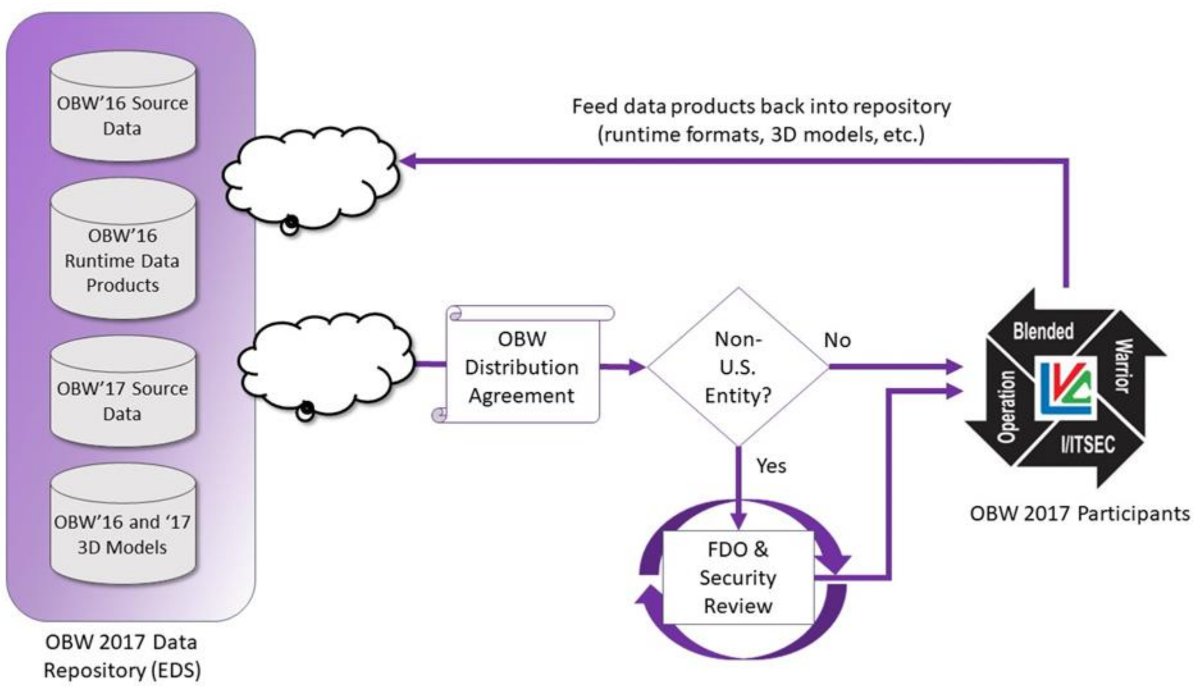

Figure 2. OBW 2017 Centralized Data Distribution Process

Since 2013, Leidos has been the prime contractor supporting the development and operation of EDS. EDS, hosted on the Defense Intelligence Systems Agency (DISA) Military Cloud (MilCloud), brokers network access to four primary types of data for Modeling and Simulation (M&S) use: digital terrain, visual (3D) models, order of battle data, and training support plans (TSP). This data currently comes from 14 different data providers across the Department of Defense (DoD) and Intelligence communities, many of them specifically for M&S use.

In January 2017, PEO STRI and Leidos partnered on the work effort to support OBW 2017 by developing and deploying a repository based upon a special version of EDS. The OBW EDS modifications were:

- Provide immediate download of terrain, runtime formats, and 3D model data files
- Support data access months prior to I/ITSEC during the preparation period, as well as during the OBW event during I/ITSEC
- Support all of OBW participants, including international users
- Control access to U.S. Data for U.S. personnel only ("US only"), while also providing access to public data for all users

The EDS team began supporting OBW 2017 meetings and developing software in June 2017; OBW created four primary challenges for EDS:

- EDS on DISA MilCloud performs a broker service and consequently does not store data, but points to the source of the data using metadata cards (metacards). The first challenge was to upgrade the EDS software to support direct data storage (self-service upload) and retrieval (download) while connected to the internet prior to I/ITSEC and disconnected from the internet on the OBW Local Area Network during I/ITSEC.
- EDS on DISA MilCloud needs only one access control level as it references DoD data at one distribution level (level C) and one security classification (Unclassified). The second challenge was that OBW 2017 required two distribution levels and, therefore, two access control mechanisms. Since OBW participation extended to both U.S. and International participants and the data distribution levels were both "US Only" and Public, multi-identification, multi-authorization, and multi-access control mechanisms had to be implemented.
- OBW support also required time-phased data availability for early consumption. Public data from OBW 2016 was to be made available early and OBW 2017 special "US only" data followed in August, both well before the multi-authorization software changes could be implemented. Consequently, the EDS team prioritized storing and distributing data functions early but could only do so at one level of authorization. The highest authorization was at the "US Only" data level. This meant that, initially, public data could only be accessed by those who could obtain the highest authorization level ("US Only").
- Finally, terrain data imagery files were (relatively) massive in storage size, especially for the dense urban terrain of ECI (downtown Seattle) which was to be used in OBW 2017. EDS not only needed to store large files but had to be able to provide a hard drive shipment should a request for urban terrain be received.

To respond to these requirements, the EDS team wrote broker service software to interface to the Amazon Web Services® (AWS) Simple Storage Service™ (S3) Application Programming Interface (API). The EDS team chose AWS S3 because Amazon storage costs are relatively inexpensive and S3 is a popular storage mechanism with open source software available using the S3 API to also control local storage. By using S3, and later reusing the same API by mounting a USB hard drive with an open source local storage S3 interface, the EDS team solved the challenge of making files available on the internet during the preparation period and then, later, while disconnected from the internet during I/ITSEC OBW exercises. The EDS broker service natively responds to searches with metacards describing searched data. The EDS team added services to download data by clicking a link presented to the user as part of the search results. Since data self-storage was also a requested feature, the EDS team provided a user interface to automate metacard creation as part of self-storage. In this way, searches could find the (self-stored) data via the metacard. The EDS team was able to provide access to files stored on AWS in the middle of August.

Authorization proved to be much more complex than anticipated. PEO STRI implemented a special authorization process for the PacNW database, to review and allow international access. The EDS team created a Portable Document Format (PDF) authorization form to download and upload. In this way, by reusing existing PDF software and providing a U.S. government person control over approvals, the EDS broker quickly supported a work flow well beyond the limited reach of the software. Once U.S. government officials approved the access, the U.S. government administrator could approve the account directly and open access to all authorized data. To enable that access, the EDS team created controls at the file level that mapped to the provided authorizations, such that the administrator could specify authorization at the file level or at the group of files level.

Since large file transfer is not well supported on the internet and terrain files are often very large, the EDS team tested file transfer mechanisms. For file transfer, the ultimate question was "how big is too big?" The team's answer was to measure how fast a file could be downloaded (based on the server speed). If a file could be downloaded in an eight-hour business day, then the team considered it small enough to download directly; otherwise, a request to ship a hard drive was generated to the SE Core program. Experience with AWS proved that file transfer speed was being throttled, so the team employed Amazon CloudFront®, a web service that speeds up distribution of web content to users, to double the speed. Further work had to be done to ensure that the download software was reliable, as no one wants a download/upload to fail after investing more than an hour to transfer the file. Unfortunately, this work was completed after OBW 2017 started at I/ITSEC.

Since EDS is a metacard system, some fairly significant work goes into providing metacard content. This was perhaps the most underestimated terrain task for OBW. SE Core had a significant number of files, but in order to make them accessible in useful ways, a metacard needed to be generated representing either the individual or group level. Thousands of individual files precluded individual file representation. Obvious groupings were all models, imagery by operational areas, etc., but determining what groups made sense to the user was not obvious. Unfortunately, this task did not complete prior to OBW, so EDS-OBW users were left with some uncertainty as to what data was represented by each metacard.

TERRAIN ISSUES DISCOVERED DURING OBW 2017

Despite using a single terrain distribution process, there were still clear difficulties in terrain interoperability. These problem areas were expected, since additional data refinements (after the data had been obtained from a single source) and data tailoring based on specific application needs or limitations are often significant sources of disparity in data and lead to interoperability problems. These issues are explored below from a technical perspective and also from the perspectives of several OBW participants. Multiple systems used by various organizations – both government and industry – resulted in variations in appearance and quality of the terrain and models displayed. In some cases, hardware and rendering capabilities were insufficient for processing or displaying the high-density terrain databases. In others, anomalies were caused by discrepancies between different visual systems.

Most issues were noticed during the use of the ECI terrain database for at least two reasons. First, scenario events and activities were close to ground, and therefore differences in content, appearance, position, and other attributes were more apparent and noticeable (in contrast to flying at several thousand feet above the terrain, where small or medium differences may not even be noticed). Second, the density of the ECI terrain database was significant and at times caused issues for some systems, either during pre-exercise processing of the data or at run-time. Both of these types of issues are expected in any large-scale interoperability event but they are further amplified when there is not enough time or opportunity during the planning and execution process to review and analyze detailed requirements of participants' systems or to provide remedies for avoiding the identified issues.

The terrain issues observed during OBW 2017 fell into four general causal areas: hardware, synthetic natural environment and 3D model properties, source data differences, and image generator capability differences.

Cause and Effect

Program Manager Training Systems (PM TRASYS), Marine Corps Systems Command fields the Deployable Virtual Training Environment (DVTE) to Marine Corps units in order to sustain individual, team, and unit critical war fighting cognitive skills associated with the application of combined arms, squad, and platoon level tactics. DVTE is capable of emulating organic and supporting Infantry Battalion weapons systems and training scenarios to facilitate Training and Readiness (T&R) based training while aboard ship, forward deployed, in garrison, or in schoolhouse environments. PM TRASYS participated in OBW 2017 using (among others) DVTE. The software component used was VBS3, in which individual students or groups of students can interact to complete mission scenarios in a first-person shooter format. The standard DVTE hardware is a Dell Precision®[1] laptop. While this system meets the VBS3 minimum hardware requirements for normal training, it was insufficient for OBW when running the ECI terrain database. This created several extreme issues for the Marines operating the system as part of OBW:

- lag in on-screen response to mouse movements for looking, aiming, and firing
- lag in movement through the environment when depressing the movement keys (WASD)
- slow "painting" (screen refresh) of the terrain, fixed models, and moving models (including avatars)
- system crashes

These issues often resulted in PM TRASYS not being able to fully participate in a scenario.

[1] Dell Precision is a registered trademark of Dell, Inc. in the United States and/or other countries.

As shown in Table 1, VBS3 was one of the terrain database simulation formats created by SE Core for ECI. VBS3 users experienced several issues with the VBS3 version of the ECI database, reportedly related to database property settings. Some of the property settings and issues related by the users included:

- Ground clamping of fixed physical models, resulting in some "floating" buildings
- Incomplete road splines, resulting in some broken roads that vehicles could not use for pathfinding
- Ground clamping of moving models, resulting in some avatars walking in air
- Bounding boxes around fixed physical models, resulting in some objects such as trees that vehicles could drive through with no adverse effect
- Surface clamping on moving models, such as ships, resulting in avatars standing ankle-deep in steel
- Surface coding for trafficability, resulting in avatars instantly dying when exiting vehicles in some areas

The aggressive schedule associated with developing runtime formats for the ECI meant that OBW participants had less time for integration and testing prior to OBW execution. Many of these issues identified by participants would have been identified and mitigated given additional time for incremental testing and delivery of runtime products.

FAIR FIGHT

Fair Fight is defined as "A condition when the differences between the performance characteristics of two or more interoperating simulations have significantly less effect on the outcome of a simulated situation than the actions taken by or resources available to the simulation participants." (DMSCO, 2016) There are many reasons for potential problems with fair fight in interoperable simulations. Here are some examples related to the synthetic environment (Siegfried, Lüthi, Herrmann, & Hahn, 2011):

- Different environment representation: consider the situation where a river is represented only in one simulation participant preventing it from moving forward, whereas in another simulation system the same position can easily be passed [synthetic natural environment]
- Different object representation: for example, a house may not be represented in one simulation system allowing a tank to continue driving "through" that house as it is represented in another simulation system [physical models (fixed)]
- Different definitions of capabilities for entities: for example, in one simulation, a tank may be able to pass narrow points with a width of 6m, whereas in another simulation system an entity of the same type may not pass the same bottleneck [physical models (moving)]
- Different weapon effect computation: the same hit by the same ammunition at the same target causes different effects in two simulation systems, because different algorithms to calculate the weapon effects are used [behavior models]

During OBW 2017 we observed fair fight issues resulting from two different causes. First, some participants in OBW developed their own runtime databases separately. Different source data was used, resulting in fair fight differences between participants running these independently-produced runtime databases and those running other runtime databases. Second, differences in image generators resulted in differences in the observed terrain. Differences in image generator quality results in differences in the number of models displayed, levels of detail, refresh speed, anti-aliasing, light points, shadows, etc. These are all factors that can affect the fair fight in an LVC environment. Purely visual differences do not necessarily affect fair fight, however; the effect on the outcome must be evaluated.

In actual LVC events, where participants and the scenario planners have more control over their resource availability and planning (and they are not doing something for a "show"), they should have a better approach to avoiding the problems described earlier. Side-by-side comparison methods can be a significant aid to understanding and avoiding the differences and interoperability issues, if used early in the process. Similarly, deliberate analysis of interoperability requirements early in the planning process, and developing appropriate remedies according to importance and type of problems, will go a long way in avoiding issues. This is not something that OBW was able to do because of the various non-technical aspects of how participants could make themselves and their exact systems available in advance of the event at I/ITSEC. Understanding fair fight issues requires additional research and application of the results of that research as specific "commodity-level" steps. We cannot solve terrain interoperability problems, if we are not at a point to be able to connect systems "out-of-the-box" on a network and encounter no issues. Most of today's system integration resources are still spent on resolving system connection issues – what should, by now, be plug-and-play.

This leaves little time, especially on projects such as OBW, for analyzing and tackling larger interoperability topics that include behaviors, terrain, and other critical semantics.

CONCLUSION

This paper provided an overview of the improvements made to the Operation Blended Warrior (OBW) terrain process for the third-annual event at I/ITSEC 2017. These improvements were the result of lessons learned from previous year OBW events along with addressing specific 2017 U.S. Army objectives and existing OBW challenges. Two significant data-related developments contributed to the overall success of OBW 2017. First, the development of a publicly releasable, DoD-developed, Dense Urban Terrain product (ECI) allowed OBW participants to showcase their state-of-the-art simulation capabilities through the integration of this feature-rich product. Second, the development and use of a single, centralized repository reduced configuration management challenges and provided all participants with a standard process for sharing, finding, and obtaining access to the full-spectrum of OBW data, old and new. Valuable feedback was received on these enhancements by OBW 2017 planners and participants after the event. This feedback will allow the U.S. Army and the OBW Leadership to refine both of these solutions in order to improve their functionality and usability for future LVC activities. Several terrain interoperability issues were also identified during the OBW events; however, the issues identified can be remedied in the future through better processes, adherence to standards, and better understanding of the involved requirements for LVC interoperability. Other remedies will require deliberate decisions on tradeoffs, which may vary based on the types and details of LVC events and the systems involved.

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