DEVELOPING CREATIVE SOLUTIONS TO SIMULATOR DATABASE ENGINEERING PROBLEMS

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ABSTRACT

The 58th Special Operations Wing's Training Support Squadron, Mission Training Support Systems (MTSS) at Kirtland AFB, New Mexico provides initial/mission qualification and refresher training for Combat Search and Rescue and Special Operations Air Crew members. Training is conducted using several different media, including networked Weapon System Trainers. To provide visual realism in training, mission scenarios are fabricated in concert with a 3D visual environment, or visual database. In order to perform effective mission scenarios, however, extensive effort has been required to successfully integrate the dissimilar Visual Databases (VDBs) of these flight and mission simulators.

Because the initial fabrication of the VDBs required significant investment, the VDBs are an important training resource. The need for an ongoing VDB maintenance program has emerged as a result of technological advances, concurrency modifications, and changes in simulator training requirements. The MTSS team has learned that unless proactive processes for VDB maintenance is embedded in normal operational procedures, hardware and software upgrades, as well as networking compliance requirements tend to render a VDB less effective over time.

This paper discusses the reasons that VDB maintenance becomes necessary, and the lessons learned in dealing with VDB maintenance issues. The MTSS has taken its lessons over nine years of experience supporting VDBs on nine simulators, and specific examples of problems and associated resolution techniques are discussed.

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INTRODUCTION

Although built to appease original specifications, training simulators are dynamic in nature. In fact, strong empirical data exists to support a recurring need for upgrades and changes to a training simulator (Nullmeyer, Cicero, Spiker, Tourville, and Thompson; 1998). Yet, within an evolving environment, visual databases, as a resource of a simulation training system, may fail to be considered as a unique asset.

The 58th Special Operations Wing's Training Support Squadron (TRSS), Mission Training Support Systems (MTSS) at Kirtland AFB, New Mexico provides initial qualification training, advanced combat mission training, and refresher training for a variety of helicopter and fixed-wing crews. Since 1990, this wing has been developing a sophisticated set Weapons Systems Trainers (WSTs) and electronic training technologies (Spiker, Tourville, and Nullmeyer; 1997). In order to perform effective mission training, using these technologies, extensive effort has been required to successfully integrate and maintain the dissimilar Visual Databases (VDBs) of the varied training simulators.

This paper begins with an example of a lesson learned, then discusses the nature of VDBs, the root causes for which VDB maintenance becomes necessary, and the corrective action that has been developed to assist with VDB maintenance issues.

The MTSS has accumulated nine years of lessons learned in supporting the various VDBs on the wing's nine simulators. This paper includes examples from seven of these simulators: MH53J-WST, MH60G-WST/OFT, TH53A-OFT, AC130U-BMC, MC130H/P-WST, and the Aerial Gunner Scanner Simulator (AGSS).

The MTSS has learned that, unless proactive processes for VDB maintenance are embedded in normal operational engineering procedures, the dynamics of a simulation site will render VDBs, and hence full simulators, less effective. In fact, large VDBs may be rendered inoperable by unattended VDB maintenance issues.

Consider the following example:

A simulator is slated to get a new wrap-around (220° FOV) display to replace the current CRT display system. The image generator and mission parameters have not changed only a portion of the display architecture has changed. Thus, the decision is made that the existing VDBs will perform the same after this modification. Or worse, the decision fails to consider the VDBs!

The VDB had been specifically tuned to the old display channel design, and the wrap-around display allowed the trainee pilot to see the (previously acceptable) reduced visual range of the side window, while looking out the forward window. In front of the pilot, the distant mountain horizon was incomplete, the visual anomaly was a large negative cue, and overall training value was seriously reduced. The new wrap-around display was a technological advancement that should have yielded enhanced training, except the VDB was designed to optimize the old display system and an overall reduction in training effectiveness was the final result.

This is a true story, a tough lesson learned, and a central point of this paper. Before we discuss the root causes and corrective actions necessary when dealing with VDB maintenance, consider some background information.

BACKGROUND

An effective simulation system should [effectively] orchestrate the simulator architecture, the mission parameters, and the VDB (Figure 1). For this paper, the phrase mission parameters may be regarded as the training requirements.

A VDB is a 3D digital environment that is fabricated for visual simulation. Usually, VDBs are removable and can be swapped out with a different VDB to match the current training scenario and should be regarded as separate from the simulator hardware and software. In recent years, the cost of VDB development has risen (Burnham, Fortin, and Jaquish; 1996) and thus, makes the VDBs an important training site resource. Also, since an image generator cannot display everything, the VDB engineer must make design decisions concerning what shall be in the VDB and at what resolution, when trying to portray structure, density, position, and relative arrangement of different features.

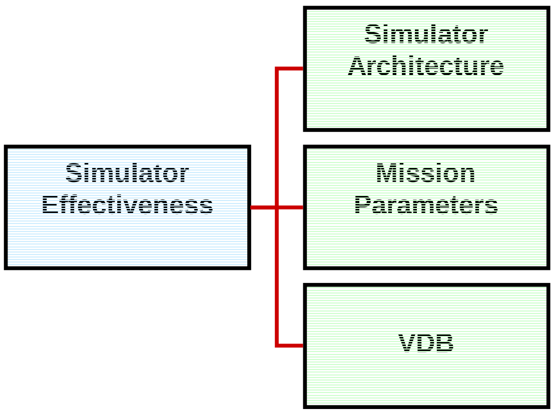

Figure 1. Three Variables That Drive System Effectiveness

A good VDB design uses the best source data available, optimizes the simulator architecture, seeks to specifically achieve mission parameters and correlates to other data. A VDB is correlated if the features in the VDB match other simulator subsystem VDBs, other simulator VDBs in a networked environment, or other data sources (e.g., maps and flip charts used during simulator training.

VDB development consists of the design, fabrication, integration, documentation, and test of a new VDB; whereas, VDB maintenance is the management of the ongoing engineering effort, which attempts to retain the initial value of the VDBs. The VDB value, to be maintained, is the collection of factors that comprise training effectiveness.

Each of the MTSS simulators may have a unique image generator, multiple visual subsystem databases, and Special Operations Forces Network (SOFNET) compliance requirements (Briand, Lombardi, and Shearer; 1998). Once developed, each VDB is an engineering accomplishment and should be appropriately considered in operational processes.

Simulators often require modifications for new technological advancements, concurrency updates, and various other mission parameter changes. These are the root causes that often necessitate ongoing VDB maintenance.

ROOT CAUSES

The root causes for VDB maintenance may be grouped into technological, concurrency, and mission parameter changes. Consider Figure 1 as an equation. When one term on the right-hand side changes, then another term, on the right, must change to keep the left-hand side (simulator effectiveness) constant. Likewise, if training simulator effectiveness is to be enhanced, then one or more of the parameters on the right must change.

Technological Change

Technological change includes hardware and software updates to the systems. MTSS simulators have been improved with greater storage, faster processors, and newer operating systems. Also, simulation-unique products become available; for example, the initial example of a wrap-around display is a technology advancement (SEOS Displays Limited, Panorama Series projection system) that was chosen for its improved cross-cockpit viewing and hence, more effective simulations.

Technological change has altered the simulator architecture. Figure 1 suggests that simulator effectiveness get impacted unless the mission parameters or the VDB is manipulated respectively. This is the first lesson learned.

Storage. The advent of greater storage capability meant different storage media were necessary. Encore 1G drives were replaced with Mountain Gate 4G drives, requiring all of the associated VDBs to be moved to the new packs, header files changed, and all the data revalidated. Two advancements were incorporated to accommodate these changes: (1) to keep more VDBs on-line, and (2) to combine VDBs into larger units. For example, HOTEL and OSCAR (two of the many MTSS site VDBs) were combined into one VDB. These two VDBs were adjacent, but too large to play at once. A second lesson learned.

VDB combination is straightforward from an engineering aspect; both VDBs' tables (color, texture, face attribute, range etc.) had to be condensed into one. The action allowed for a larger gaming area, many more training possibilities, and lowered administrative overhead (Lombardi and Reed; 1994).

We should note that the new drives were a significant improvement, but the impact on the existing VDBs required much consideration. With unchanged mission parameters, we were able to retain simulator effectiveness by adjusting the VDBs to reflect the simulator architecture changes (refer to Figure 1).

Processors. Faster processors (PowerPC for the MH60G-WST host, RSX/DEC Alpha for the TH53A-OFT and MH53J-WST hosts, and RSX upgrades for the image generators) meant that more data could be processed and displayed; but the existing VDBs were designed with lesser processors in mind. Training did not fully leverage the new processors until the VDBs were made denser, or the visual ranges extended. To solve this, the MTSS automated the addition of geo-typical features across the gaming areas and then tapered off the density in target areas, where specific features were added at user request. Then training effectiveness was left in tact by VDB maintenance. A third lesson learned.

Operating System. On the MH60G-WST, more processing power meant an operating system upgrade from Encore 3267 to MPX-32 RSX. In doing this, the MTSS had found that the proprietary Special Effects Editor software became inoperable ("special effects" are the action in a VDB; they are a moving-model with an associated sequence of state changes). The MTSS has long had all the required special effects and have not utilized this code for several years, but this is one of the reasons that no one had caught the discrepancy during the design reviews for the associated. Another lesson learned.

Although unimplemented at the time of this paper, the MTSS plans to design, tune, and test special effects on the AGSS and then convert image generator formats from the AGSS SE2000 to the MH60G-WST C-V. Effectively, the MTSS is avoiding the need for the unique code through VDB maintenance procedures – lesson learned.

Display Example. In the case of the new SEOS display on the MC130P-WST, the MTSS had to significantly redesign the VDB. The VDB was originally copied from the MH53J-WST, which also had a C-V image generator. We should note that reusing a VDB is a sound business decision since the cost savings from not producing a new VDB, is great. This VDB was tuned as best as possible without feature redesign to fulfill the mission parameters, but the VDB pressured the simulator effectiveness (Figure 1) since the mission parameters had changed from a rotary-wing to fixed-wing.

Eventually, the new display was the final straw, even with upgraded processors (an Encore RSX re-host), and the VDB needed to have the terrain re-triangulated based on fixed-wing requirements, that is, fewer triangles per square nautical mile. The crews are currently pleased with the resultant smooth display, and the bonus is an extended visual range (a fixed-wing requirement) now that there are fewer triangles per square. However, reworking the terrain is basically a major overhaul in any VDB format and the labor was significant. Next time, the MTSS will not miss advance warning of such a grand VDB maintenance issue. Another lesson learned.

Concurrency Change

Technology advances are continual, but site modifications are also driven by the dynamic nature of the real life entities that are simulated. This is the problem of concurrency change.

When the aircraft experiences a change, then the simulator often also needs to change. Secondly, the real world gaming area, modeled by the VDB, may also experience change. In each case, especially the second, VDB maintenance must be considered.

Aircraft Model. One example of a recent concurrency change is the addition of a Digital Radar Land Mass Simulator (DRLMS) unit on the MC130H-WST. In an effort to achieve correlation between the visual and radar databases, the existing VDB was used as the source data for the DRLMS database and a software conversion process was created. Thus, the existing VDB was an integral part of the modification and key to maintaining correlation (a mission parameter), and hence, simulator effectiveness.

In another example, the MTSS had designed and developed a VDB to meet the small field-of-view (FOV) requirements of an All Low-Light TV

(ALLTV) channel of the AC130U-BMC at Hurlburt Field, FL. FOV, along with visual range, is directly related to number of features displayed. If the ALL-TV is enhanced with a wider FOV, and the AC130U-BMC is to remain current, the associated VDB may be invalidated. An effort must be made to equally enhance the image generator processor capability, shorten the visual range(s), or thin the number of VDB features. That is, change the simulator architecture, mission parameters, or VDB to retain simulator effectiveness. Another lesson learned.

***Gaming Area Model*.** Other concurrency modifications include real-world changes. For example, the old Kirtland AFB control tower was leveled in 1994 and the Kirtland area VDBs had to be respectively altered; likewise, the real-life runway was refitted with new VASI lighting and the VDB was similarly edited. When the CV-59 USS Forrestal aircraft carrier was decommissioned, the modeled version essentially became a negative cue (the real life version didn't exist anymore), although the MTSS chose to retain it as a moving model in the VDB.

Gaming area non-concurrency may not allow realistic planning, but is quintessentially the reason why VDB maintenance is so important. Technological change and concurrency change are important causes for an ongoing VDB maintenance program.

Mission Parameter Change

A third type of event, that could cause the need for VDB maintenance, is a change in training requirements. When mission requirements change, the VDB must be considered, to keep simulator effectiveness intact (Figure 1). Overall productivity has been increased by the on site development and modification of course materials (Riley, Gallo, and Beebe; 1996). Likewise, the VDB assets must be considered when mission parameters change. Another lesson learned.

***New Gaming Area*.** Training parameters may require increasing the number of geo-cells to existing VDBs, or new areas of the globe. New VDB development is the obvious solution, but conversion of data from a different simulator is the appropriate first place to look. MTSS has successfully converted data, at some level, between many dissimilar VDB formats (Figure 2), and realized significant savings in the process.

VDB conversion is an important part of VDB maintenance at the MTSS, especially since conversion processes also provide a means of achieving correlation among networked trainers. VDB format conversion is usually more work than expected, but we have learned this involves much less work than modeling an area from scratch (Lombardi and Reed; 1994).

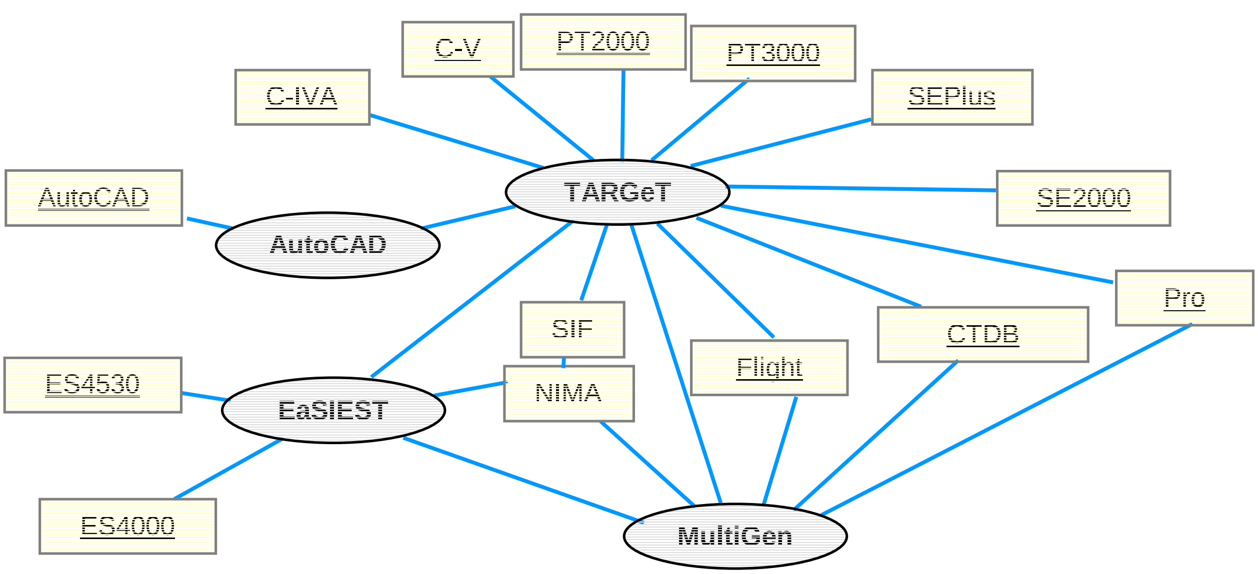

Figure 2. Overview of MTSS VDB Conversion Capability

***Target Fidelity*.** Since an initial assessment, VDBs have been enhanced to provide additional detail in areas of operation (Nullmeyer, Bruce, Conquest, and Reed; 1992). The mission(s) required more data than the involved systems could handle and simulator effectiveness was bounded. To solve this, the site began maintenance of mini-VDBs, which were only a few square nautical miles total. The mini-VDBs effectively took feature load from distant range and used it in the immediate vicinity of the target area. The mini-VDBs were cut out from the main VDB and then heavily enhanced (Figure 3). The ingress and egress routes were practiced on the larger version of the VDB and the arrival/departure were practiced on the mini-VDB.

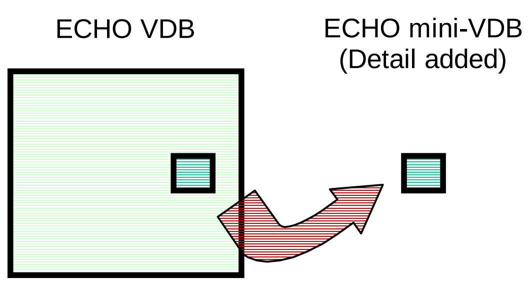

Figure 3. Mini-VDB Cut Out

In the years to follow, as the technology allowed, the MTSS was able to incorporate the enhanced mini-VDB features into their larger counterpart. For example, the ECHO VDB had a mini-VDB, which was combined into ECHO when the simulator architecture was enhanced with greater processing power. The MTSS successfully balanced simulator architecture, mission parameters, and VDB to achieve simulator effectiveness.

Since the site's inception, the team has manipulated VDBs based on intelligence data (Nullmeyer, Bruce, Conquest, and Reed; 1992). New intelligence data may be a mission parameter change and necessitate change to the VDB. Consider the unclassified SWUSA VDB as an example; the SWUSA VDB was upgraded, via VDB maintenance procedures, with ten more enhanced airfields in 1995 to satisfy extended mission parameters, and then eight more were added in 1996.

***Classification*.** Mission parameter change may also include classification level. Sometimes VDB classification change drives a repackaging of the VDB. A secret level mission may be designed to operate in an unclassified VDB, in which case another version of the VDB should be created and the new secret level features added. Conversely, a VDB can be desensitized by correctly stripping out sensitive data. This activity is part of VDB maintenance.

***Network Compliance*.** Network compliance implies both the matching of VDBs as well as network interchange issues. Since networked simulation requires some degree of correlation for the simulated world used by all players, the VDBs used in a Distributed Mission Training (DMT) scenario, need to be kept in synch with other sites' VDBs. Without VDB correlation, a whole host of "ground-truth" realism issues arise. Once VDB issues are resolved, then network connectivity should be addressed. If insufficient bandwidth or network communication protocols exist that prevent the achievement of the desired simulation rate (typically 30 to 60 hertz for real-time simulation), display anomalies arise that can cause network jitter, or prevent exercises such as air-to-air refueling from taking place. Network compliance is mandatory to ensure that a student "buys into" the realism of the network scenario.

Along with existent SOFNET compliance requirements, this year, the Theatre Air Combat and Command Simulator Facility (TACCSF) is co-locating with the MTSS campus. Although the DMT network connection had been previously demonstrated (Briand, Lombardi, and Shearer; 1998), the MTSS is ready for VDB maintenance issues nonetheless.

After many years of R&D into transmission of VDB data (four years for the SSDB Interchange Format (SIF), and five years for the Synthetic Environment Data Representation and Interchange Standard (SEDRIS)), there is still no general purpose tool widely used in industry to ensure VDB transfer and correlation. The MTSS utilizes VDB conversion techniques to ensure that the VDBs maintain networked simulation correlation.

Each of the above situations exemplified a VDB maintenance issue that had arisen from a technological, concurrency, or mission parameter change. Each situation had a unique reaction, yet the real challenge is to alleviate root causes with action that is embedded in normal operational procedures.

CORRECTIVE ACTIONS

Corrective actions are the evolved business practices that help solve the root causes described in the previous section. The corrective actions are presented in three categories: configuration, the identification and tracking of the VDB product; methodology, the engineering principles involved; and processes, the specific ways business is performed.

Configuration

The first course of action is configuration management (CM), to include VDB testing and libraries.

For example, if an instructor wishes for his MH53J crew to mission plan a route through a specific piece of countryside, he need only check the VDB Status Matrix to verify that that VDB is currently available on the necessary simulator. In fact, as we will see below, he may review any discrepancies that have been reported against the VDB throughout its life. For example, the SWUSA VDB may have a discrepancy at Edwards AFB, but may still provide effective training in a Kirtland AFB to Holloman AFB route.

Testing. VDBs that have been developed and have passed an internal Acceptance Test Procedure (ATP) are handed over to the control of the CM team. The VDB engineering team works closely with the CM team to ensure that all the correct files are part of the baseline capture. This VDB becomes permanently associated with the simulator in which the Acceptance was performed.

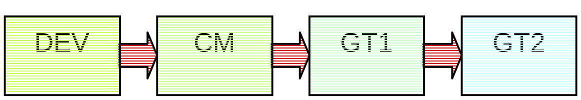

Figure 4. VDB Baseline Process

The CM team retains control of the physical media and makes additional media for Government Training (GT1) after a "customer" ATP. The GT1 packs are used for two weeks before a second set of training packs (GT2) is created. Thus, there are three sets beyond the original development packs (Figure 4). The VDB assets are effectively protected from change, thoroughly tested, and baselined.

Libraries. The VDB engineering team uses another type of configuration to solve root causes of VDB maintenance. The MTSS site is collocated with the Simulator Database Facility (SDBF), which is a VDB feature warehouse (Lombardi and Reed; 1994). The SDBF houses and organizes (Mil-Std 1820 and 1821) the MTSS site VDBs data along with off site data. Other programs have realized savings by converting internal formats to SDBF standards (Merchant; 1996) as well.

The SDBF data is organized by feature, not just whole VDBs. Thus, individual features (buildings, trees, textures, terrain skin, etc.) may be easily reused. Leveraging existing data is inherent in the MTSS operational processes.

Just as the SDBF houses previously developed VDB features, the MTSS has an Intelligence Team that collects and controls source data (imagery, maps, digital data, etc.). In this way, the best source is always in use and a VDB can be traced back to the source data by which it was developed (Lombardi and Reed; 1994).

Methodology

Once configuration needs are met, the site is ready to operate. Some of the overarching principles involve quality, communication, and engineering best practices.

Quality. In 1996, the International Standards Organization (ISO) awarded the MTSS with ISO-9001 accreditation. The accreditation verifies that the MTSS has mechanisms in place for continuous process improvement and recurring VDB maintenance root causes are effectively reduced.

For example, the Corrective Action Board (CAB) is a team that meets every month. The CAB is a management review of site operational procedures that monitors process improvements.

Communication. Whenever feasible, avenues of communication are established between the engineers and the instructors. The instructors provide Subject Matter Expert (SME) skills to the engineers and the engineers provide engineering background to the instructors. Thus, the engineers can understand user needs first hand

and the instructors can knowingly leverage the best characteristics of the simulator.

For example, instructors play a significant role in modifying materials to suit individual class needs (Riley, Gallo, and Beebe; 1996).

***Best Practices*.** Examples of engineering best practices are the use of automated processes for generation of simulator subsystems and conversions of VDBs, and VDB features, from one format to another.

For example the SWUSA VDB was created for the MH53J-WST in C-V (an image generator) format and passed along to the MH60G-WST. Instead of using the source data to build the Harris Nighthawk DRLMS database, an automated process was created to generate the radar database from the visual database; the radar database is a VDB in its own right. When the MH60G-OFT simulator came on line, the SWUSA VDB was then converted to the MH60G-OFT PT3000 (another image generator) format. When the two simulators were networked, the VDBs were correlated and the two simulators could effectively operate together as provided by VDB design.

Every time the MTSS requires new VDB data, engineers endeavor to find the best conversion process (Figure 2). In this way they can most effectively migrate VDB resources from one simulator to another. The best-looking oak tree model in a VDB on the AGSS can be leveraged for use in a VDB on the MC130P-WST.

Another engineering best practice is the use of a standardized library and the VDB source files. Unlike the SDBF, which is an expansive library of all VDB features, the standardized library is the best of the best for individual database features. Usually these features are geo-typical, that is, a single-family dwelling as opposed to the geo-specific Empire State Building, but can also be colors, textures, table formats, density limits, etc. The standardized library is a starting point for a new VDB and permits extremely efficient VDB development (Lombardi and Reed; 1994).

Once, the SWUSA VDB had been migrated to every simulator on site and the MTSS required an effective way to migrate VDB change from one simulator to another.

The answer is to keep the SWUSA source files - data format beyond the imagery, maps, and digital data, but short of simulator ready processed files (Figure 5). One set of SWUSA source files means that a change on the MH60G-WST SWUSA will eventually flow to the TH53A-OFT or the MC130P-WST. The crews experience the best data possible. As we will see below, full records of these changes are kept by an automated management system.

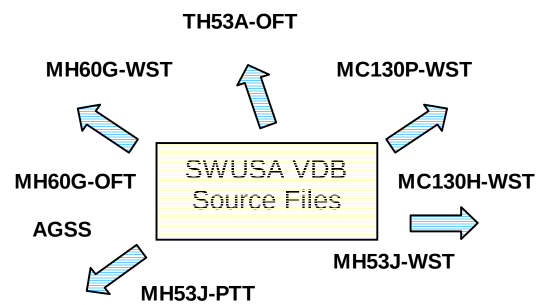

Figure 5. One VDB Source, Many VDBs

Attention to continuous improvement, communication and VDB conversion techniques are all instrumental to the resolution of root cause VDB maintenance issues.

Processes

The third type of corrective action is process. The MTSS has a management organization that provides a single point of contact for each simulator. This point of contact is familiar with the students, instructors, and engineers involved and facilitates prioritization at Integrated Product Team (IPT) meetings.

Other processes, that help provide corrective action for VDB maintenance, include Internal Maintenance Management System (IMMS), the Engineering Review Board (ERB), and the Configuration Control Board (CCB).

Students, instructors, and engineers have access to the IMMS, an on-line discrepancy database. Instructors enter new discrepancies as part of the exit procedure for a training mission and engineering efforts are geared toward the most critical problems based on customer priority.

The ERB is the forum that approves any engineering change and in attendance is a representative from VDB engineering. The ERB is arguably the most formidable aid for the avoidance of VDB maintenance problems.

Finally, the CCB is the protector of the baseline; all parties meet a final time to approve any simulator baseline changes, to include any of the VDBs.

The most important process is the simple acknowledgement that VDBs need maintenance. The MTSS has learned that VDBs, and their value, shall be a discussion item during every engineering maneuver and that integrated VDB maintenance is a critical component to the retention of VDB value and, in turn, simulator training effectiveness.

CONCLUSIONS

An effective training system orchestrates the simulator architecture, the mission parameters, and the VDB. VDBs play a vital and critical role in the training effectiveness of a simulator system and are certainly a resource to acknowledge. VDBs should be considered an asset separate from the simulator hardware and software and, as such, should have operational processes that protect their value.

Unless the simulator facility is completely static, technological advances, concurrency modifications and mission parameter changes may cause anomalies with the existing VDBs. In an effort to retain initial value, the VDBs should go through regular maintenance and should be considered during any engineering change proposal.

VDB maintenance, to include VDB format conversions, is almost always less expensive than recreation. Much of avoiding VDB maintenance rests in the knowledge that maintenance is necessary and should not be a surprise.

This paper has outlined the root causes for VDB maintenance, with examples, and the corrective actions that the MTSS has employed over years of lessons learned.

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