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Conceptual Methods for Generation of Urban Terrain Data for Military Operations in Urban Terrain (MOUT)

Charles D. Hahn, Laura S. Bunch, and Jerrell R. Ballard, Jr.

December 2002

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Conceptual Methods for Generation of Urban Terrain Data for Military Operations in Urban Terrain (MOUT)

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Preface

This report describes conceptual procedures for the generation of urban terrain data and the application of those procedures to an urban area in Mississippi for application/demonstration on the OneSAF test-bed. This study was conducted with funds provided by the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers, under the Research, Development, Test, and Evaluation (RDT&E) Program. The aim of this study was to provide procedures and a realistic data set to improve the understanding of robotic mobility vehicles and evaluation of candidate smart sensors for use in Military Operations in Urban Terrain (MOUT).

This report was prepared by Mr. Charles D. Hahn, Environmental Systems Branch (ESB), Ecosystem Evaluation and Engineering Division (EEED), Environmental Laboratory (EL), Vicksburg, MS, U.S. Army Engineer Research and Development Center (ERDC); Ms. Laura S. Bunch, MEVATEC Corporation, Vicksburg, MS, and Mr. Jerrell R. Ballard, Jr., ESB.

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This report was prepared under the general supervision of Mr. Harold W. West, Chief, ESB; Dr. David J. Tazik, Chief, EEED; and Dr. Edwin A. Theriot, Director, EL.

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1 Introduction

Background

As the world's population increases and urbanized areas develop, it becomes more and more apparent that military operations in urban terrain (MOUT) will be likely in future conflicts. Historical MOUT operations (Panama City and Kosovo) have illustrated a need to develop new tactics and procedures and an ability to train forces and staff in realistic urban simulations. The Army Simulation and Modeling for Acquisition, Requirements, and Training (SMART) Execution Plan recognizes this need and has prioritized MOUT functionality in its top band of requirements to be funded starting in Fiscal Year (FY) 2003. Also, the Army Model and Simulation Office (AMSO) established the MOUT Focus Area Collaborative Team (FACT) at the direction of the Army Modeling and Simulation Executive Council (AMSEC). The MOUT FACT is a priority component of the Army SMART Execution Plan and is a joint effort with the U.S. Marine Corps. Both of these efforts have the vision to develop capabilities to conduct comprehensive analysis, training, and acquisition related tasks in a credible MOUT Modeling and Simulation (M&S) environment to accomplish the full spectrum of urban operations.

In partnership with these programs, the U.S. Army Engineer Research and Development Center (ERDC) has initiated an M&S program to facilitate the transition of research-grade models and corporate knowledge into the M&S community at large. As a part of these efforts, a deficiency was identified in the area of small vehicle mobility in urban terrain and the effects of resolution on current mobility models. To improve this deficiency, several different synthetic rural and urban landscapes will be developed for modeling and evaluation of these mobility platforms.

Purpose

The purpose of this project was to develop, test, and document conceptual procedures for generating three-dimensional (3-D) urban terrain landscape data/ databases. These databases are to be used to determine the effects of urban landscape characteristics on smart weapons and small unmanned sensor-based ground vehicles including robotic vehicles. Several dissimilar simulation test-bed

systems (OneSAF,[1] JSAF, ModSAF) require urban terrain data/databases for evaluation and potential development of U.S. Army vehicles and training in Army tactics.

Approach

The goal of this project was to determine a practical, cost-effective method for generating urban landscapes. The urban terrain elements considered most important for the priorities at hand were buildings, streets, curbs, sidewalks, streams, parks/grassy areas, and utility poles. Other features would be considered during the next phase. All features are to be characterized to reflect the 3-D geometries and the material characteristics of the urban terrain elements/features. In the urban landscape, buildings will be first characterized/modeled as solid, opaque, 3-D, geometric shells. The elevations of each building (including multistory) will be based on ground elevations within the urban area of interest. Windows and doors will be characterized/modeled using texturing methods; therefore, material characteristics (such as glass or wood) will be characterized/mapped using the texturing procedure. Also materials for doors and windows are mapped as solid, opaque materials. Other ongoing ERDC studies[2] are evaluating methods and techniques for modeling buildings more precisely, including the interiors of the building. Once these methods become available (FY 03), a second-generation urban terrain database will be developed.

Scope

Several analytical and measurement methods exist for characterizing (generating) urban terrain landscapes. In this study, three of these methods were examined to determine the method that depicts (recreates) the area to be modeled in the most cost-effective manner. After the optimum method was determined, the exact procedures were examined and detailed to generate the landscape data. Then a demonstration site was selected and the landscape generation process used to develop a first-generation database. The database was then used with test-beds for simulation/evaluation.

[1] "One Semi-Automated Forces (OneSAF) Operational Requirements Document (ORD), Version 1.1 (ORD)," www.onesaf.org.

[2] M. E. Pace and W. R. Bennett. (2001). "Preliminary investigation of the visualization of buildings in the OneSAF environment," ERDC CR-01-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

2 Conceptual Methods for Urban Terrain Database Generation

The urban landscape consists of buildings, streets, sidewalks, trees, streams, grass, utility poles, fences, fire hydrants, parks, and other features commonly found in urban areas. These features create obstacles to mobility and interfere with targeting systems. In the digital world, all of these features must be described/modeled so that they perform just like their real-world counterparts. Three basic approaches were considered for modeling the urban landscape: (a) artificial modeling, (b) precise modeling, and (c) hybrid modeling. These are discussed in the following paragraphs.

Artificial modeling consists of creating simple 3-D shapes (boxes), applying a standard simple texture (such as brick, stone, or stucco), and placing individual feature models in a defined urban landscape. It is the digital equivalent of a child creating a town on the floor using blocks. This approach can provide simple or complex landscapes as desired. However, because this model is completely artificial, it may not accurately replicate situations encountered in the real world.

The second approach, precise modeling, involves undertaking an intensive survey to model precisely each structure to be included in the database. Precise models would then be used to create the building geometry, similar to an architect designing the buildings in the first place. Then these structures are placed in a landscape area, and features such as roads and sidewalks are generated. Finally complex models of trees and other vegetation are generated to create an exact digital representation of the total urban landscape. This approach is very precise; however, it is also very labor intensive and therefore expensive.

The approach described in this report is a cross between these two approaches. It uses actual structure footprints obtained from existing data sources, textures created from actual building facades, with estimated heights and modeling software to produce realistic digital models of the structures without the expense of generating actual models in cyberspace.

Eight steps are necessary to generate an urban landscape database:

- Select urban site.
- Acquire topographic data.
- Generate 3-D terrain surface.
- Acquire aerial imagery of site.
- Acquire building texture data (building façade models).
- Develop 3-D building models.
- Integrate building models with terrain data.
- Generate other features.
- Generate 3-D urban landscape database.

a. *Step 1: Selection of urban site.* In order to generate an urban landscape database, it is necessary to select a urban site. This can be an actual urban area (town or city), or a MOUT training site at a military installation. The size of the area selected will control the amount of effort needed for the development of the urban landscape database.

b. *Step 2: Acquire topographic data.* Topographic elevation data are available from a variety of sources. For urban areas (cities and towns), the municipal offices may be able to provide suitable data. For MOUT sites on military bases, data may be available from the construction drawings. Ideally these data should contain not only elevation data, but also other attributes such as building footprint data. These data may also contain the locations for other key features in the area such as trees, power poles, and sidewalks.

c. *Step 3: Generate 3-D terrain surface.* The 3-D terrain surface is generated by digitizing and editing the topographic data obtained in step 2. Depending on the form of the elevation data, different standard processes are used to create a digital terrain surface. Where buildings exist, a flat surface is generated at the lowest elevation against the footprint. This simplifies the processes of creating the building models by allowing buildings to be modeled with rectangular walls, even in sloping terrain.

d. *Step 4: Acquire aerial imagery of site.* High-resolution aerial or satellite imagery is necessary to depict the complexity of the urban site in terms of buildings, streets, and other features and also to provide information on building footprints. Additionally it can provide realistic texture data to the areas outside of the modeled area to avoid the *flat earth* problem (nothing at the edge of the data).

e. *Step 5: Acquire building texture data.* Building texture data (the appearance/characteristics of the walls or façade models) are obtained using digital photographs of the actual building facades. These photographs are edited and stitched together using special software as necessary to provide an accurate representation of the exterior surface of the building. Texture data are needed to depict the different types of materials such as concrete, glass, wood, asphalt, or brick without actually mapping the extents of these materials.

f. *Step 6: Generate 3-D building models.* To generate 3-D building models, the building footprint, obtained either from the topographic data or aerial photography, is captured into a Computer-Aided Design (CAD) file (if it is not already in one). There it is rotated to be aligned with the coordinate axis and then translated to the origin. It is then exported from the CAD program to a second special software package (Multi-Gen Creator™ for example) where the actual 3-D building model is generated. First the walls are extruded from the footprint using a wall height estimated (or measured) when the digital texture photographs are collected. Flat roofs (no pitched roofs) are then added to complete the building. Finally textures are applied to the walls and the roof. Wall textures are obtained from digital photography of the building as described in step 4. Roof textures are selected from a standard building texture library in the Multi-Gen Creator program. Exposed basement walls are treated as part of the wall texture. Wall texture for the exposed portion is typically collected with the other wall textures. Textures are generally not applied to unexposed (underground) portions, because these parts of the wall are below ground level and not visible in the final landscape database or projected scene. Basements that are not visible above ground level are not modeled. No effort is made to model the interior of buildings at this time. Work is currently underway in the ERDC Information Technology Laboratory to model the building interior.[1]

g. *Step 7: Integrate building models.* Once the 3-D terrain surface has been generated, the building models can be integrated into the terrain model. First, the Universal Transverse Mercator (UTM) coordinates of the southwest corner of the building are determined. These coordinates will be the position in which the building will be placed in the 3-D terrain database. Next, the southwest coordinates are located in the database and the building object is inserted. A previously built 3-D model file is assigned to the object. The building attributes are modified by scaling the model to the correct units (meters) and rotating the model to its original orientation in the digital survey.

h. *Step 8. Generate other features.* Once the 3-D building models have been integrated, other urban features such as trees, power poles, and fences can be added. Models for each of these features are obtained either by generating them in the same fashion that the buildings were

[1] Pace and Bennett (2001), op. cit.

generated or by obtaining them from one of many standard visual libraries. For the scope of this project, these models were obtained from the visual standard library provided by WorldPerfect™.[1] These models are inserted into the database in the same fashion as the building models, and attributes such as tree height and fence height can be modified as well.

i. *Step 9: Generate the 3-D urban landscape.* Once all features have been accounted for, the final 3-D urban landscape database is generated and is exported as two databases: a compact Terrain Database (CTDB) used for modeling and simulation and a visualization database used for visualization studies. The CTDB is used to support simulations using systems such as OneSAF, JSAF, and ModSAF. The visualization database is used to support 3-D viewing of the landscape using Stealth viewer systems.

Each of these steps is discussed in more detail in Chapter 3 describing the application of these procedures for terrain landscape within Vicksburg, MS.

[1] MetaVR, Inc. (2001). "Virtual Reality WorldPerfect™ (VRWP™), Version 3, User's Guide," Brookline, MA. www.metavr.com

3 Application of Urban Landscape Generation Process

Step 1: Selection of Urban Site

To demonstrate the process, a site was selected in Vicksburg, MS, which is located on the banks of the Mississippi River midway between Memphis and New Orleans on Interstate Highway 20. The urban terrain site in Vicksburg is approximately 55 m (180 ft) above sea level. The terrain in the area is sloping from east (high) to west.

Step 2: Acquisition of Terrain Data

The site selected for the application of the urban landscape procedures was a three- by three-block area of downtown Vicksburg (Figure 1). The City of Vicksburg provided a digital map database of the urban area containing some of the information needed to develop the urban digital terrain database. In addition to topographic data, this database also included data on road characteristics, the locations of large trees, and footprints of each of the buildings within the area. These types of data are critical for accurate development of the urban terrain database.

Within the selected three-block-square urban area there are 57 buildings, which are mostly commercial buildings with a few residential buildings. This area also has two churches, four local government buildings, and two federal government buildings. Topographic contour data were obtained at a 0.6-m (2-ft) contour, and there is a 12-m (40-ft) relief. Roads include seven 7-m- (24-ft-) wide two-lane roads and one 14-m- (45-ft-) wide four-lane parkway. There are 2-m- (6-ft-) wide sidewalks throughout and also large trees in the area.

The basis for the development of this urban landscape model was digital map data obtained from the local municipal government. This database includes information for the development of a digital terrain database (topographic data, roads, and the locations of large trees) and building footprints. This database was provided as two Microstation DGN files, which were imported into AutoCAD Map 2000 to extract the building footprints.

Figure 1. Satellite image of Vicksburg site, 1-m resolution, 14 Feb 1994

Step 3: Generation of 3-D Terrain Surface

A digital elevation model was first generated using contour data contained in the DGN files. Where buildings were present, a flat area was digitized at the lowest point on the building. As explained in Chapter 2, this was done to simplify the creation of the 3-D building models by allowing the models to be generated with rectangular walls, even in sloping terrain. The digital elevation model was used for the foundation for the digital terrain database shown in Figure 2. Road data were also extracted from these files to provide the road network for the urban landscape and added to the digital terrain database, in addition to other feature data (telephone poles, park areas, and trees) also extracted from these data to complete the digital terrain database.

Figure 2. Digital terrain data of Vicksburg site

Step 4: Acquisition of Aerial Imagery of Site

Digital satellite imagery (1994) was obtained of the downtown Vicksburg area. Figure 1 shows the three- by three-block area.

Step 5: Development of Texture Data

Development of the textures for the buildings is a multistep process. Digital imagery must be acquired, edited, and stitched together to accurately portray the building façade. Each step in the process must be carefully executed to minimize the difficulty involved in the subsequent steps.

Collection of digital ground photographs/imagery

Collection of digital image data is the first step in the process of building the textures to model the urban environment. For the best results, imagery should be taken perpendicular to the building façade being modeled; however, this may not always be possible. This will minimize distortions due to perspective and make the next editing steps simpler (Figure 3).

Figure 3. Unedited image of 1316 Monroe Street

Editing consists of correcting any rotation in the image and any perspective distortions. The first step is to rotate the image to correct for any tilt of the camera during the capture of the image (Figure 4). A simple way to check the rotation is to use the window selection tool in the image editing software. After the image is checked for any rotation, the **Undo** tool clears the window selection action without altering the image. It is critical to do this because any future actions would be performed only on the selected portion and not the entire image.

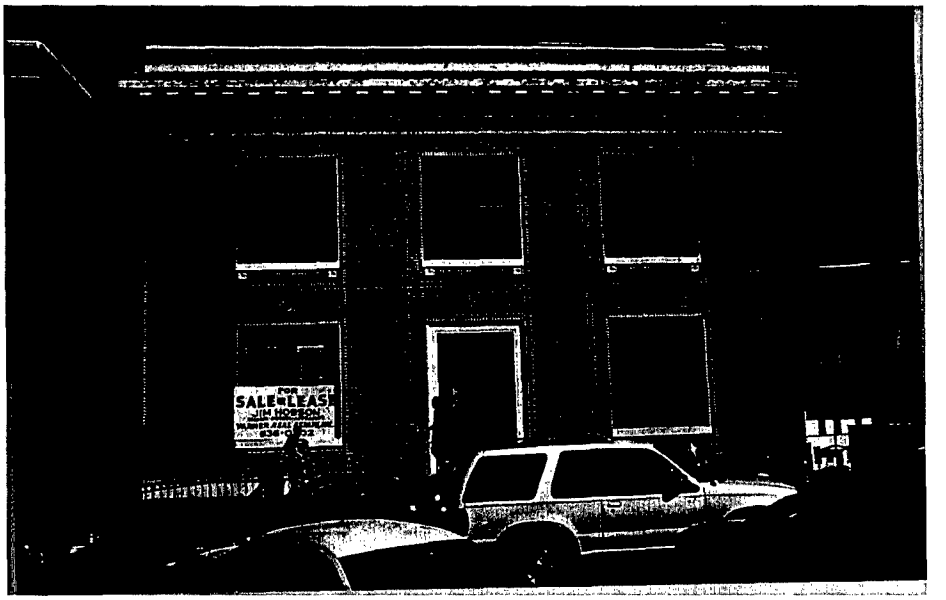

Figure 4. Image of 1316 Monroe after rotation

The next step is to correct the image for distortions due to perspective. The perspective distortion is most often vertical; however, if the image was not captured perpendicular to the facade, then horizontal perspective distortion may be present also. In correcting vertical perspective, the object is to make the vertical lines in the image truly vertical (Figure 5).

Figure 5. 1316 Monroe after vertical perspective correction

Stitching

If more than one image is necessary for the composite building façade image, then a series of images must be assembled together using an image stitching program. To stitch images together, the images must overlap at least 10 to 20 percent. The more overlap, the better the results will be. In the example shown in Figure 6, there is approximately 50 percent overlap, which is sufficient for good results in stitching the two images together. Most stitching programs allow for manual stitching of the images and require two common points for accurate stitching. For best results, these two points should be fairly distant and aligned vertically for horizontal stitching. In the example shown, the lower right corner of the door and the upper right corner of the window above the door would be good choices.

The stitched composite building image shown in Figure 7 is ready for final editing. Objects such as vehicles, trees, signs, or utility poles in the final image (either a stitched image or a single image) are removed. In Figure 7, these objects include the automobile, street sign, and power lines. It is also necessary to remove the shadowed area on the left side of the building and portion of the sidewalk/street in front of the building. The object of this editing is to create a rectangular image of just the building. Small objects such as power lines, street signs, and utility poles can be removed by using the image processing program

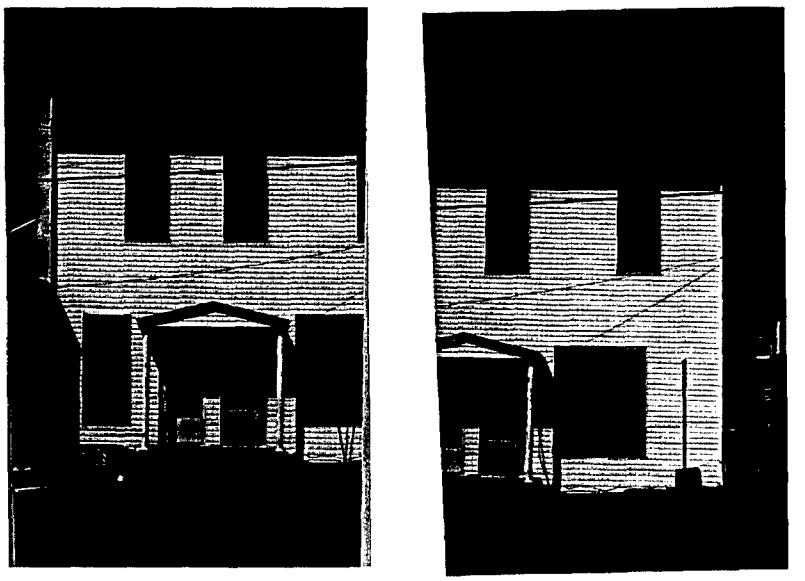

Figure 6. Left and right sides of 805 Clay Street

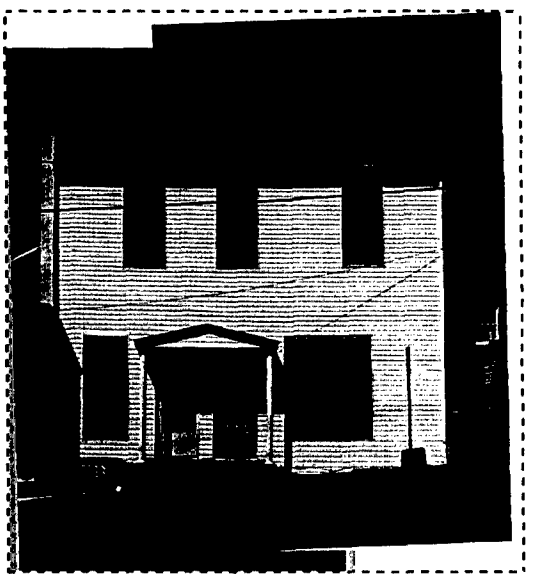

Figure 7. Stitched image of 805 Clay Street

clone tool. For larger objects such as automobiles and trees, clear areas are copied over the objects to be removed. The front porch shown on this structure was not modeled other than as a different texture on the face of the building. It was not included in the footprint of the building. For porches that span the full width of a building, the porch is treated as an exterior wall.

The image (Figure 8) is now ready to be output as a texture file. First the image resolution is reduced to either 512 × 512 pixels or 256 × 256 pixels. This choice is based on the size of the final edited image. Then the resulting (de-rezzed) image is now saved in the Silicon Graphics RGB Image format and is archived/tagged to be used as a texture file in the Multi-Gen Creator program.

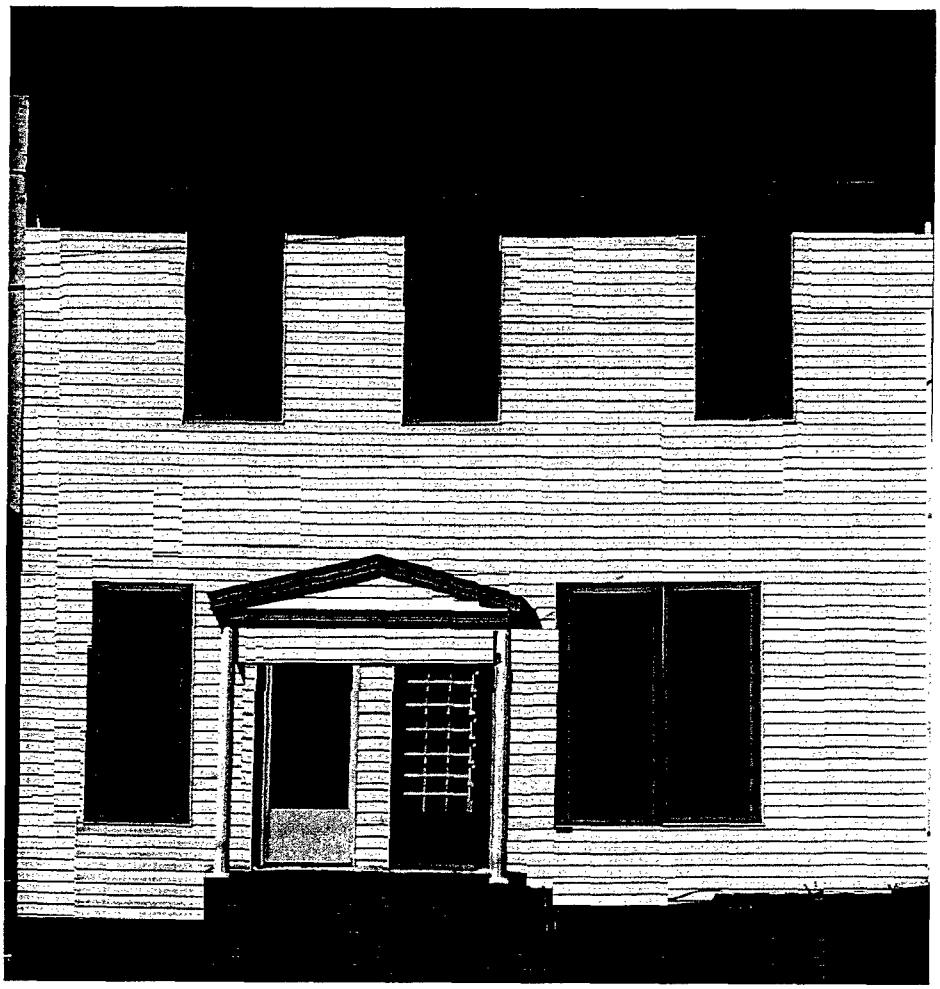

Figure 8. Final edited image of 805 Clay Street

Step 6: Development of 3-D Building Models

Three-dimensional models of the structures can be created once the textures have been developed. First, obtain, extract, and edit the footprint for each building. Then use Multi-Gen Creator Version 2.5 to import the building footprints, extract walls, and apply textures. Save the file as an OpenFlight FLT file and convert it to a MetaVR HPS model file by using MetaVR's oflt2Hps utility.

In this section, a 3-D structure model will be created using the building located at 1221 Washington Street as an example. The file containing the building footprint is 1221WASHINGTON.DXF, and the texture files for the walls are as follows:

a. 1221WASHINGTONSB.RGB (south side)

b. 1221WASHINGTONWB.RGB (west side)

c. 1221WASHINGTONREDWALL.RGB (north and east sides)

d. CNCR26.RGB (foundation)

e. SHNG09L_GREY.RGB (roof)

Extract/edit footprint

As stated previously, the first step in building a 3-D model of a structure is to obtain, extract, and edit the building footprint. The two Microstation DGN files that were the sources for the topographic elevation data and building footprints were imported into AutoCAD and joined into one AutoCAD digital terrain database drawing as shown in Figure 9. Footprints were extracted separately for each building and saved to separate files.

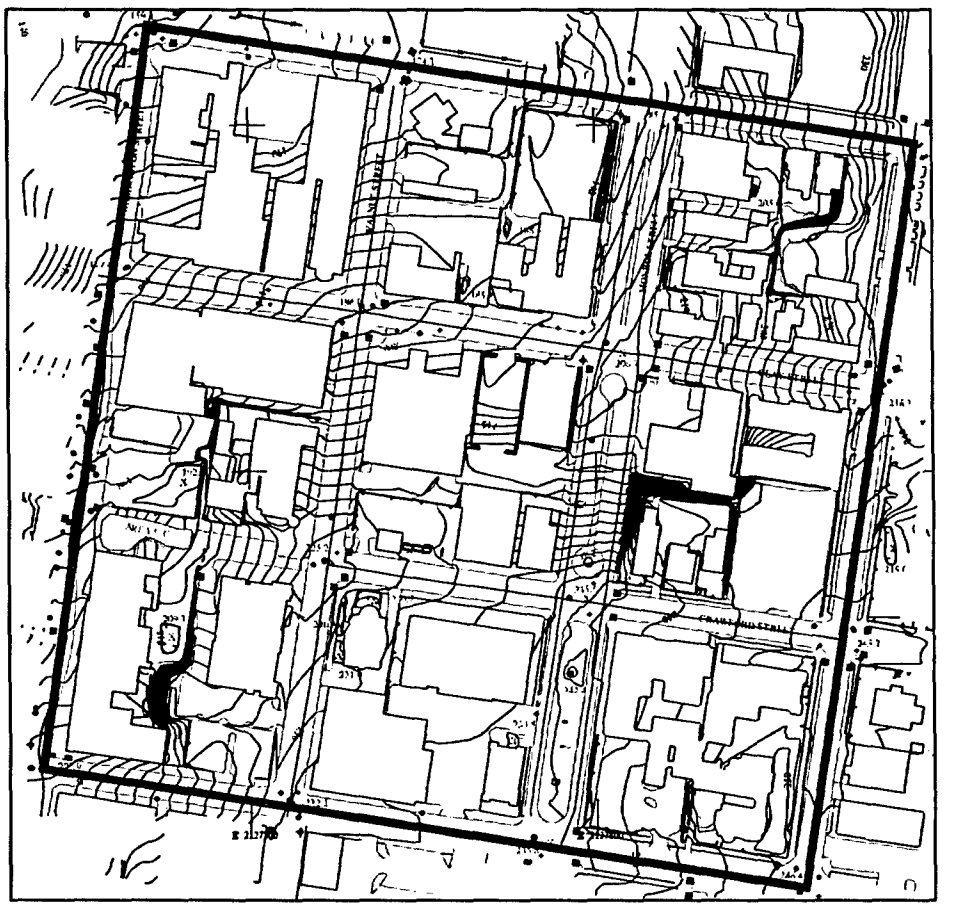

Figure 9. Digital terrain database

To extract the footprint of a building, first move the coordinates of the southwest corner to the origin (0, 0) and rotate the footprint so that it is aligned with the coordinate system. This step is important to ensure proper orientation of the footprint when it is imported into Multi-Gen because AutoCAD references

the coordinate system of the AutoCAD drawing while Multi-Gen Creator references the origin (0, 0). If this step is omitted, the buildings will not be oriented in the proper direction and the walls cannot be extracted correctly. Next, simplify the texture generation and modeling by replacing any irregularities of the building shape (curved walls, portals) with straight lines and corners (Figure 10).

Next, save the drawing as an AutoCAD DXF Release 12 format file. The DXF format is the interchange file format for Autodesk's AutoCAD package, and it contains the 2 × 2 dimensions of the building only. Information regarding wall heights, textures, and materials is not included in the DXF format and is added later in Multi-Gen Creator.

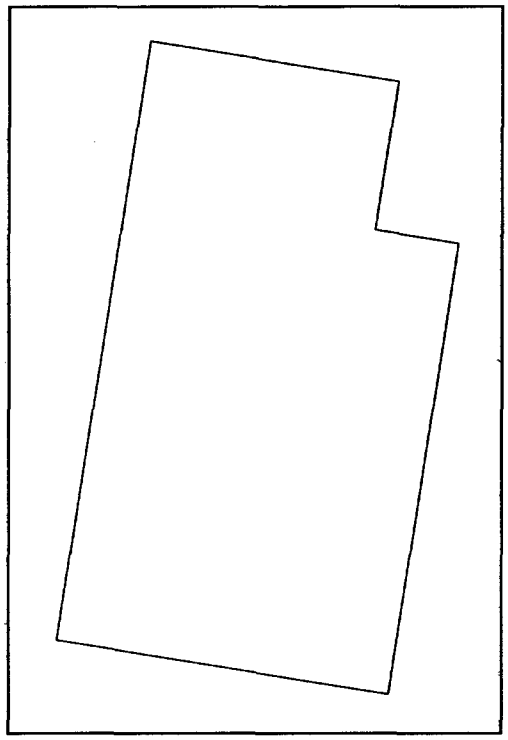

Figure 10. 1316 Monroe building footprint

Import footprint

The second step to building a 3-D structural model is to import the footprint into Multi-Gen Creator Version 2.5 and edit its attributes if necessary. To import the file, select **File-Import** and the filename (1221WASHINGTON.DXF). The footprint should appear in Multi-Gen Creator as a solid-framed white object as shown in Figure 11.

Adjust the viewing area and/or grid size if the entire footprint is not within the area or on the grid. Zoom out and/or pan over to move the footprint into the viewing area and click the **Grid Larger** button on the **View** panel to make the grid larger, if needed.

The footprint must appear as a solid-framed white object in order for the textures to be applied correctly. If it does not, change the attributes of the footprint. To do this, first change the model from **Object** to **Face**, select the footprint face by clicking on it, and select **Attributes**. To change the frame to a solid frame, select **Solid Frame**. To change the color attributes, open the color palette by selecting **Color** from the **Palettes** menu. The screen should look like the one in Figure 12. Change the color ID to white by changing the **Primary Color** ID number to 127. Click **OK**. Now return the mode to **Object**.

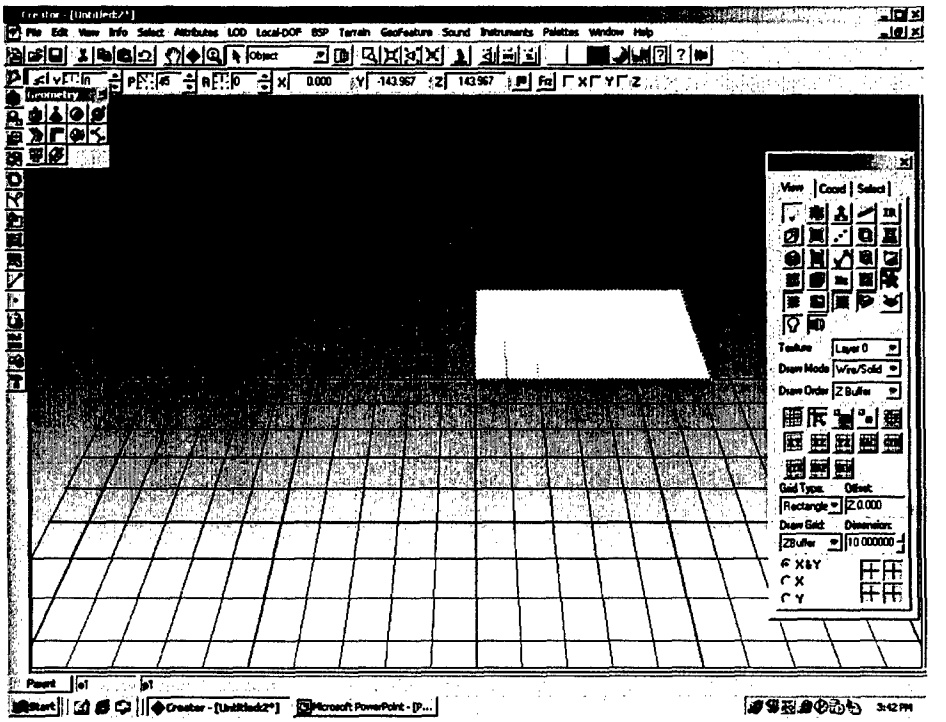

Figure 11. Multi-Gen Creator grid

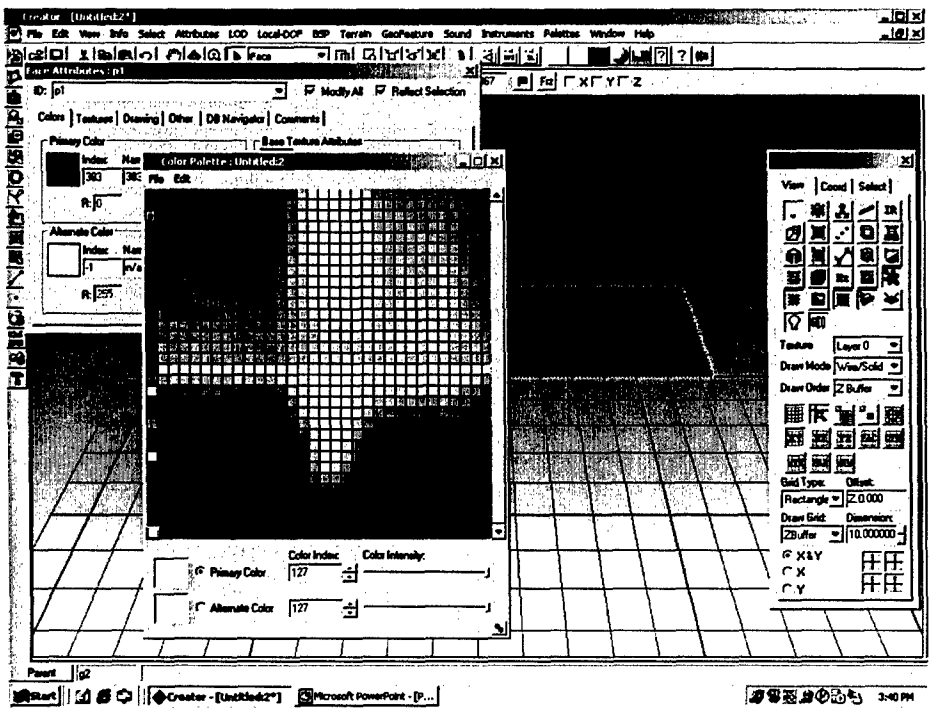

Figure 12. Color selection window

Extrude walls

The third step in generating the model is to add walls to the footprint of the building. Select the **Wall Tool** from the **Geometry Tools** button which is the second button on the left tool bar. Check the **Keep Bottom** button. Enter the wall height in the same units as those of the building footprint. The height of the building at 1221 Washington Street is 36 ft (11 m). Click **OK**. The Creator graphics window now looks like Figure 13.

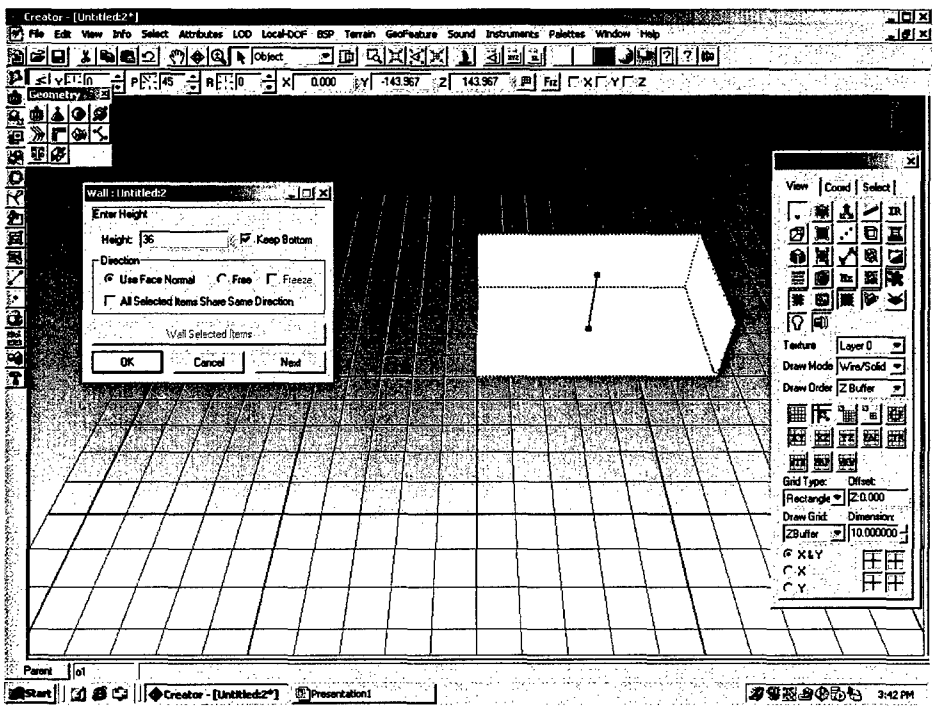

Figure 13. Multi-Gen Creator showing extruded walls

Apply textures

The fourth step to building the 3-D model of the structure is to apply textures to the building. First, load the Texture Palette with the images for the building. Then, apply the images to the appropriate faces of the building. Use the **Rotate View** button located on the top toolbar to rotate the viewing area to view different faces of the building.

Load the texture palette by selecting **Palette > Texture, File > Read Pattern.** Assign the palette location for the image and click **Open** to load the image into the texture palette. Load one image per palette location. Start by accepting the default location (0, 0) shown in the lower left corner for the **Read New Pattern** dialog box for the first image, and then click on subsequent box numbers for the next image. Continue to load the palette until all images for the building have been loaded.

Second, select a texture and its corresponding face. Turn on the texture display in Creator's graphic window by clicking on the **Draw Texture** button in the **View** panel (Figure 14). Change the mode to **Face**. Select a face of the building and its corresponding texture by clicking on the face and clicking on the texture in the **Texture Palette**. Select the **Put Texture** tool from the **Map Textures Tool Chest** located on the left toolbar.

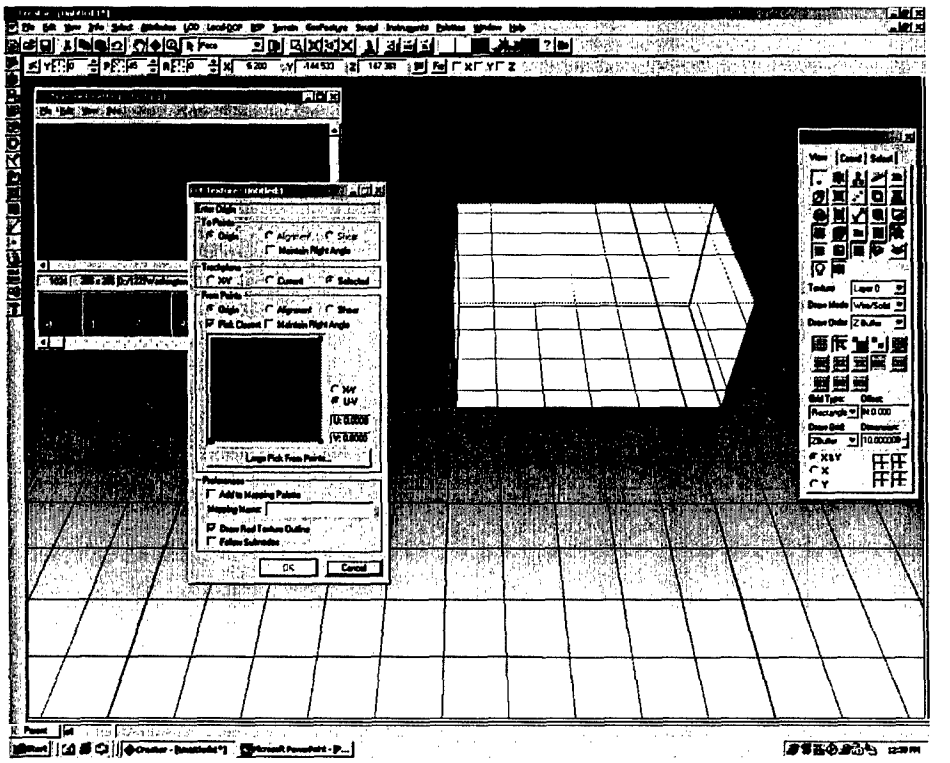

Figure 14. Texture application window

Third, map the texture to the face by selecting the origin, alignment, and sheer points. Do this by using the left mouse button to click on the lower left corner of the face for the origin, the lower right corner for the alignment, and the upper right corner for the sheer. If the pattern of the texture is smaller than its corresponding face (such as shingles to a roof), repeat the texture along the face. To do this, select a point between the origin and the lower left corner for the alignment and a point perpendicular to the alignment point but between the alignment and the upper left corner. Click **OK** when the placement of the texture on the face is satisfactory (Figures 15-17).

Save model

Save the model once all of the textures have been applied to the building. First, reorient the screen display so that the building appears in its original position and change the model to **Object**. Save the file in FLT format.

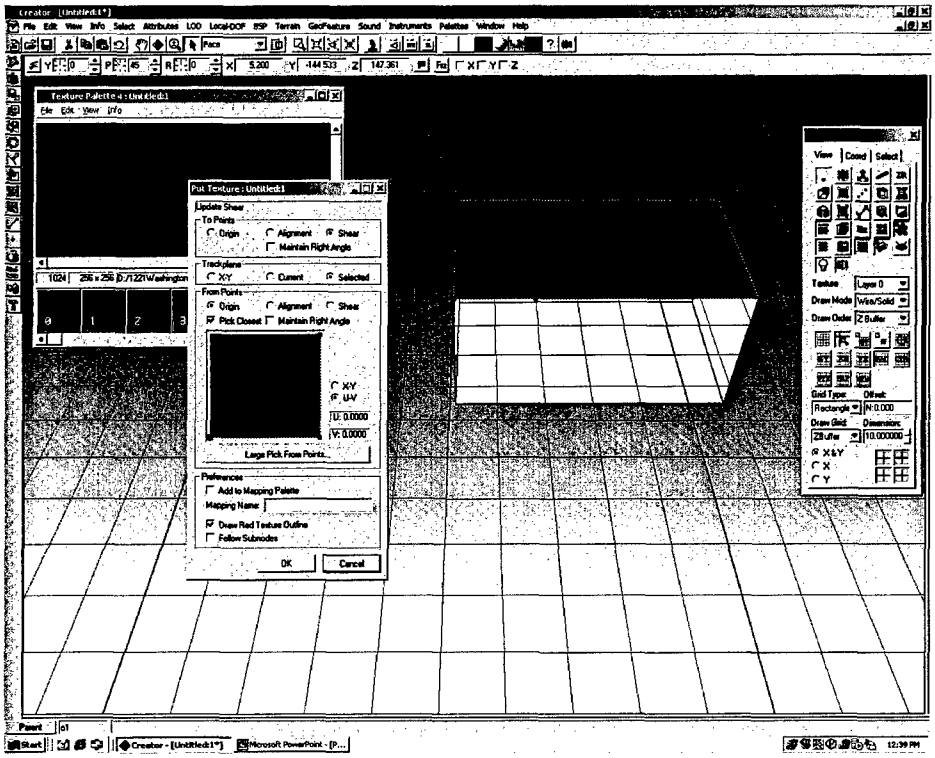

Figure 15. Building model with roof texture applied

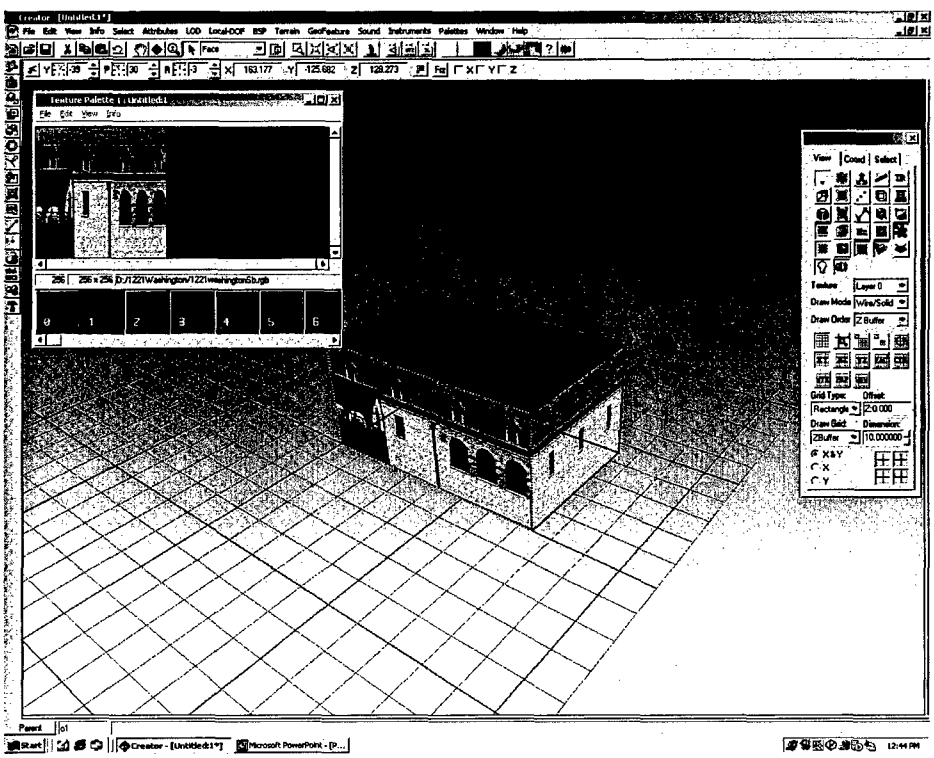

Figure 16. Building with roof and wall textures applied

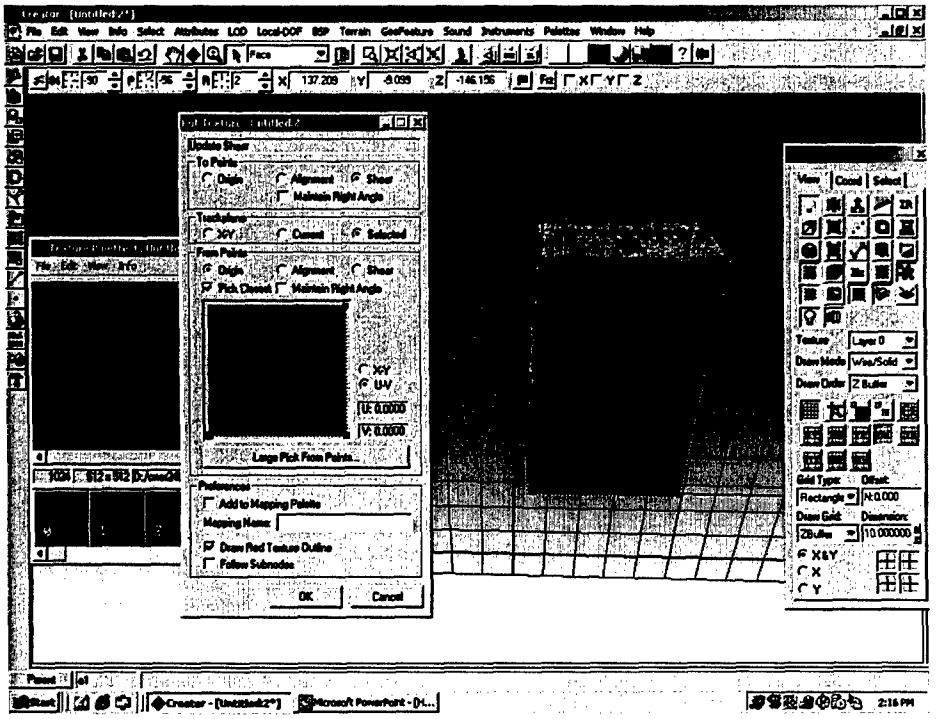

Figure 17. Application of floor texture

Convert the model

Convert the FLT file to the MetaVR HPS format using MetaVR's oflt2Hps.exe converter. To do this, copy all files associated with the building model into one directory. Open a DOS window and locate the directory that contains oflt2Hps.exe. Change the current directory to the directory containing the OpenFlight file to be converted. Type in the following command:

oflt2Hps file name.flt file name.hps

where **file name** is the name of the building model.

The oflt2Hps utility output file is a MetaVR HPS file, which is an ASCII file. This file contains a list of all the textures included in the model. Use the HPSViewer.exe utility or double-click on the HPS file name in Windows Explorer to view the HPS model.

Steps 7 and 8: Integration of Building and Feature Models and Development of Urban Landscape Database

Once the building models are developed and the imagery has been generated, the virtual urban landscape model can be built in WorldPerfect. To do this create a new project in WorldPerfect, specify the terrain and imagery information, and add objects and their attributes to the terrain. Next, save the project and generate

a MetaVR MDX database. This database can then be viewed using MetaVR's Virtual Reality Scene Generator (VRSG).[1]

Steps for building the urban landscape will be discussed in the following paragraphs using building the database for Vicksburg as an example. The elevation data used was ogrid_6_17.lan, and the imagery file was 32090C82.TIF. The bounding box for this virtual terrain is defined by the following UTM coordinates:

699236.92, 3581339.74		**699689.03, 3581339.74**
699236.92, 3580930.33		699689.03, 3580930.33

The latitude/longitude zone is 15. The patch size and post spacing chosen for this database were 25 and 1, respectively.

Create a new project

Start WorldPerfect by choosing MetaVR WorldPerfect from the Windows Start Menu. Choose **File > New**, and the **Terrain Attributes** dialog box will appear.

Specify terrain information

Enter the geographic information about the terrain database. This includes the bounding box of the intended virtual world, the elevation data source, and the levels of detail for the terrain geometry. First, enter the **Elevation Source** for the data (ogrid_6_17.lan). Second, enter the bounding box for the virtual world in UTM coordinates by entering the **Location** and **Database Extent**. To enter the **Location**, locate the southwest corner of the box and enter its x-coordinate for the **Easting** and its y-coordinate for the **Northing**. The **Database Extent** is the distance from the southwest corner of the bounding box to the northeast corner. Enter the distance between the x-coordinates for the **East** extent and the distance of the y-coordinates for the **North** extent. Third, enter the latitude/longitude zone. Fourth, enter the geometry constructs for the database by entering the **Patch Size, Posting Spacing**, and **Level of Detail Ranges** for the terrain (Figure 18).

Specify imagery information

Select the photorealistic imagery that will be applied to the terrain and specify the imagery attributes. To select the imagery file, select **File > Base Map > Add**, locate the file, and click **Open**. The screen now appears as shown in Figure 19. Now specify the attributes by clicking **Attributes > Imagery**

[1] MetaVR, Inc. (2001). "Virtual Reality Scene Generator™ (VRSG™), Version 3, User's Guide," Brookline, MA. www.metavr.com.

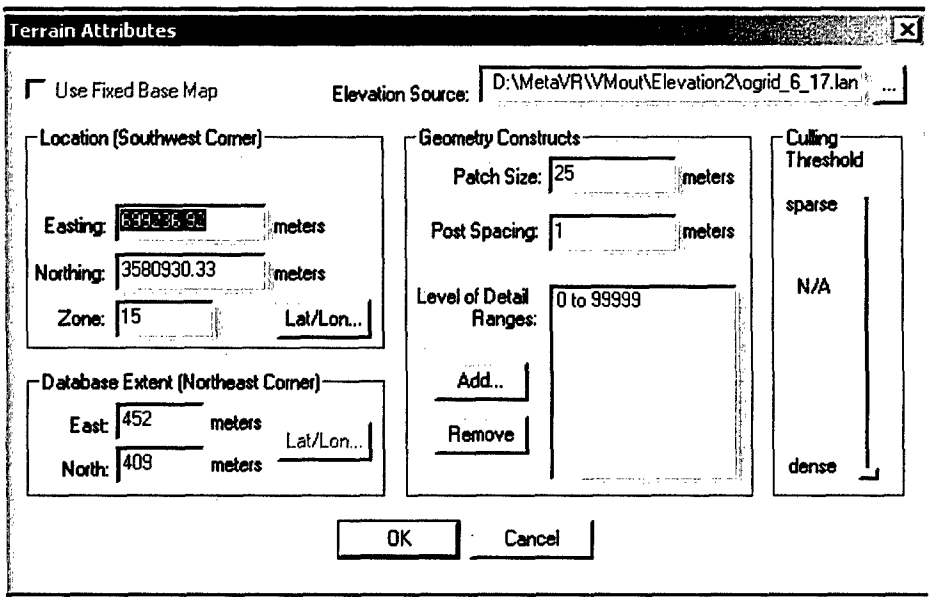

Figure 18. Terrain Attributes window

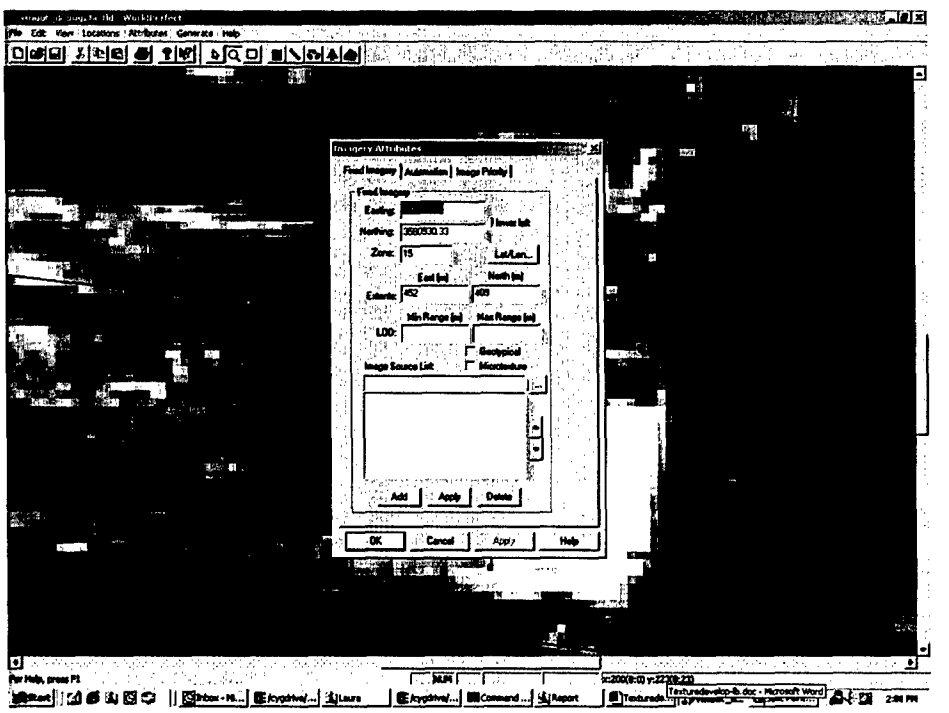

Figure 19. Imagery data

Attributes > Automation, check the **Pull Imagery** box, enter the directory containing the imagery TIF file in the Default GeoTiff Directory box, and click **OK**.

Adding objects to the terrain

Once the terrain information and imagery data have been specified, add the objects, or cultural features, to the terrain. WorldPerfect supports several kinds of objects including buildings, lines, vehicles, trees, and polygons. Depending on the attributes of the object, lines can represent roads, rivers, rail tracks, or tree lines. Figure 20 depicts the a two-dimensional view of the urban landscape database including roads, buildings, trees, and parking lots.

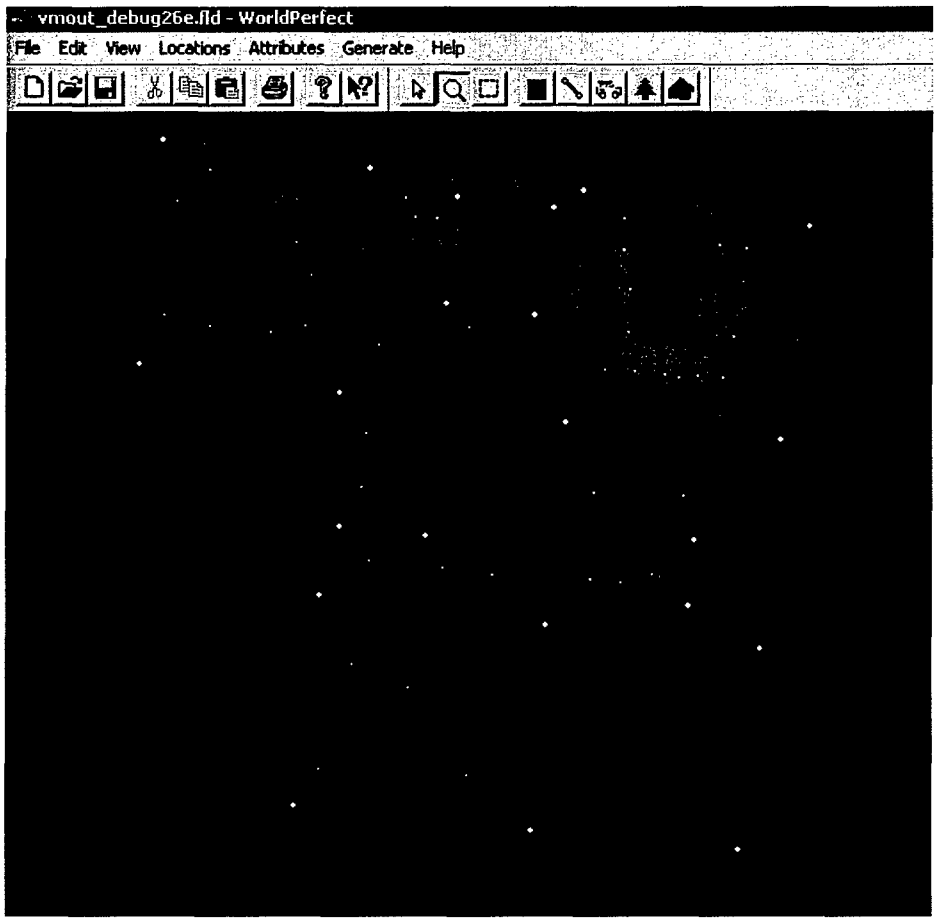

Figure 20. Two-dimensional view of urban database

To add an object to the terrain, first click the corresponding object type from the toolbar. Notice that the pointer will change to a cross hair. Locate the position of the object and left-click. If adding a linear feature, position the pointer at the beginning of the feature and left-click. Drag the pointer in the direction of the feature and left-click with each change in direction. Otherwise, position the pointer at the southwest corner of the object and left-click. Once the object has been inserted into the terrain, click the **Select** tool to exit the **Add Object Mode**.

Edit object attributes

To select an object click on the object or use the **Selection Box** tool on the toolbar. The selected object(s) will turn red. Choose **Attributes > Object Attributes**, and an **Attributes** dialog box will appear for the type of object selected. Enter the appropriate data and select **Surface Texture** directory and the texture file.

If the object is a lineal feature, the dialog box shown in Figure 21 will appear.

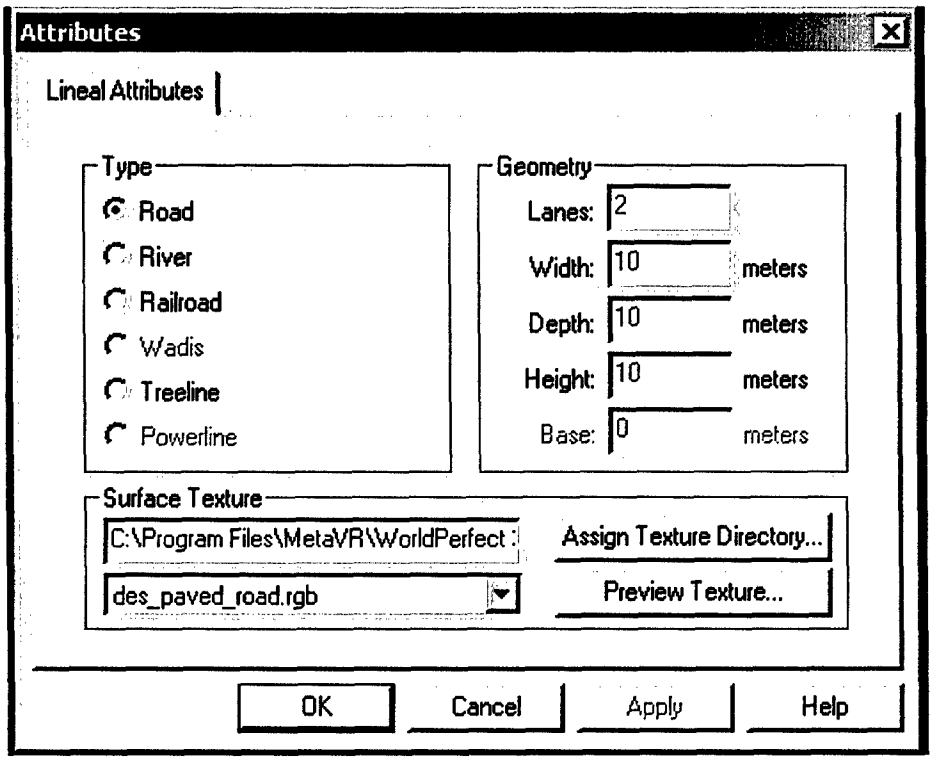

Figure 21. Lineal Attributes selection window

Select the feature type and enter its geometry data. (Figure 21 shows the **Lineal Attributes** selection window options.) Enter the number of lanes and width for a road, the width and depth for a river, the width and height for a railroad, and the tree height for a tree line. Sidewalks and curbs were not included in the database, because these features could not be accurately modeled due to the resolution of the terrain database.

If the object is a building, select the model to associate the building with. The **Building Attributes** options window is shown in Figure 22. Enter the orientation of the building and its scale. First, enter the yaw (horizontal rotation) so that the building will be placed in its original position in AutoCAD; recall that its coordinates were realigned to match those in Multi-Gen Creator. Second, scale the units of the building to metric units. (Note, the AutoCAD survey and the building models were created in feet and must be converted to meters.)

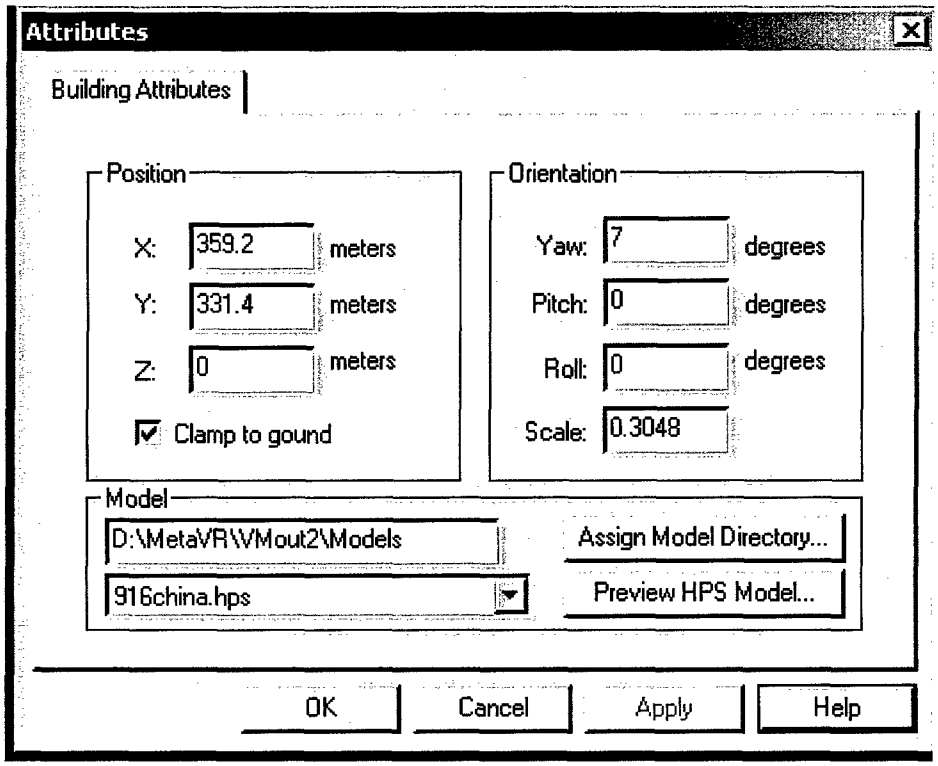

Figure 22. Building Attributes selection window

Trees were inserted into the urban landscape in a similar way to that of a building. Models are selected from a MetaVR library based on the type of tree (deciduous or evergreen). Trees are then scaled to the appropriate height and diameter.

Saving the project

Save the project at any time during its development as an .FLD extension, WorldPerfect's project format. To better organize the projects, it is recommended that the projects be saved under a Projects subdirectory.

Step 9: Generating the 3-D Urban Landscape

Once the urban landscape project has been completed, create a MetaVR MDX database that can be visualized three-dimensionally in VRSG. To do this, first click **Generate > MetaVR MDX**, and select **Yes** when the message box "Would you like to test the road topology before compiling?" appears. Next, specify the path and filename with the .MDX extension in the **Output File** field. (For organization purposes save the .MDX file in the **Terrain** subdirectory.) Leave the **Feature/Road File** field blank and click **Generate** (Figure 23).

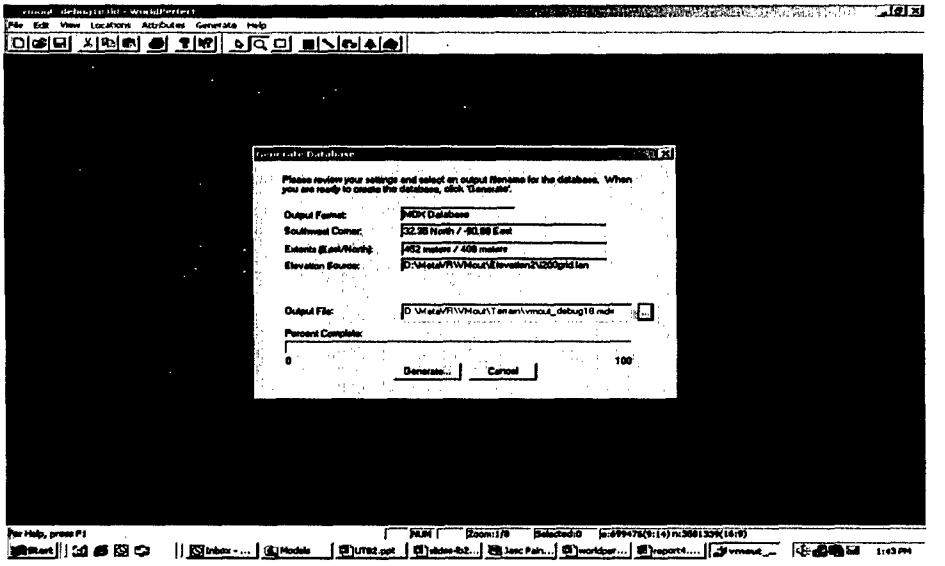

Figure 23. Generate Database dialog box

Viewing the Generated Urban Terrain Database in VRSG

The WorldPerfect database can be viewed three-dimensionally in VRSG. Exit WorldPerfect and start up VRSG by selecting VRSG from the **Start** menu. Enter the filename of the WorldPerfect database to view and click **Start VRSG**. Figures 24 and 25 show various 3-D views of the urban landscape database.

Figure 24. View looking north of the generated urban terrain landscape

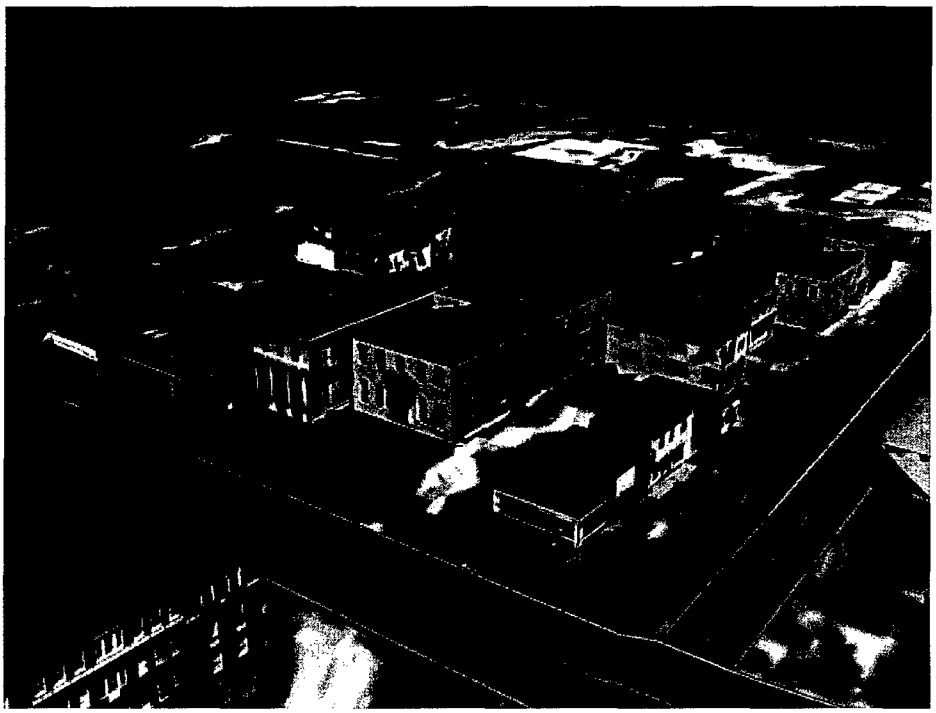

Figure 25. View looking northwest of generated urban terrain landscape

3 Summary

The conceptual urban landscape development process presented herein provided a fairly straightforward and reasonable method to model urban landscapes. The resulting landscape data set is currently being used on the OneSAF test-bed for simulations of vehicle mobility modeling and smart sensor performance, in mobility studies, and for mounted urban warfare training. While no effort has been made in this study to model building interiors (necessary for dismounted simulations/training), other efforts are underway within ERDC to develop procedures to model building interiors. The process presented herein should allow for the addition of building interior models without modification to the building shell models developed here. Fifty-seven buildings were modeled in a nine-square-block area (27.8 acres (0.1 sq km)). These buildings were primarily commercial or government with a few residential structures. Eight streets were mapped/modeled; seven were two-lane roads with parking on each side, and one was a boulevard type road (grassy median separating the traffic lanes). Other features such as trees and utility poles were also included in the urban terrain database.

Several limitations/technical challenges were encountered during the application of the conceptual procedure for generation of the urban terrain database: data resolution, feature details, and terrain description. These are discussed in detail in the following paragraphs.

Data Resolution Limitations

Urban landscapes contain small but important features such as curbs, sidewalks, and gutters. Current limitations with the development software (MetaVR) were in representing features that were typically smaller than 1 m. Depending on the application of the database, this may not be a serious problem for some applications such as movements of larger vehicle systems. However, this could pose a problem for small conceptual robotic-type vehicles that consider large curbs as obstacles. The version of software used in this project (MetaVR WorldPerfect 3.0) did not adequately represent features smaller than 1 m.

Building Feature Details

Buildings were represented in this project only as empty shells (only walls and roofs). Other studies[1] are underway that are examining different methods of construction and digital representation of building interiors in CTDB for OneSAF.

Terrain Description

Urban landscapes are dramatically different and somewhat more complex than their rural natural landscapes because of the many discontinuous surfaces that are typical in man-made constructions. These discontinuous surfaces can be difficult to measure and represent digitally. The urban area selected for this project had a vertical elevation range of approximately 80 ft (24 m) within the three-block area. The steep change in terrain slope along with complex buildings that were built into the hillside was a challenge to model correctly.

[1] Pace and Bennett (2001), op. cit.

Appendix A
Three-Dimensional Graphics Terminology

Texture – A two-dimensional bitmap pasted onto objects or polygons to add realism.

Texture mapping – Improves visual detail by simulating the material properties of a surface. The simulation is achieved by mapping a stored bitmap onto the object. It is computationally intensive but can simulate/represent real materials like bricks, wood, or steel.

Bitmap – A bitmap is a pixel by pixel image.

Wireframe – All three-dimensional models are constructed from lines and vertices forming a dimensional image of the image. Then texture, shading, or motion can be applied.

Appendix B
Commercial Software Information

Adobe Systems, Inc.
San Jose Corporate Headquarters
345 Park Avenue
San Jose, CA 95110-2704
(408) 536-6000
(800) 833-6687

www.adobe.com

Adobe Photoshop	$609.00	PC

Autodesk
111 McInnis Parkway
San Rafael, CA 94903
(800) 964-6432
(415) 507-5000

www.autodesk.com

AutoCAD 2000	$3,750.00	PC

Environmental Systems Research Institute
380 New York Street
Redlands, CA 92373
(800) 447-9778

www.esri.com

ArcView GIS 3.2	$1,195.00	PC

Jasc Software, Inc.
7905 Fuller Road
Eden Prairie, MN 55344
(952) 934-8888

www.jasc.com

Jasc Paint Shop Pro	$109	PC

MetaVR, Inc.
37 Elm Street
Brookline, MA 02445-6813
(781) 891-0060

www.metavr.com

MetaVR WorldPerfect	$15,000.00	PC
MetaVR VRSG	$7,000.00	PC
Spacetec IMC SpaceOrb 360	$100.00	PC

Multigen
Corporate Headquarters
550 South Winchester Boulevard, Suite 5000
San Jose, CA 95128
(408) 261-4100

www.multigen.com

Multi-Gen Creator	$9,500	PC, SGI

PanaVue
616 boul. Rene-Levesque Quest
Quebec, Quebec GIS 1S8
Canada
(800) 656-5443

www.panavue.com

PanaVue ImageAssembler	$64.00	PC

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14. ABSTRACT

Computer modeling and simulation (M&S) for military purposes has become more and more important with dwindling military budgets but more complex military equipment. M&S allows military weapons designers to test weapons systems under a variety of environmental conditions and under many varying terrains at a far lower cost than testing under real conditions. M&S also provides troops with intensive training on complex military systems without fuel costs, wear and tear on equipment, and risk of injury or death from training accidents. The OneSAF, JSAF, and ModSAF systems have all been developed to meet the needs of the M&S community. However, there has been one deficiency in all of the previous M&S work: all of the efforts have focused on rural environments. The Army M&S Office (AMSO) established the Military Operations in Urban Terrain (MOUT) Focus Area Collaborative Team (FACT) as part of an effort to expand M&S into the urban landscape. The Army realizes that as military operations become more frequent in the urban environment, it becomes even more important to train and test in that environment.

This project was undertaken in an effort to develop a process to generate realistic urban terrain databases that may be used in M&S systems in a cost-effective and efficient manner. This report discusses the procedure developed to generate an urban landscape database and the application of that procedure to a real urban landscape.

15. SUBJECT TERMS

JSAF	ModSAF	OneSAF	Urban landscape
Modeling and simulation	MOUT	Terrain database	Urban terrain

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