

## **Rapid Generation of Digital Terrain Models using Total Station Data and Aerial Images or Satellite Imagery**

**Mike Kennedy, ACTAR, Paul Hetherington BTACS, and Craig Luker P. Eng, P.E., ACTAR**

### **ABSTRACT**

Many crashes occur on terrain that cannot be assumed to be flat. In many cases if investigators made the assumption that the surface on which the vehicles collided was flat, it would introduce serious errors to any analysis or computation of reconstruction findings.

Most modern reconstruction experts, whether employed as independent consultants to the litigation industry, or employed as police experts will rely on total station measuring instruments to establish the coordinates of the overall scene geometry as well as any relevant measurement points. Once measurement points are established it can often be seen that the scene was not flat as the measurement points will show significant differences in the elevation (Z) values.

A DTM (Digital Terrain Model) has been developed in the Aras 360 HD software product to allow investigators to model the scene three dimensionally by uniting the scene measurements with accurate satellite or aerial images. The procedure is described and reviewed in this paper.

### **INTRODUCTION**

Most modern reconstruction procedures involve using discreet positional data that has been captured using total stations or similar equipment. This data includes distances that are adjusted for elevations. The reconstruction process may include a linear momentum analysis, energy analysis, a simulation procedure, roll over calculations, or vehicle launch velocities from take-off and touch down information. In all cases, the reconstruction procedure is dependent on accurate modeling of the scene. Furthermore, as an important part of the reconstruction reporting procedure a 3D animation or static visualization is often generated to allow interested parties a complete understanding of the event.

The generation of an accurate 3D scene model including terrain has been a technical challenge often requiring complex procedures and the application of several software applications.

There is however, a strong need for 3D crash scene models.

Software engineers at Aras 360 Technologies Incorporated have established algorithms and procedures to accurately unite measurement data and imagery; in a time frame of minutes. The result is a strong payback on the investment in total station equipment. This unique functionality has resolved a long standing challenge in the field of crash reconstruction – to generate an accurate 3D roadway upon which to base reconstruction procedures and visualizations.

## Imagery

Accurate satellite imagery has become more accessible over recent years via distributors such as Google, Bing, and other providers.

Google buys its imagery from different imagery suppliers, please see the list below

<http://www.spatialenergy.com/>

<http://www.digitalglobe.com/>

<http://www.geoeye.com/CorpSite/>

<http://www.satimagingcorp.com/gallery.html>

<http://www.usgs.gov/pubprod/aerial.html>

Although Google uses the word *satellite*, most of the high-resolution imagery of cities is aerial photography taken from aircraft flying at 800–1500 feet rather than from satellites; while most of the rest of the imagery is in fact from satellites.

The imagery selected for use in Aras 360 HD may be from any source including:

1. Custom aerial photograph from a manned or unmanned aircraft
2. Satellite image from any source
3. Directly from the Google maps interface within the program

In Aras 360 HD users have the option to import and scale an aerial image or to import the image directly from

Google maps as Aras 360 has licensed the Google Maps API.

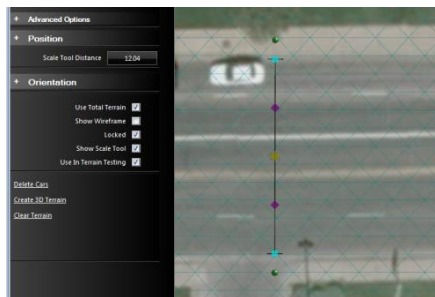
Here is how to insert the various types of imagery:

### Custom aerial images are inserted and scaled as follows:

- a. Click anywhere on the scene plane to see the left scene properties panel on the left
- b. Beside the Google icon, use the drop down and choose "Import Scaled image".



- c. Browse and import the image
- d. Click on the image and see the scale tool.
- e. Drag the ends of the scale tool to measure a known distance



- f. On the left panel type in the real world distance
- g. Now the image is to scale. Turn off the tool in the properties at left.

### Using Google Earth directly

- a. Click on the Google icon on the left panel
- b. Use the navigation window by typing in the address or zip code of the scene
- c. Use the navigation window and mouse wheel zoom
- d. Re-size the navigation window to create the aspect ratio for the scene
- e. Click OK

### After the scaled image has been inserted, remove unwanted objects from the image

- a. Click on image
- b. On left panel click on "delete cars"
- c. In new form drag cursor around an object to be removed and release mouse
- d. Continue to clean up image
- e. Click ok to return to diagram mode

## Explanation of the Auto-Scaling of Google images in Aras HD

### 1. Retrieving the Image:

Aras HD users click on the Google icon and navigate to the chosen location and then simply click OK to place the selected image. We use the monitors output and a function designed to take the pixel data and draw it into an image. Essentially taking a screen shot and converting it into a bitmap that we can then manipulate.

N



### 2. Calculating the Length and Height:

Once the image is in a bitmap we can then modify it to force it from Google's scale into our internal measurement system. This allows us to display the photo easily while ensuring that the photo remains the proper size relative to the Aras HD system.

### 3. Get the photos Width / Height

*Ex: Width:*

645

*Ex: Height:*

526

#### 4. Retrieve the Google Earth Measurements

Uses the Document object to retrieve the latitude / longitude values from the attributes saved in the HTML Code returned from the Google maps website.

*Ex: Latitude NE: 50.670947188042646*

*Ex: Latitude SW: 50.670049625853764*

*Ex: Longitude NE: -120.31816452741623*

*Ex: Longitude SW: -120.31989991664886*

**Calculates the difference in width and difference in height.**

*Ex: Latitude Angle: 0.000900268555*

*Ex: Longitude Angle: 0.001739502*

**Uses retrieved values to calculate the size of the image from the earth's radius.**

**Convert the latitude / longitude values into Radians**

**Use the earth radius and the angle and pixel widths to calculate the size in feet.**

***This sets the image to have the real world width / height in feet.***

With the calculated values we can now set the bitmap to be the right size. So that when it is used as a texture for a surface in ARAS HD or ARAS 360 we can get the right color in the right area.

## Align Survey Data with Image

Aras 360 HD users can import total station data, point cloud data or any other form of measurement data as coordinates by simply clicking on the Measurements tab and following these steps:

1. Click on down arrow under measurements tab
2. Choose the file type from drop down
3. Browse to file
4. Import points without any connection

Align X,Y measurement data with image as follows:

- a. Make all points one clear color by clicking on point color button on left panel
- b. Select point set axis by clicking on it on scene or by clicking on the file name on measurements tool bar
- c. Click 2D button to create perfect orthogonal view (no perspective distortion)
- d. Move the points and rotate the points using the grips



- e. Align the point set with the image using known common points or aligning with curb edges etc.
- f. On left panel with image selected click “create 3D terrain”.
- g. This will model the scene by instantly creating a 3D mesh between measurement points and stretching the image over the points.

## Selection of Measurement Points for use in the DTM

When the Aras HD users download the measurement data to the scene it is immediately visible in a measurement log at the bottom of the program window.

Notice the measurement log has a column labeled “Terrain”. This allows users to de-select points that are not meant to model the terrain surface like tops of guard rails, stop signs, etc. therefore the user should de-select

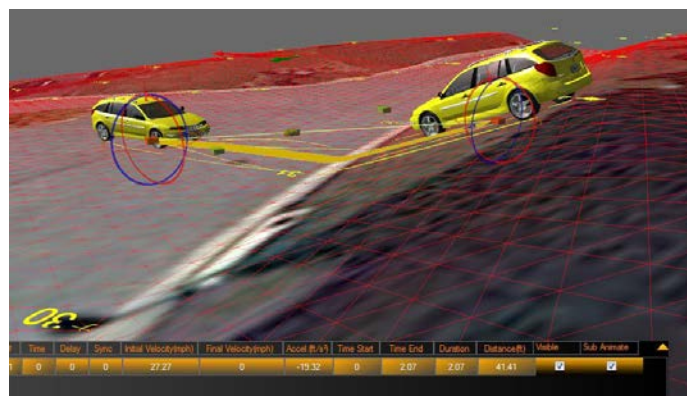
those points and then click “Create 3D Terrain” again which will correct the spikes on the terrain caused by non-terrain points.

#	North (Y)	East (X)	Elevation (Z)	Description	Color	Terrain	Super Size	Modified
1	-159.277	-88.591	4.615	Z1	Black	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	-140.445	-70.972	4.143	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	-120.728	-55.774	3.465	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	-99.431	-42.453	2.863	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	-78.284	-31.792	2.464	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	-55.093	-22.313	1.773	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	-31.199	-15.252	1.012	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	-18.549	-12.415	0.739	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	-7.846	-8.759	0.478	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	5.858	3.898	-0.325	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	10.57	15.644	-0.837	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	11.624	49.759	-3.776	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13	11.911	65.346	-5.468	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14	13.32	102.305	-10.127	X1	Green	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### The Aras Digital Terrain Model - ADTM

Once the user has aligned the image and points and clicked to create 3D terrain the internal algorithms generate a 3D mesh to connect the points. Simultaneously, the image is resized to conform to the mesh and the result is a 3D model of the scene.

The purpose of the DTM is to provide an accurate roadway surface upon which to perform 3D simulations, animation and reconstructions. The DTM within the Aras HD system allows users to apply models, animation and simulation paths, momentum vectors all of which recognize and evaluate the DTM. Therefore any vehicle model set in motion with a path across the DTM will auto adjust pitch and roll values and move at the correct elevations as provided by the mesh.







### Accuracy

The resulting DTM can be relied upon as very accurate near the points and the further the position is from the points the less accurate depending on terrain. Therefore, more points will equal more accuracy in the final DTM.

The DTM from Aras HD can be exported as a .dxf file for use in other applications such as PC Crash and HVE as a basis for simulations.

The mesh density may be adjusted to a minimum size of 1 foot.

The DTM will not model roadside objects such as guard rails, jersey barriers or other man made surfaces because they change in elevation too much over too short a distance. Instead the Terrain model has been optimized to create realistic and accurate terrain.

### Mathematical Procedure

Aras software engineers have developed unique code to subdivide the aerial photograph surface into a Triangular Grid based on the Triangles X/Y parameters set by the user. The Y value specifies the number of rows of triangle to create. The X is actually the number of triangle pairs to create along the columns. The total number of triangles along the columns is actually  $2*x + 1$  due to the oscillating triangle pattern used, as opposed to the Rectangular Grid pattern that is often used. When the user clicks "Create 3D Terrain" the program generates a set of 3D Triangles using a specific and refined procedure based on Delaunay Triangulation. The function then iterates through all of the triangles in the Surface Triangle Grid and hit tests the 3 points of the triangle against the generated Triangles and adjusts the z value of each point on the Surface Triangles to match the location hit on the Delaunay Triangle.



## Measurement Procedure

This function will only provide an accurate 3D surface when the foundation of the process is based upon precise measurements captured with a calibrated total station or point cloud scanner.

In addition to the measurements one would normally record of the overall roadway geometry additional measurements to define the surrounding terrain are required to define the overall scene.

In the image below a suggested pattern of measurements is shown.



**Measured scene in Aras HD**

Once the 3D terrain is established, the resulting scene can easily demonstrate issues such as vertical visibility obstructions imposed by the landscape.



**Scene in Aras HD in 3D**

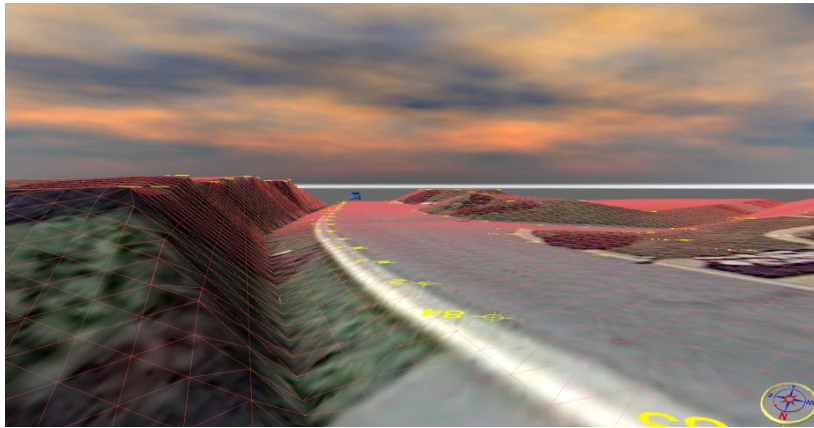
## Editing Tools in Aras HD

Aras software engineers experimented with several procedures to provide additional tools for improving the DTM once the procedure was complete but may not have modelled certain aspects of the scene to the satisfaction of the user. Normally this occurs when insufficient measurements were recorded, and/or measurements were not recorded at the correct positions so that roadway features like ditches, or berms did not appear realistic.

The additional tool is that the polyline tool in Aras HD that has the option to become a “Terrain Edge”. Although not apparent to the user, once the user draws a polyline to define the edge of a ditch or berm, and checks the box in the software to make the polyline a “terrain edge” points are established invisibly along the polyline at 2 ft intervals that will be considered by the terrain system.

Users can use this special function to create terrain edges from fewer points or even where no points exist knowing of course the accuracy of the terrain where no points exist is questionable. One of the most helpful uses of this feature is that road edges and painted lines can be used as boundaries for the DTM analysis. That mimics the real work in that road beds are smoothed along their length when the road is built. As result small hills, dips and other terrain disturbances are interrupted by the road’s edge. When the road edges are defined as a “terrain edge”, ARAS will ensure that all of the points between the road edges are smoothly connected to one another, ignoring off-road bumps. Those off-road terrain disturbances will be smoothly joined to the road edge, but the disturbances will not continue out *into* the road as a bump. The final result is a smooth road cutting through undulating terrain, just like in the real world!

The image below demonstrates the effect of adding a terrain edge off roadway at a lower elevation to create ditch like effect.



#### Acknowledgments

The authors are grateful for assistance in the explanation from our senior graphics programmer Ponnuchamy Varatharang, and assistance in gathering relevant scene data from our senior reconstruction software trainer Mike Greenfield.