Building Hawaii
MAK's Streaming Terrain Database

Designing the terrain for a simulation environment always requires a balance between fidelity and cost. The trick is to spend only as much time and money as is needed to meet the operational requirements. MÄK's Hawaii terrain was built to demonstrate how the many terrain techniques supported by MÄK's VR-Vantage, VR-Forces, and VR-TheWorld Server can be combined to cost-effectively create a correlated, seamless, global 3D environment - with just the right amount of fidelity in each area for the tasks at hand.

Use Cases
Our Hawaii terrain was designed to support the following use cases:

- **Air Traffic Management** R&D activities, including global air navigation, as well as taxi, take-off, and landing of commercial air traffic.
- An **Intelligence, Surveillance, and Reconnaissance laboratory** with Simulated Sensor Video, Sensor Tracking and Coverage Visualization.

Terrain Requirements
Our two use cases gave rise to the following terrain requirements:

- **Whole-earth elevation and background imagery** to support global air traffic navigation
- A fairly **large area of higher-quality imagery** of coastal waters to support Terminal Air Control around the Hawaiian islands
- A higher-fidelity representation of the **entire island of Oahu, with 1ft imagery, and 100,000+ buildings and light points** to support ship channel surveillance and background clutter for all missions
- A **high resolution model of the Honolulu airport**, including geospecific buildings, trees, terminals, and runways to support tower and cockpit views during taxi, take-off, landing & airport surveillance
- A second high-resolution area of interest around the **Waiau neighborhood, including houses, trees, and street lights** for ground vehicle surveillance scenarios

Terrain Techniques
To support these requirements, we combined the following techniques:

- **Streaming tiled elevation and imagery** from VR-TheWorld Server and procedurally generating textured terrain-skin polygons at run-time
- Streaming tiled feature data from VR-TheWorld Server, procedurally creating 3D buildings by **extruding polygons from geospecific building footprints**, and applying geotypical textures

- Loading local shapefiles direct-from-source and performing "**point feature substitution**" – placing pre-built 3D visual models of trees and buildings at geospecific locations
- Loading **hand-modeled high-resolution 3D site insets** and seamlessly stitching them into the lower-resolution background terrain at run-time
- Loading **multiple terrain patches at once** and displaying them simultaneously

We are demonstrating all of these techniques live in our VR-Vantage visualization applications and in the VR-TheWorld Server at I/ITSEC 2011. Many of the techniques are already supported in our VR-Forces CGF and VR-inTerra terrain agility SDK for full correlation across our various simulation and visualization products. A few of the approaches are still being implemented in VR-Forces, and will be released in 2012.

Composing the Hawaii Terrain
Even when source data is freely available and when tools such as VR-Vantage can do much of the visual database generation "on-the-fly", it still takes time and expertise to put together a coherent 3D virtual environment. For the Hawaii terrain, our graphic artist and engineers spent about 4-5 person-weeks locating, acquiring, rectifying, and editing source data, as well as modeling some of the inset sites and specific buildings and objects. However, once this source data preparation was complete, it was immediately usable in VR-Vantage without requiring an additional step of compiling a visual database.

MAK's Hawaii project sheds some light on the data sources and modeling techniques used to visualize the desired terrain in VR-Vantage. Let's have a look:

Step 1: Connect to VR-TheWorld Server to stream whole-earth global elevation and imagery
Historically, terrain databases would cover only the "gaming area" and have a hard edge beyond which there was nothing. But when you use MÄK's VR-Vantage visualization products or VR-Forces CGF with our VR-TheWorld streaming terrain server, the whole Earth becomes the "gaming area". VR-TheWorld Server comes with many data layers, but these two are used in the Hawaii terrain:

Global Elevation – 90m elevation posts covering the Earth's land masses, derived from the SRTM dataset. Ocean areas are at zero elevation mean sea level.

Global Imagery – 15m imagery derived from LANDSAT 7 source. Ocean areas are depicted by a shaded relief of the bathymetry (ocean flBefore VR-TheWorld Server was launched in 2010, we had to create these free, raw source datasets to make them appropriate for real-time simulation. We processed the original mosaic of images - color-correcting them to appear as a seamless global whole. We also pre-tiled the elevation and imagery down to all mipmap levels, so that the server could answer a request for any desired resolution immediately at run-time.

While this process was intensive in both labor and compute resources (required a large Linux cluster), it only had to occur once when we first obtained the data.

Since September 2010, the resulting layers have been provided as a standard part of the VR-TheWorld Server product, so no additional work was necessary as part of the Hawaii terrain composition process. We just pointed our VR-Vantage applications at the pre-existing layers on VR-TheWorld Server and we were flying over textured global elevation data at 60Hz.

Time required: None

Step 2: Add Harris Terracolor Hawaiian Island imagery to VR-TheWorld Server
Now that we had the global background, we needed to start adding fidelity to our areas of interest. Our scenarios mainly take place around the Hawaiian Islands, so we wanted the ocean and coastal areas around Hawaii to look a bit better than the background LANDSAT imagery. We licensed the following data from Harris:

> **Hawaii Imagery -** 15m Harris Terracolor imagery**,** added to make the area surrounding the Hawaiian Islands look more like deep blue water. This product has a very nice view of the shallow water boundaries between the ocean and the islands.

We uploaded this imagery (about 15 GB) to VR-TheWorldServer and configured VR-Vantage to stream in this layer "above" the Earth imagery.

Time required: Perhaps a few hours of research and conversation with Harris to find the imagery and a few minutes to upload the imagery to VR-TheWorld Server.

Step 3: Add higher-resolution elevation and imagery for the entire island of Oahu
The scenario activity centers on the island of Oahu, so we fetched high resolution elevation (10m) and imagery (1ft) from the United States Geological Survey (USGS) web site. You can do the same: http://hawaii.wr.usgs.gov/oahu/data.html.

> **Oahu Elevation –** 10m Digital Elevation Model made for 1:24,000 scale mapping
> **Oahu Imagery** – 1ft USGS Mosaicked Digital Orthophoto Quadrangles (MDOQs) produced through the National Digital Orthophoto Program (NDOP)

High resolution files are huge (60 GB for the final Oahu imagery), so it took many hours to download them and then upload them to the instance of VR-TheWorld Server that we used for this Hawaii project. Once on the server, the higher resolution elevation and imagery was available to be served instead of the lower resolution data in this area. This allows us to immediately use VR-Vantage to fly through and validate the data. This was very helpful in choosing locations that would support our VR-Forces scenarios. We started a tiling task on the server to optimize the data for faster streaming but we didn't have to wait for it to complete before continuing. VR-TheWorld Server will create tiles "on-the-fly" upon request from a client.

Time required: About 40 hours combined for steps 3 and 4 – mostly on source data acquisition. For these three steps, we performed numerous Google searches and browsed numerous web sites for elevation, imagery, and feature source data for the island of Oahu. We downloaded and evaluated various datasets, each of which took up to a couple of hours due to their large size. Uploading the final versions to VR-TheWorld Server took only about an hour or two.

Step 4: Rapidly add 100,000+ procedurally-generated 3D buildings to the island of Oahu

To make our simulations look realistic from relatively low altitude, we needed 3D models of the buildings on the island of Oahu. Since our scenarios do not require the buildings to have geo-specific textures, we took advantage of VR-Vantage's ability to procedurally generate and texture building geometry by extruding from areal footprints on the fly. While this technique does not allow as much control over the visual result as you would have in a database generation tool, it allows you to work directly in your run-time engine and achieve great scalability and reasonable fidelity with minimal time and effort.

We found a structures_facilities shapefile at the Honolulu Land Information System (HoLIS) website http://gis.hicentral.com/data.html that contained more than 123,000 building footprints:

> **Oahu Structures** – area shapefile (StructuresA.shp) containing 123,000 building footprint area shapes.

We uploaded this shapefile to VR-TheWorld Server where it was tiled for rapid response. In VR-Vantage, we edited a configuration file (.earth file) to specify a set of mappings that would tell VR-Vantage how to generate building geometry from footprints. In this case, our scripts said to extrude exterior walls to the height specified by a particular attribute in each feature description and to select from a set of geo-typical building wall textures from our pre-existing texture library.

Feature data is streamed from the server and geometry generated by VR-Vantage only for buildings that come near the viewing frustum.

Time required: About 40 hours combined for steps 3 and 4 – mostly on source data acquisition. See step 3 description above.

Step 5: Add light points along roads and alongside buildings on Oahu

To add a touch of realism to dusk and night scenes, we used GIS tools to derive thousands of light points from the building shapes and road vectors.

> **Oahu Lights** – point shapefile (LightsP.shp) derived from road network

VR-Vantage loads the resulting shapefile containing thousands of point features, and performs point-model substitution at run-time – placing pre-existing 3D models of lamp posts, etc. at the geospecific locations indicated by the shapefile.

Time required: About 2 hours with the GIS tool.

Step 6: "Clean" source imagery around Honolulu airport
The USGS does not make its imagery products specifically for the purpose of visual simulation. Consequently, they made no effort to blend the 1ft Oahu imagery into any whole earth imagery dataset. So you can see where the high resolution imagery ends and the Harris Terracolor water begins. However, one of our requirements was to take-off and land at the Honolulu Airport. Since the boundary between datasets fell right in the aircrafts' flight path, we decided it was worth "fixing" the imagery in this high-interest area.

We went to Harris for a solution. Together we worked out a plan where they would acquire a single scene of 50cm imagery from Digital Globe World View 2, blend it into the Harris Terracolor ocean imagery, and feather it into the natural land water boundary of the high-resolution Oahu Imagery. The result is a more realistic scene for airport operations.

> **Honolulu Water Imagery** – 1ft water replacement imagery custom built by Harris, includes Digital Globe WV2 Imagery blended into Oahu Imagery and Harris Terracolor Imagery – about 12 GB of data.

A second annoying artifact associated with the high resolution imagery is that it contains pictures of vehicles. This is fine when viewed from high above, but it is unsettling to see the image of an aircraft plastered on the tarmac as you are taxiing over it. So, we used Adobe Photoshop to remove the airplanes and other airport vehicle images from the imagery.

Time required: About 2 days to clean the tarmac images. About 8 hours of discussion with Harris, and time spent obtaining, evaluating, and uploading the resulting imagery.

Step 7: "Stitch in" high-resolution runway model at Honolulu airport
The terrain at the airport is fairly flat, so our 10m Oahu elevation posts actually work fine for non-critical ground operations, even taxiing to the runways. But we wanted to make the take-off and landing experience as real as possible.

We used the "cut-in site" technique to add fidelity to the runways. In this technique, you can point VR-Vantage at a pre-existing 3D model (e.g. OpenFlight) of a site to be used as an inset. VR-Vantage processes the 3D model to find its boundaries, avoids requesting data from the server for the area within these boundaries, and automatically "stitches" the site model together with the streaming elevation data in the surrounding areas at run-time so that there are no cracks or seams. With VR-Vantage and the VR-TheWorld Server, you don't need to create a large area "skirt" around each of your high-resolution insets. The entire world is your "skirt" and it immediately fits perfectly.

In many cases, users already start with a pre-existing site model, and they are able to *immediately* stitch it into the VR-TheWorld background. In our case, we first had to build

the geospecific site model. Our site consisted of just a runway, built using a polygonal modeling tool to include detailed textures, hold lines, and runway painted markings. This technique produces the resolution needed for views from the cockpit of the aircraft.

> **Airport Site Model** – Geospecific OpenFlight model of the airport runways, dynamically cut into the streamed terrain skin.

Time required: About 8 hours to create a high-fidelity geospecific runway model. A few *seconds* to specify the runway model to be stitched into the larger Oahu and global skirt at run-time.

Step 8: Further flesh out Honolulu airport with terminal buildings, a geospecific tower, trees, and other props

To support air and ground traffic management requirements, the airport site was further developed with geospecific models of the control tower, terminal buildings, and thousands of trees.

The tower was purpose-built in a polygonal modeling tool and imported into VR-Vantage using a variant of the "point-feature-substitution" technique described earlier: The location of a point feature in a shapefile specifies where to place a 3D model, but since there was only a single tower, we used the "prop creation" dialog in VR-Vantage, rather than a .earth file script to specify the mapping to the correct 3D model. (Prop mappings are saved out in a .mtf (MÄK Terrain File) metafile.)

Seven thousand geospecific trees were added to the airport area based on a vegetation shapefile, mapped to 3D models via a .earth file.

Finally, terminal buildings were built as geocentric site models and imported directly into VR-Vantage as terrain patches. Because terminal buildings sit on top of the terrain, there is no conflict with the underlying terrain, and no "cutting in" is necessary. We were able to simply tell VR-Vantage to add multiple terrain patches to the scene and save out the full configuration in an .mtf file.

> **Site Buildings** – point shapefile (BuildingsP.shp) converted to props in the .mtf file.
> **Site Trees** – point shapefile (vegetation.shp) loaded direct-from-source on disk.
> **Airport Terminal Buildings** – geocentric OpenFlights files loaded as terrain patches.

Time required: 40 hours to hand-model the terminal buildings and tower.

Step 9: Build up Waiau Neighborhood Site using similar techniques as in the airport area

The Waiau neighborhood is the site of our vehicle surveillance scenario. For this area, the building extrusion technique, used generally on the island, did not provide sufficient resolution. So we employed some of the same techniques we used in the airport area to

add higher fidelity. In particularl, we used the "point feature substitution" technique again, to place pre-existing 3D models of houses, trees, and street lights at runtime, based on the geospecific locations of point features in shapefiles.

Unfortunately, we did not have a source shapefile that described the locations of the buildings in this neighborhood as point features (we only had building footprint areal features, which could have been used for the lower-fidelity extrusion technique). Similarly, we did not have a source shapefile containing point feature locations of trees and street lights that was precise or detailed enough to correlate with the high-resolution imagery in the area. We addressed this problem by using ArcMap to create new "source" data by placing point features at the appropriate locations on top of the imagery: We added new trees to the vegetation shapefile by placing point features where tree pixels appeared in the imagery; we added new lamp posts to the infrastructure shapefile by placing point features where street lights appeared in the imagery; and we added- point features to the Site Buildings layer to represent buildings by placing point features where buildings appeared in the imagery (or where building footprints appeared in the buildings areal layer). Enhancing our source data in this way took some time but once the shapefiles were updated, we could immediately re-load them into VR-Vantage to generate a richly modeled 3D representation of the neighborhood on-the-fly.

> **Site Buildings** – point shapefile (BuildingsP.shp) converted to props in the .mtf file.
> **Site Trees** – point shapefile (Vegetation.shp) loaded direct-from-source on disk.
> **Site Lights** – point shapefile (InfrastructureP.shp) loaded direct-from-source on disk.

Time required: About 40 hours to create enhanced "source" data in ArcGIS, including adding about 3,000 individual tree point features.

Step 10: Resolve conflicts between point and areal features in the Waiau neighborhood
Once we completed step 9, VR-Vantage was placing pre-existing 3D building models into the scene based on the locations specified in our point feature buildings shapefile. The only problem was that VR-Vantage was *also* still generating lower-fidelity models of some of those same buildings based on the footprints in the original Oahu Structures areal feature shapefile. Because two different techniques were at work simultaneously, we had dual, conflicting representations for some of the buildings in the 3D scene. So the final step was to remove the unwanted areal representations of the buildings within the Waiau neighborhood by editing the Oahu Structures shapefile in ArcMap and uploading the edited version to VR-TheWorld Server.

Time required: An hour or two.

Quick Reference

The chart below is a quick reference that lists each of the areas we needed to represent, along with the source files we used to generate a 3D representation at the appropriate level of fidelity for our use cases:

Earth – Global Air Traffic Navigation
Hawaiian Islands – Terminal Air Control
Oahu Island – Ship Channel Surveillance, background clutter for all missions
Honolulu Airport – Taxi, Take-off, Landing & Airport surveillance
Waiau Neighborhood - Ground Vehicle Surveillance

	Earth	Hawaiian Islands	Oahu Island	Honolulu Airport	Waiau Neighborhood
Earth Elevation	✓	✓			
Earth Imagery	✓				
Hawaii Imagery		✓			
Oahu Elevation			✓	✓	✓
Oahu Imagery			✓	✓	✓
Oahu Structures			✓	✓	
Oahu Lights			✓	✓	
Honolulu Water Imagery				✓	
Airport Site Model				✓	
Airport Terminal Buildings				✓	
Site Buildings				✓	✓
Site Trees				✓	✓
Site Lights				✓	✓

Summary

The Hawaii terrain provides a working example of how the many terrain techniques supported by MÄK's products can be combined to cost-effectively create a correlated, seamless, and global 3D environment - with just the right amount of fidelity in each area for the tasks at hand. Call on MÄK to help you develop a terrain strategy for your next project.