The Creation of GrafenBob for the JTEP LVC Demo

Michael Beebe, Mark Faust, Reginald Ford, John Shockley
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025
650-859-6734, 650-859-4165, 650-859-4375, 650-859-4434
mike.beebe@sri.com, mark.faust@sri.com, reginald.ford@sri.com, john.shockley@sri.com

Mark Johnson
SRI International
4111 Broad Street; Suite A-7
San Luis Obispo, CA 93401
805-542-9330
mark.johnson@sri.com

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ABSTRACT: *The Joint Training Experimentation Program (JTEP) is a multiphase, multiyear effort to develop a distributed training capability for the California National Guard (CANG) that includes live, virtual, and constructive (LVC) training simulation to support multiechelon training. The second JTEP demonstration was a battalion-level exercise conducted in December 2003. This demonstration linked the Joint Combat and Tactical Simulation (JCATS), a constructive simulation; the Close Combat Tactical Trainer (CCTT), a virtual simulation; the Deployable Force-on-Force Instrumented Range System (DFIRST™), a live instrumented training system; and observers at the Office of the Adjutant General (OTAG). JCATS and CCTT were located at Camp San Luis Obispo, California; DFIRST was located at Camp Roberts, California; and the OTAG observers were located at Sacramento, California.*

An early finding in the development of both JTEP demonstrations was that in order to provide a sufficient level of interoperability for company, battalion, or brigade level exercises, all federates needed to operate on correlated terrain. For the second JTEP demonstration, this requirement proved particularly difficult to satisfy, since the live (DFIRST) entities would be at Camp Roberts, while the best terrain available to the virtual federate (CCTT) was Grafenfels. For strong correlation among terrains, one must be the primary terrain and all others must be derived from that primary terrain. In this case, neither terrain could be modified; JTEP had two primary terrain sets. In order to create a single battlespace in which all LVC federates could operate, JTEP created "GrafenBob," a stitched synthetic environment that included portions of both Camp Roberts and Grafenfels. Correlated terrain was then created for JCATS, the JTEP constructive federate. The correlated terrain was used for direct and indirect fire engagements among LVC federates, a stealth viewer for 3-D display and after-action reviews (AAR), and a virtual-constructive unmanned aerial vehicle (UAV) that provided real-time imagery of all LVC entities in the battlespace. The creation of GrafenBob enabled a maximum level of interoperability.

This paper describes the process of creating GrafenBob, starting with a SEDRIS Transmittal Format (STF) of Grafenfels, stitching it with the National Guard Bureau (NGB) Geographical Information System (GIS) source data of Camp Roberts, and creating derivative correlated terrain for the remaining federates. It discusses lessons learned, including the discovery of a difference between federate representations of height (based on geoid vs. ellipsoid reference systems), and plans for future work.

1. Introduction

1.1 JTEP overview

The Joint Training Experimentation Program (JTEP) is a National Guard Bureau project managed by the California National Guard (CANG). The Guard currently uses advanced live, virtual, and constructive (LVC) systems[1] to support training, but each system is stand-alone. JTEP is intended to bring to the Guard the benefits of integrating existing or readily available training environments, and to enable LVC interaction over nondedicated wide-area networks (WANs).

JTEP started with an initial study to determine which candidate systems and integration mechanisms would achieve the greatest training impact. After the initial study, the first demonstration, linking live and constructive training systems, was conducted in May 2003 [1]. The second demonstration, conducted on December 11, 2003, was a complete LVC integration. This was a battalion-sized demonstration with approximately 125 total live and simulated entities. An overview of the JTEP LVC Demo is available in [2], which includes discussion of innovative features such as a virtual Unmanned Aerial Vehicle (UAV) for reconnaissance and the use of pop-up gunnery targets to facilitate Live-Constructive engagements. Additional companion papers presented at this workshop address specific technical aspects of this demonstration, including the distributed after action review (DAAR) [3], the training value provided [4], and the integration of CCTT and JCATS [5]. General JTEP information is available at www.jtepforguard.com.

1.2 Motivation

The December JTEP exercise used CCTT, JCATS, and DFIRST[2] as the main federates. It was recognized early on that correlated terrain was essential to interoperation [6]. Since DFIRST was to operate on Camp Roberts and JTEP already had a Camp Roberts terrain database (TDB) for use in JCATS in the previous (May 2003) demonstration, Camp Roberts would have been the best choice for terrain for the LVC demonstration. Unfortunately, Camp Roberts was not among the set of TDBs available for use by the third principal federate, i.e., CCTT. Our choice was either to have CCTT operate in one of its TDBs separate from the other federates or figure out a mechanism to enable CCTT to play in the same overall playbox as an integral federate within the demonstration. Our solution was to create a combination of a CCTT TDB and Camp Roberts, i.e., by stitching the two areas together, that would enable all of the federates to operate within the same exercise space. The principal issues, then, were (1) what CCTT terrain set would be used for the exercise and (2) how we would create a hybrid terrain that encompassed both the CCTT TDB and Camp Roberts so that all of the LVC entities could interact.

In identifying candidates for CCTT TDBs, we had to consider a number of factors: (1) which TDB had an available SEDRIS Transmittal Format (STF[3]) that would enable us to convert the TDB to something that could be stitched to Roberts and correlated with JCATS, (2) which TDB was capable of running on the CCTT processors resident in the mobile CCTT set that was available for use by the CANG, and (3) which TDB would match the general look and feel of Camp Roberts so that the transition between the two areas would not be too abrupt. CCTT's P6, Grafenfels, TDB was eventually chosen. Although there is considerable contrast between the German countryside it represents and Camp Roberts, it was the only CCTT terrain that had an available STF 3.0 and would run on the hardware and operating system of the CCTT mobile trailers that were used in the exercise.

Once the TDBs were chosen, the next issue was how to develop a single terrain set that would serve as the "truth" set from which the remaining data products could be correlated. For the degree of correlation required, the terrain creation process would need to use one federate's terrain as "truth," and the rest of the terrains would be created directly from that TDB. In our case, however, neither the P6 nor the Camp Roberts TBDs could be altered or rebuilt to create a single "truth" set. The solution was to create a canonical terrain that was a hybrid of Grafenfels and Camp Roberts, i.e., GrafenBob, and use this as the "truth" set from which correlated terrain products could be built.

Once GrafenBob was built, we were able to develop correlated terrain on which:

- JCATS and CCTT entities interacted in "fair fight" direct and indirect fire engagements, and JCATS and CCTT entities worked in a

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[1] A live "simulation" comprises real people, real vehicles, real environment, and simulated weapons. A virtual simulation comprises real people, simulated vehicles, simulated environment, and simulated weapons. A constructive simulation comprises some real people, some simulated people, simulated vehicles, simulated environment, and simulated weapons.

[2] CCTT: Close Combat Technical Trainer; JCATS: Joint Combat and Tactical Simulation; DFIRST™: Deployable Force-on-Force Instrumented Range System.

[3] STF: Synthetic Environment Data Representation and Interchange Specification (SEDRIS) Transmittal Format.

[5] M2SAF: Multi-Modal Semi-Automated Forces.

coordinated fashion as cross-attached company teams.

- A virtual-constructive unmanned aerial vehicle had a seamless view of the LVC battlespace.

- JCATS constructive and DFIRST live entities interacted in “fair fight” direct and indirect fire engagements.

The following sections describe GrafenBob, the terrain creation process that yielded GrafenBob, the JTEP terrain lab and tools, challenges encountered, and the overall results of the effort. Following these sections is a brief discussion of future work and a summary.

2. GrafenBob Description

2.1 Structure of GrafenBob

The GrafenBob TDB was created from two separate source data groups. The first was the STF for CCTT’s P6 terrain, Grafenfels. The second set of source data was high-resolution GIS data for Camp Roberts provided by the NGB GIS project. Early on we realized that GrafenBob would need to be in a single geographic location, i.e., either in Germany or in California. Because JTEP had more direct access to the DFIRST software than to the CCTT software, we decided that it would be much easier to convert DFIRST locations to Germany than to convert CCTT locations to California. Consequently, the GrafenBob TDB was created in the same geographic location as P6, i.e., Germany. We first identified a section of P6 to form the overall boundaries of GrafenBob and then selected an irregular area in the southwest corner of that section to be replaced with a portion of Camp Roberts. A portion of the Roberts terrain data was then stitched into that irregular area to form GrafenBob. Because the elevations of Camp Roberts and Grafenfels differ by approximately 300 ft., the Roberts portion of GrafenBob was raised to form a smoother border with P6.

An additional aspect of the GrafenBob structure is that the two component TDBs are different general types. The Camp Roberts TDB from the NGB GIS program is high-resolution geo-specific terrain based on aerial photo imagery. For the May JTEP demo this TDB was the basis for DFIRST and JCATS interactions. The Grafenfels TDB is lower resolution geo-typical German terrain developed for CCTT. The overall structure of GrafenBob, then, is a stitch of geo-specific with geo-typical terrain that is combined into a single playbox. Correlated JCATS (DAF) terrain was developed from that to support interactions between the JTEP federates.

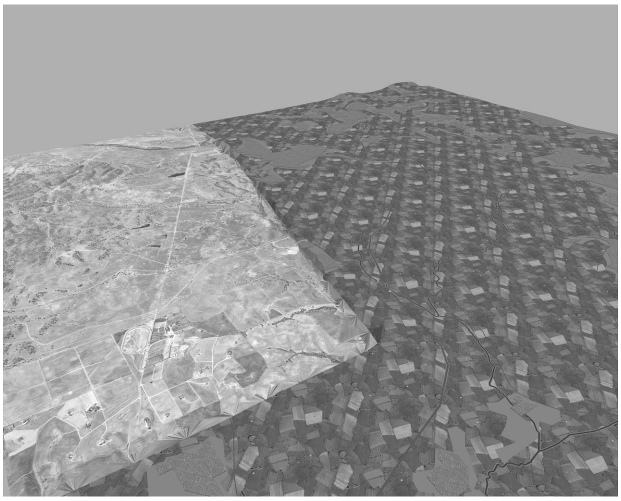

Figure 1. GrafenBob TDB without unit graphics

2.2 Products

For the December demonstration several terrain products had to be created.

- For 3-D visual databases, we created TDBs in mdx format to run on MetaVR’s™ Virtual Reality Scene Generator (VRSG), acting as a virtual sensor payload for the UAV. Figure 1 shows the stealth observer running the mdx file format for GrafenBob. (See www.metavr.com/technology/mdxformat.html for a description of the mdx format.)

- We added an overlay of the unit graphics and created a separate mdx file for the VRSG acting as a stealth observer.

- To allow JCATS to act on the entire playbox, a DAF terrain, the JCATS terrain format, was created directly from GrafenBob. This TDB was tightly correlated to both P6 and Camp Roberts.

- An electronic 2-D map of GrafenBob was created for SRIdisplay as a 2-D viewer.

- For the soldiers’ operational use, 1:24,000 paper maps in Military Grid Reference System (MGRS) with 20 m contours were also created.

- An Openflight TDB was created for testing and external distribution.

The challenge of making these products drove the design of the JTEP terrain creation process and terrain lab. The process, lab, and lessons learned are addressed below.

2.3 Results

The final result of GrafenBob was the creation of a synthetic natural environment in Germany that stitched together a geo-typical portion of CCTT P6 TDB and a geo-specific Camp Roberts. A number of correlated terrain products were then derived from that environment to provide TDBs for JCATS operation, UAV, 3D Stealth views, 2D SRIdisplay views, and paper 1:24,000 maps.

The practical result of the creation of GrafenBob was that JTEP was able to demonstrate indirect and direct fire engagements between live (DFIRST) and constructive (JCATS) entities; indirect and direct fire engagements between virtual (CCTT) and constructive (JCATS) entities; doctrinally correct cross attachment of JCATS and CCTT entities; and a virtual-constructive UAV with a seamless view of all LVC entities in the GrafenBob battlespace. The tight integration between CCTT, JCATS, and DFIRST was a key factor in JTEP's success in providing excellent training value.

3. Terrain Creation Process

3.1 Information flow

The flow of information between the tools in the terrain lab was not simple or linear. The P6 data were used to generate terrain in CCTT's native location, but the Roberts portion had to be built and then translated to Germany. Once the canonical TDB was built, the subordinate 3-D and 2-D products were extracted from it. Frequently, the data flow looped between several of the tools. Testing was an integral part of the entire process. During the processing, we designed the information flow to avoid redundantly processing data.

During the creation of the terrain products, we deliberately processed the source data as little as possible. Whenever we could get data by reimporting source data instead of extracting it from an intermediate product, we went to the source. The more the data were manipulated, the more noise and artifacts were introduced. This was especially true when reprojection was required. Certain coordinate transforms do not preserve geometry [7]. When such involved transforms are required, every effort must be made to minimize their impact on correlation.

We kept a strong idea of context throughout the process. For example, it is generally a waste of effort and time to oversample data. The relative accuracies and envelopes of correlation significantly affect the amount of time needed to verify a given step's accuracy and determine whether a test result is acceptable. We also considered how the data were going to be used. A visual database does not need to be correlated as tightly as a TDB that determines the results of engagements. In short, we tried always to remember what we started with and what we were trying to create. Figure 2 illustrates the general data flow for the development of GrafenBob.

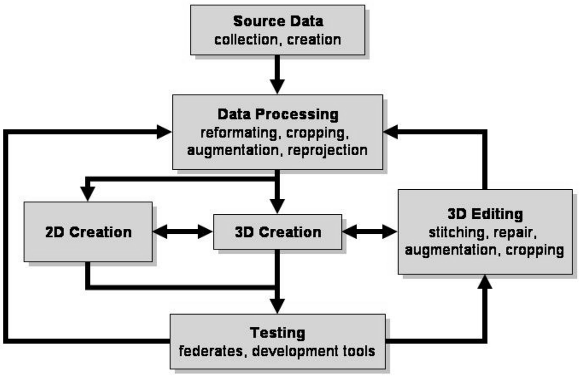

Figure 2. Data flow of GrafenBob development

3.2 Development principles

In developing JTEP's terrain products, we found ourselves in new territory several times. Some concepts of our development work proved particularly valuable. These are addressed below.

While it may make sense that all that is required to achieve correlation between TDBs is to have the TDBs to be of the same place, such a view is oversimplified and ignores numerous problems: places change, different methods are used to collect source data at different times, and those source data are sampled at different intervals. The solution seems to be to use the same source data. While this is a better solution than using different source data, we believe that a single, canonical TDB is necessary for generating a highly correlated TDB [8]. This TDB is the source for all the other terrain products. In our case, the hybrid GrafenBob terrain had to be considered as our single source for generating other products, even though GrafenBob was itself derived from two separate sources.

The processing that goes into creating a terrain product sometimes adds distortion to the data. It is important to push the branch points in the development path for the terrain products as far as possible to the end of the process. In other words, the longer one can work with a single, unified set of data before splitting into different paths for each format, the better the correlation.

Another tenet of our development was that it is not possible to develop terrain products in a vacuum. What the end user is going to do with the TDB is an essential part of the development process. Specifically, the visualization of the terrain drove many of the parameters of our products. This is important for those of us who must reuse TDBs from other projects. To reuse terrain data well, one must be able to edit, recompile, or otherwise alter it for use in a specific application. Interchange standards like STF and Openflight make TDBs more reusable, but the current standards and technology do not support the idea of effortless “drag and drop” terrain. The constraints and strengths of the specific image generator (IG) and functional use can cause a terrain that worked perfectly in one case to be unacceptably slow or artifact filled in another case. The details we encountered that influenced TDB performance and quality include the use of secondary textures, polygon draw priority, LOD switch distances, and variations in the amount of available texture memory.

The importance of testing through the whole development process is impossible to overstate. Without testing during development, the source of a large error can be very time-consuming to determine. In our work on JTEP we tried to identify and solve problems early, because we recognized that a number of problems had their source in an earlier stage of terrain production. Failure to correct a problem early could easily have resulted in a cascading error correction process that might have prevented us from meeting our overall demonstration deadline.

Our testing methods were twofold. We used the JTEP testbed with the federates to examine the terrains and to check for correlation. An excellent way to check several components at once was to run a test between two federates, e.g., place a unit at an intersection and see where that unit appears in CCTT and in JCATS. We also focused from the start on making the testbed as close as possible to the final configuration of both hardware and software. This enabled us to minimize the number of surprises toward the end of development.

In addition to testing with JTEP federates in the testbed, we used one development tool (e.g., MAK Stealth) to check the results obtained with the other tool (e.g., MetaVR VRSG). The concept that emerged was to use at least two tools to look at any piece of data. Thus, if we obtained an erroneous result we could quickly determine whether the problem lay with the data or the tool that was doing the processing. While it is possible that both of the tools used to check a piece of data are incorrect, our final testing with the testbed showed that this never happened. This second independent view technique was very valuable in resolving questions relating to projections, datums, and origins.

4. Terrain Lab

4.1 Development tools

The JTEP Terrain Lab was built with all-COTS products. It uses standard PC hardware for both development and deployment. All of its software runs on Windows XP or Windows 2000. Another key aspect of our development environment was the excellent relationship the JTEP team established with our vendors. This relationship created a true partnership for success by creating a high level of intellectual buy-in from the vendors. This buy-in allowed us to focus on integration and data production. The technical support we received closely matched to our project’s needs.

We decided to take full advantage of the rapid advances in consumer-level video cards for image generation. The amount of money that the gaming community generates annually drives a massive, continuing development effort that is irresistible to leverage [9]. We believe that the simulation community cannot and should not use proprietary solutions unless very special requirements bar the use of consumer video cards. Performance decisions should consider the rapid pace of innovation in the market. When we started development, the video cards we used did not have sufficient performance to meet our goals. We had confidence that ATI Technologies would soon have a solution available, and it did, with ample time for integration and testing.

4.2 Testbed

The JTEP Testbed was another valuable resource in the creation and testing of GrafenBob. The testbed is a single logical location for all of the component systems that are or may be used in JTEP. The key systems in the testbed used for TDB testing were VRSG, JCATS, CCTT M2SAF[5], and DFIRST. This capability was invaluable for verifying TDB correlation between systems (e.g., the correlation check between CCTT and JCATS); the suitability of TDB products for each system; and suitability of the terrain to support the level of interoperability needed for the demonstration.

5. Terrain Product Development

5.1 Terrain stitching

The most unusual part of the JTEP terrain effort was the use of hybrid terrain. To stitch Grafenfels and Camp Roberts together was difficult primarily because it was novel. After trying several different approaches we achieved a breakthrough by using the tools non-linearly. For example, we used the import and export capabilities of several tools multiple times.

Our second enabling insight was to decouple the elevation from the vector culture data. This allowed the more difficult elevation portion of the stitch to be done with the tool best suited to that task. The NGB GIS data and the P6 STF were first used to create Openflight terrains. The Openflight terrains were then stitched together. This was the source for the GrafenBob’s elevation model. The vector data from NGB GIS was shifted to Germany and cropped in a GIS program. The elevation file and the vector data was reimported into the main 3D creation tool where they were combined with vector data from the P6 STF. These were the core steps for the creation of GrafenBob.

5.2 From CCTT STF to JCATS DAF and Openflight

JTEP imported the STF 3.0 version of the CCTT's P6 database to build the Grafenfels portion of GrafenBob. Working with the STF presented some challenges. At the beginning of our work we hoped the STF would be a turnkey solution to creating an Openflight version of P6. This was not the case. In creating the first JCATS TDB from the STF, we discovered an elevation offset of 32 m between the OpenFlight version that we made and the elevation reported by JCATS. We looked for a missed setting or a wrongly configured import option without success. Finally, we noted that 32 m was close to the difference between the ellipsoid and the geoid in that region, i.e., Germany. We hypothesized that the wrong definition of height was being used. After we postprocessed the DAF file to switch height definitions, the vertical miscorrelation dropped to less than 1 m.[6]

Another issue arose as a result of the way P6 was created. The P6 TDB spans two UTM zones; it is mostly in zone 32 but spills over to zone 33. To avoid a discontinuity, CCTT treats the entire P6 TDB as if it were all in zone 32. This sort of extension is not unique to CCTT; it is frequently used in work with large playboxes in UTM. GrafenBob was originally intended to use a patch of P6 that was in this zone 33 portion of P6. When we built OpenFlight and DAF TDBs of the area, we saw massive miscorrelations between entity positions in CCTT and JCATS. Errors were on the order of 200 m in different directions throughout the playbox.

The issue was which UTM zone the federates were using. Our entire playbox was in zone 33, but to correlate with CCTT, the coordinate system being used was an "extended" zone 32. JCATS has no mechanism for forcing an artificial UTM zone, so it considered the area to be zone 33. The topographies of the two TDBs were identical, but when the entity positions were sent through with DIS PDUs, the coordinate transformations were not able to place entities correctly. We solved the problem by relocating the playbox entirely within zone 32.

When all of the apparent critical issues affecting interoperation had been overcome, we still found that differences between VRSG and CCTT appearances remained and could not be fixed. The P6 TDB was developed for the particular CCTT combination of hardware, operating systems, and image generators. Some of the details that exist in P6 in native CCTT were not possible to replicate with JTEP's run-time configuration. The issues were not performance limitations but differences in sets of supported functions. For example, Evans and Sutherland Image Generators (ESIGs) use secondary textures differently than VRSG running on a PC with a Radeon 9800 XT video card. As a result, the scene on VRSG appeared brighter than inside the CCTT trailers.

To think of an STF version of a terrain as a complete solution to TDB exchange is akin to thinking of DIS as a complete solution for interoperation between simulations. It is part of the answer, but what is put into the STF, the coordinate systems used, and the receiving federate's hardware and software configuration must be considered in porting a TDB [10]. Translating file formats is the beginning of the work, not the end.

5.3 DFIRST translation to Germany

In order to interoperate with JCATS and CCTT in the JTEP demo, the live instrumented vehicles from the DFIRST system had to appear, to those other systems, to be moving across the same synthetic GrafenBob battlefield as their own entities despite actually being at Camp Roberts, California. This was accomplished with a simple software modification in the DFIRST base station.

The DFIRST Participant Instrumentation Package (PIP) reports its position over a radio network to the base station as meters East, North, and up in a local tangent plane (LTP) centered on the base station's GPS reference receiver antenna. Software in the base station then translates this radio position message into a geodetic (latitude and longitude) world coordinate and broadcasts the result on the local area network (LAN) for consumption by the rest of the system (data loggers, map displays, etc.). The DFIRST DIS gateway converts these network messages into DIS PDUs and forwards them on to the JCATS and CCTT gateways for use by those systems.

For JTEP, this DFIRST software was modified to use an alternative origin, located within GrafenBob, for the LTP-to-geodetic transformation. That way, all PIP position reports on the LAN contained GrafenBob latitudes and longitudes. Fortunately, a bush very close to the real-world DFIRST origin was faithfully represented in the aerial photography skin laid over the

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[6] Note that a constant correction of ~32 m was applied through the GrafenBob TDB. We understand that the ellipsoid vs. geoid difference is not constant over that area. This simple correction proved adequate for the December demonstration, but future efforts will include the standard correction formula.

NGB GIS data. That allowed visual correlation of the real origin with the equivalent GrafenBob point.

The DFIRST dismounts had to be handled slightly differently because they report their actual geodetic position over the radio networks. Their time-space position information (TSPI) was first converted in the base station to the same base LTP that the vehicles used, and then converted back to geodetic via the GrafenBob origin. The result was the same as in the vehicle case, i.e., all base-station LAN dismount messages contained GrafenBob latitudes and longitudes.

5.4 Unit graphics overlay

Unit graphics are the lines and other symbols used by the unit commander to indicate Tactical Assembly Areas, Lines of Departure, locations of Objectives, etc., on maps. In a typical training exercise, these lines are drawn on acetate overlays and the overlays are taped over paper maps of the area of interest. As part of the terrain generation effort, JTEP added these graphics to a visual database so that the database could be used to facilitate vehicle location relative to objectives, etc., and therefore, be a valuable addition to the after-action report (AAR).

Figure 3. Detail of unit graphics on acetate overlay (right); same graphics overlaid on TDB (left)

From the warfighters' point of view, exercise planning and preparation was not impacted by the creation of unit graphics. They did not have to use special tablets for entry or submit final plans early. In fact, the plans were revised several times in the few days before the exercise. We added the revised plans to the TDB overnight: less than 12 hours elapsed between a change being made and the new TDB being ready. While the process that we used was sufficiently fast, it was labor intensive. For the future, we are looking to exploit several improvements in our tools to make the process much faster and automatic.

5.5 Hardware performance limitations

VRSG was running on Windows XP with a 256 MB Radeon 9800 XT video card. The main limitations that we had to consider were the amount of texture that could be used without paging and the memory footprint of the TDB. While MetaVR claims the mdx format pages textures well (i.e., swaps textures from disk to video memory), we decided to stay under the paging limit because (1) we could easily afford to do so with the size of the playbox involved and (2) we wanted to ensure that we experienced no performance issues. Roughly, with 1 m pixels, the largest geo-specific playbox that could be run on a 256 MB card without paging would be 84 km^2.

The other limitation had to do with available RAM. Windows XP has problems with more than 3 GB of RAM and cannot recognize more than 4 GB. However, an even more restrictive limitation is the approximate maximum of 2.3 GB of RAM that can be used by any single application, irrespective of the amount of physical memory available. As with the texture, we preferred to avoid paging geometry. Our scenario was small enough that keeping applications under 2 GB was not a problem.

6. Results

The creation of GrafenBob was not a straightforward process. Even the concept itself was the result of some unusual circumstances. JTEP is chartered with creating an LVC training environment with existing or readily available CANG assets, which included CCTT, JCATS, and DFIRST. No single terrain area on which all of these could operate simultaneously was available to us. GrafenBob was, therefore, born out of the necessity of making the JTEP LVC demonstration a reality.

The creation of GrafenBob and the resulting correlated terrain sets for all of the federates of the JTEP LVC demonstration became a cornerstone on which LVC interoperability was established. Through GrafenBob, we were able to develop a TDB that was sufficiently correlated to allow direct and indirect fire engagements between CCTT and JCATS and between JCATS and DFIRST. It also enabled JCATS and CCTT entities to operate in cross-attached company teams as they would normally do according to doctrine. The smooth stitching of the Graf and Bob portions of the TDB enabled JCATS entities to transition between the two areas during the exercise.

GrafenBob obviated the necessity of segregating CCTT entities into their own portion of the battlespace, and thereby enabled true LVC interaction. As a result, the JTEP demonstration was able to provide a view of the value of LVC-based training. This training was subsequently reported by participants to have been the best they had ever received in the Guard.

So, while the creation of GrafenBob revealed a number of key findings related to terrain generation, stitching of terrain sets of differing resolutions, correlation, and terrain formats, the ultimate result of GrafenBob was a solid training experience.

7. Future Work

7.1 Automation

The broadest improvement in the JTEP terrain work will be increased automation throughout our entire production process, from source data acquisition through final testing. Some improvements will be achieved through the creation of simple elements like scripts, while other improvements will come from the addition of tools or improvements in existing tools. Several of our processes will be dramatically improved with the next release of TerraVista and VRSG, two of the main tools used. Automation is important not only for speed and cost, but also for consistency. A good process should be repeatable if it is to be systematically improved. Increased automation will also allow JTEP efforts to scale more easily.

7.2 Hardware Improvements

Two forthcoming changes in PC hardware will strongly enhance JTEP's terrain and visualization work: the rollout of PCI-Express and the introduction of 64-bit computing for Windows.

PCI-Express support for multiple video cards in the same machine opens up exciting new possibilities for JTEP, since it will allow us to cost-effectively produce multiple simultaneous viewpoints.

Sixty-four-bit computing will allow a much larger amount of memory to be addressed, which will improve our ability to handle large playboxes and increased resolution. Also, our terrain building should see a boost in speed, which is significant when running multiple-day builds of terrain databases.

7.3 Military Operations on Urban Terrain

There is strong interest in the simulation community in better training for Military Operations on Urban Terrain (MOUT). A future focus of JTEP is "Urban JTEP," i.e., exercises in urban areas. As a result, the JTEP terrain generation process will need to adapt to this new environment. Building urban TDBs is a task significantly different from building TDBs for large, mostly open areas. The degree of precision required is much higher, and the creation of the buildings themselves is not easy. A simple ortho-photo set is no longer sufficient for geo-specific imagery. Not as much supplemental information about the texture and geometry of buildings is available and the formats are less mature. As with most terrain efforts, the quality and ease of creation of the TDB will be driven primarily by the source data.

JTEP is looking at fast and precise ways of capturing the supplemental data required for complex urban simulation from laser scanning to photogrammetric techniques. We expect that other disciplines, such as urban planning and movie production, will have many of the answers to the problems now facing the simulation community for MOUT TDBs.

7.4 Post-Mobilization (Predeployment) Training

Current events are causing National Guard units to be activated, i.e., mobilized, and sent overseas with increasing frequency. JTEP will be providing some of the units with post-mobilization training before they are deployed. We expect that geo-specific and purpose-built terrains, combined with 3-D visualization, will add value to the training for many of the Guard's missions, e.g., convoy support and patrols.

8. Summary and Conclusions

JTEP's creation of the GrafenBob terrain allowed us to solve several problems of LVC interoperation. The technical accomplishments are gratifying, but making the underlying technology work smoothly enough for the soldiers to focus on training was even more satisfying.

We embraced the industry's best practices and tried out a few new ideas, most of which proved successful. We pushed the limits of our tools, and as the tools grow our goals will expand to provide better training value. We hope to continue our success when we begin working with MOUT terrain creation by leveraging advances in hardware and software for both visualization and creation.

9. References

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Author Biographies

MICHAEL BEEBE, Research Engineer at SRI International, has experience in systems engineering, remote sensing, GIS, and terrain database creation. In addition to being active in the development of DFIRST for the National Guard, he has worked with the Special Operations community. His primary JTEP responsibility is synthetic natural environment creation and 3D visualization.

MARK FAUST, Research Engineer at SRI International, has been working on test and training range instrumentation systems for the Army, Navy, and Marine Corps for 10 years, primarily writing software and testing radio data links. His JTEP work has focused on DFIRST integration.

REGINALD FORD, Software Development Manager at SRI International, has 24 years of experience in test and training range instrumentation systems for the Army, Navy, Air Force, and Marine Corps. He helped establish SRI's Software Engineering and Development Program and is a member of the Instrumentation and Simulation Program. He manages DFIRST software development and the integration of JTEP software systems and components.

MARK JOHNSON, Senior Software Engineer at SRI International, has over 20 years of experience in engineering and simulation and is a member of SRI's Software Engineering and Development Program. On the JTEP project he concentrates on JCATS, CCTT and the interoperation of these systems.

JOHN SHOCKLEY, Senior Research Engineer at SRI International, has 20 years of experience in test and training range instrumentation systems for the Army, Navy, and Air Force. He began working on modeling and simulation aspects of these systems and has since participated in DIS/HLA standards development activities for over 11 years, concentrating on integrating live and virtual systems. He is the JTEP project leader.