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**DEPARTMENT OF NATIONAL DEFENCE
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OPERATIONAL RESEARCH DIVISION

DIRECTORATE OF OPERATIONAL RESEARCH (JOINT)

DOR(JOINT) RESEARCH NOTE RN 2002/03

SCENARIO RECONSTRUCTION USING STK

By

A. Hill

Dr. J. Chan

Dr. R. Mitchell

SEPTEMBER 2002

OTTAWA, CANADA



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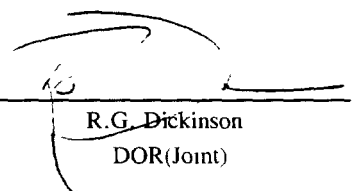
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ABSTRACT

AGI's Satellite Tool Kit (STK) visualization tools were used recently to provide detailed situational awareness of a reconstructed air force operation for the purposes of a post-operation analysis. The end products were several animations or movies mixed with audio from the cockpit of one of the aircraft under scrutiny. This research note provides a detailed description of the process involved in developing these animations. It is intended as a manual to streamline the process for future endeavors of this nature.

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GLOSSARY

AGI	Analytical Graphics, Inc.
AGL	Above-Ground-Level
ASL	Above-Sea-Level
CVR	Cockpit Voice Recorder
GUI	Graphical User Interface
HUD	Heads Up Display
LLA	Latitude, Longitude and Altitude
STK	Satellite Tool Kit
YPR	Yaw, Pitch and Roll

SCENARIO RECONSTRUCTION USING STK

I - INTRODUCTION

1. The Joint Staff Operational Research Team (JSORT) was given an ad-hoc task to provide detailed situational awareness of a reconstructed air force operation for the purposes of post-operation analysis. The tasking came as a result of JSORT's demonstrated expertise with AGI's Satellite Tool Kit (STK). The desired end product was to be an animation mixed with audio from the cockpit of one of the aircraft under scrutiny. As a group, all of the authors had, at one time or another in the distant past, made a movie in the course of our individual STK training. Re-acquainting ourselves with the movie making process exclusively from the online help files proved to be a challenge given the tasking timeline. Also, this was the group's first attempt at developing a high quality 3-D animation for a sponsor. For these reasons, it was felt that documenting this process was necessary in order to simplify future reconstruction efforts.

2. The time from the delivery of the data to the Team in the form of Excel Spreadsheets to the delivery of several animated movies produced with input from the sponsor, was five working days. Given the collective experience of the authors that is captured in this paper, this time can be considerably reduced to the point where the only true time sink will be the analyst's and/or the sponsor's preoccupation with perfecting the product.

3. Section II of this paper provides a detailed description of the movie-making process. The chapter is divided into four parts. The first part deals with manipulating the data in MATLAB to produce aircraft waypoint and attitude files from the Excel spreadsheet containing the raw data. Performing this function within MATLAB is a useful capability but not a necessary step. This is followed by a description of the basic scenario set-up using the STK Graphical User Interface (GUI) to: create the aircraft and missile objects; link the aircraft to the data files; set up the animation settings; import terrain data; and overlay imagery onto the terrain data. The third part describes available options for the appearance of the animation, the creation of the animation, and the storage of the animation as an avi file. The final part of the section describes the mixing of the video and audio to produce the final product.

4. It is assumed that the reader has a basic familiarity with STK. The STK modules needed for this work are STK Pro, 3-D Advanced Visualization Option (STK AVO) and the STK Terrain module. Additionally, the STK/Connect module for MATLAB interface and the STK Attitude module would be useful tools to consider for a more robust analytical capability. For audio and video mixing, MGI Video Wave 4 software was used. For a higher quality product Analytic Graphics recommends the use of Adobe Premiere 6.

II - PRODUCTION

5. The team was given an Excel spreadsheet of flight data derived from the aircraft heads up display (HUD) recordings and ground track position charts as well as a cockpit voice recording (CVR) to create short movie clips of the scenario. For discussion purposes, a simple and unclassified scenario is used in this document instead of the scenario processed for the client. This simple scenario captures the action of a CF-18 dropping a bomb on a stationary target on the ground. The scenario recreation and (silent) movie production was done using STK. The mixing of the audio and video tracks was performed using the video editing software MGI Video Wave 4.

6. The most challenging and yet interesting part of the production is the scenario reconstruction using STK. It involves extracting the spreadsheet data and importing it to STK, recreating the virtual environment, and synchronizing the animation with the audio conversation. Once the STK scenario was complete, the animation of the scenario was recorded in a movie format, which was then mixed with the audio track. Although this process was relatively straightforward, there were pitfalls along the way due to lack of experience in this area. The next four sections will describe the production process in detail.

FLIGHT DATA MANIPULATION

Waypoint File

7. In order to determine a flight path of an aircraft, one must provide the position of the vehicle. In addition to the latitude, longitude and altitude (LLA) of the plane, the time or the speed at each waypoint is needed to capture the motion of the object. Given a source of flight data, if it contains only the set of time-LLA or LLA-speed, one can simply put the data in an STK waypoint file, which is then imported to the software. In real flight data, it could contain time, LLA, speed, acceleration and other information. In this over-determined case, one must decide on importing either the time-LLA set or LLA-speed set to STK. If the time-LLA set is used, STK will calculate the instantaneous speed at each waypoint. Ideally the calculated speed should exactly agree with the corresponding one in the flight data but this rarely happens. One could blame the discrepancy on inaccurate calculation, air friction in real flight, error in data collection devices and so on. If the discrepancy is negligible, one must decide on which is the real data and which is the simulated data in constructing the virtual scenario.

8. A waypoint file is an ASCII file with a file extension of “.ga”. It contains the waypoint information for an aircraft. (The same file can be used for the STK ground vehicles and ships as well.) In the case where the time-LLA set is used, such file has the following format [1]:

```
stk.v.4.2.1
BEGIN GreatArc
Method DetVelFromTime
TimeOfFirstWaypoint 1 Jul 2002 00:00:00.00
NumberOfWaypoints 4
BEGIN Waypoints
0.      -1.010e+00 1.001e+01 3.000e+03
10800.  -1.020e+00 1.002e+01 3.000e+03
18000.  -1.030e+00 1.003e+01 3.000e+03
30600.  -1.040e+00 1.004e+01 3.000e+03
END Waypoints
END GreatArc
```

This example has four waypoints at positions $(-1.01^\circ, 10.01^\circ, 3 \text{ km})$, $(-1.02^\circ, 10.02^\circ, 3 \text{ km})$, $(-1.03^\circ, 10.03^\circ, 3 \text{ km})$ and $(-1.04^\circ, 10.04^\circ, 3 \text{ km})$. The vehicle is found at the first location at the time “1 Jul 2002 00:00:00.00”. It then appears at the second location 10800 seconds later, i.e. “1 Jul 2002 03:00:00.00”. For compatibility, this file can be read by STK version 4.2.1 through to the most recent version.

9. Another example of waypoint file is shown below [1]. This one contains the LLA information and the speed of the vehicle at each point. The latitude and longitude of the points are measured in degrees and the altitude and speed are in meters and meter per second respectively. In other words, this vehicle is traveling at 55 meters per second from one point to another, where the four points are identical to those in the last example. A quick comparison between the two templates concludes that the second one does not have the “Method” statement. This indicates that the default method for importing waypoints is “determine time from velocity”.

```
stk.v.4.0
BEGIN GreatArc
TimeOfFirstWaypoint 1 Jul 2002 12:00:00.00
NumberOfWaypoints 4
BEGIN Waypoints
-1.010e+00 1.001e+01 3.000e+03 5.500e+01
-1.020e+00 1.002e+01 3.000e+03 5.500e+01
-1.030e+00 1.003e+01 3.000e+03 5.500e+01
-1.040e+00 1.004e+01 3.000e+03 5.500e+01
END Waypoints
END GREATARC
```

10. It is unlikely that the flight data is stored in the correct format such that simple copy-and-paste procedure yields a waypoint file like the one above. Sometimes columns of data must be removed before copy-and-paste, or unit conversion is required. If the data is stored in an Excel file, a few MATLAB commands can easily write the data into a waypoint file. The following MATLAB commands creates such waypoint file:

```
[numericData textData] = xlsread('C:\FlightData.xls','Sheet1');
numWaypoints           = size(numericData,1);
time = numericData(:,timeCol);           % Time in seconds
lat  = numericData(:,latCol);             % Latitude in degrees
lon  = numericData(:,lonCol);             % Longitude in degrees
alt  = numericData(:,altCol) * 1000;      % Altitude in meters
fid = fopen('C:\Waypoints.ga','wt');
fprintf(fid,'stk.v.4.2.1\n');
fprintf(fid,'BEGIN GreatArc\n');
fprintf(fid,'Method DetVelFromTime\n');
fprintf(fid,'TimeOfFirstWaypoint    1 Jul 2002 00:00:00.00\n');
fprintf(fid,'NumberOfWaypoints\t%d\n',numWaypoints);
fprintf(fid,'BEGIN Waypoints\n');
for i = 1:numWaypoints
    fprintf(fid,'%16.8e %16.8e %16.8e %16.8e\n',...
            time(i),lat(i),lon(i),alt(i));
end
fprintf(fid,'END Waypoints\n');
fprintf(fid,'END GreatArc\n');
fclose(fid);
```

This example creates a waypoint file “Waypoints.ga” with the time-LLA set of data as input. The MATLAB variables *timeCol*, *latCol*, *lonCol*, and *altCol* are the column numbers of the epoch time, latitude, longitude and altitude in “Sheet1” of the Excel spreadsheet “FlightData”. The epoch time in the spreadsheet is assumed to be in seconds, and the LLA in the spreadsheet are measured in degrees and kilometers. Slight modification of this example allows one to generate a waypoint file for the LLA-speed data set.

Attitude File

11. When STK simulates a flight, it makes some assumptions on the orientation of the plane. For example the aircraft flies right side up and the front of the plane is always pointed along the velocity vector. For mission planning purposes, these assumptions are reasonable and sufficient enough. However for scenario reconstruction, they are invalid occasionally. A real aircraft rolls slightly from time to time and exhibits some degrees of pitch during some maneuvers. Such movement affects the field of view of the pilot and the footprint of any on-board sensor. Therefore it is important to import the attitude data of an aircraft into STK to reconstruct the orientation of the vehicle in the virtual environment. This can be done using an attitude file.

12. An STK attitude file is similar to a waypoint file. It contains the instantaneous yaw, pitch and roll (YPR) of a vehicle¹. The angle of yaw is a measure of deviation from the vertical plane on which the velocity vector lies. This plane is shown in Figure 1. Since it is vertical, the (unit) gravitational vector $\hat{g}$ must lie on it. The unit vector $\hat{x}$ on the plane is simply the normalized velocity vector. The last unit vector $\hat{z}$ in the diagram also lies on the plane but is perpendicular to $\hat{x}$. Given the vectors $\hat{x}$ and $\hat{z}$, one can derive another unit vector $\hat{y}$, which points into the paper, such that the set $\{\hat{x}, \hat{y}, \hat{z}\}$ forms a localized coordinate frame. STK refers to this frame as VNC(CBF) that refers to “velocity with respect to central body fixed system”. Therefore given the velocity vector and the direction of gravity, the VNC(CBF) frame is uniquely defined. The readers are reminded that the VNC(CBF) frame is one of the many reference frames they can use. Nevertheless the real flight orientation data the authors received is expressed in this reference frame. Thus in the rest of this document, the use of this coordinate frame is assumed. In the case of measuring the yaw, it is the rotation about z-axis of the VNC(CBF) frame. Similarly, the pitch is the rotation about y-axis, and the roll is the rotation about the x-axis.

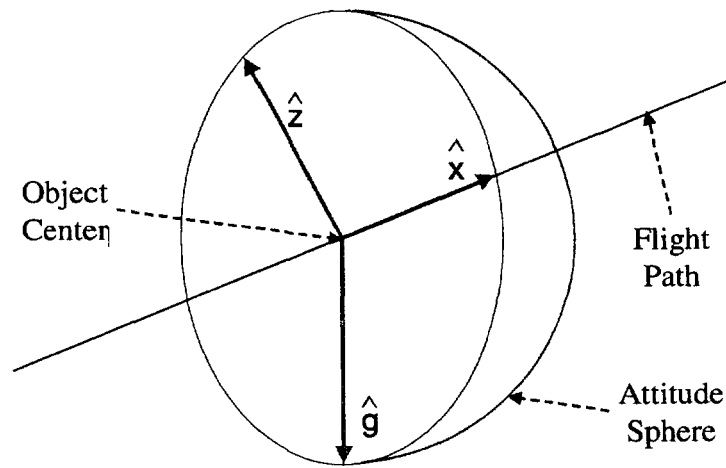


Figure 1: The Vertical xz-plane of the VNC(CBF) Reference Frame

¹ YPR is the most popular way of describing the orientation. Other ways like quaternions, Euler angles, etc. can be used in the attitude file as well.

13. The STK attitude file has a file extension of “.a”. Similar to the waypoint file, it is in ASCII format containing some script commands describing the orientation of a vehicle. An example of it is given below [1]:

```
stk.v.4.2.1
BEGIN Attitude
NumberOfAttitudePoints 4
ScenarioEpoch 1 Jul 2002 00:00:00.00
FileDisposition AddTo
Sequence 321
AttitudeTimeYPRAngles
0 0.0e+00 2.0e+00 5.0e+00
1 0.0e+00 4.0e+00 -5.0e+00
2 0.0e+00 6.0e+00 5.0e+00
3 0.0e+00 8.0e+00 -5.0e+00
END Attitude
```

In this example, the aircraft has YPR of (0°, 6°, 5°) at the time “1 Jul 2002 00:00:02.00”. The “Sequence” statement indicates that the attitude data input is in the order of yaw-pitch-roll because the three correspond to the rotation about the third axis (z-axis), second axis (y-axis), and the first axis (x-axis). If the YPR data comes from an Excel spreadsheet, the attitude file can be generated by the following MATLAB commands:

```
[numericData textData] = xlsread('C:\FlightData.xls','Sheet1');
numPoints = size(numericData,1);
time = 86400 * numericData(:,timeCol); % Time in seconds
yaw = numericData(:,yawCol); % Yaw in degrees
pitch = numericData(:,pitchCol); % Pitch in degrees
roll = numericData(:,rollCol); % Roll in degrees
fid = fopen('C:\Attitude.a','wt');
fprintf(fid,'stk.v.4.2.1\n');
fprintf(fid,'BEGIN Attitude\n');
fprintf(fid,'NumberOfAttitudePoints \t%d\n',numPoints);
fprintf(fid,'ScenarioEpoch 1 Jul 2002 00:00:00.00\n');
fprintf(fid,'FileDisposition AddTo\n');
fprintf(fid,'Sequence 321\n');
fprintf(fid,'AttitudeTimeYPRAngles\n');
for i = 1: numPoints
    fprintf(fid,'%16.8e %16.8e %16.8e %16.8e\n',...
        time(i),yaw(i),pitch(i),roll(i));
end
fprintf(fid,'END Attitude\n');
fclose(fid);
```

In this MATLAB example, the variables *timeCol*, *yawCol*, *pitchCol* and *rollCol* indicate the column numbers of the corresponding data in the spreadsheet. The epoch time in the spreadsheet has a form of “hh:mm:ss”. This is intentionally different from the one in the waypoint file MATLAB example in order to showcase different approaches².

14. Figure 2 shows an attitude sphere generated by STK³ at the time “1 Jul 2002 00:00:02.00”. The two red circles on the surface of the sphere are intersection of the sphere and the yz-plane (vertical) and xy-plane (horizontal). The three blue vectors are the x, y and z vectors in the body frame of the CF-18. (In the body frame, the YPR measures are always zeros.) The diagram shows that the xBody vector points at the vertical red circle. This implies that the yaw is zero. Similarly the deviation of the yBody vector from the horizontal red circle indicates a non-zero roll of the aircraft. Finally the diagram also suggests that the zBody axis is off the z-axis of the VNC(CBF) frame. This refers to a non-zero pitch of the aircraft. The values of YPR are shown in the upper left corner of the diagram. Although the input YPR at that time reads (0°, 6°, 5°), the STK data display shows (0°, 6°, -175°). This is a consequence of the orientation of the VNC(CBF) axes and the body frame axes. In particular, the pointing of the z-axis causes the 180° discrepancy in the roll. Nevertheless the difference makes no difficulty in the scenario reconstruction.

² Converting time format from “hh:mm:ss” to numeric format is easier using MATLAB than using Excel.

³ It requires the STK Attitude module to create this diagram.

- 9 -

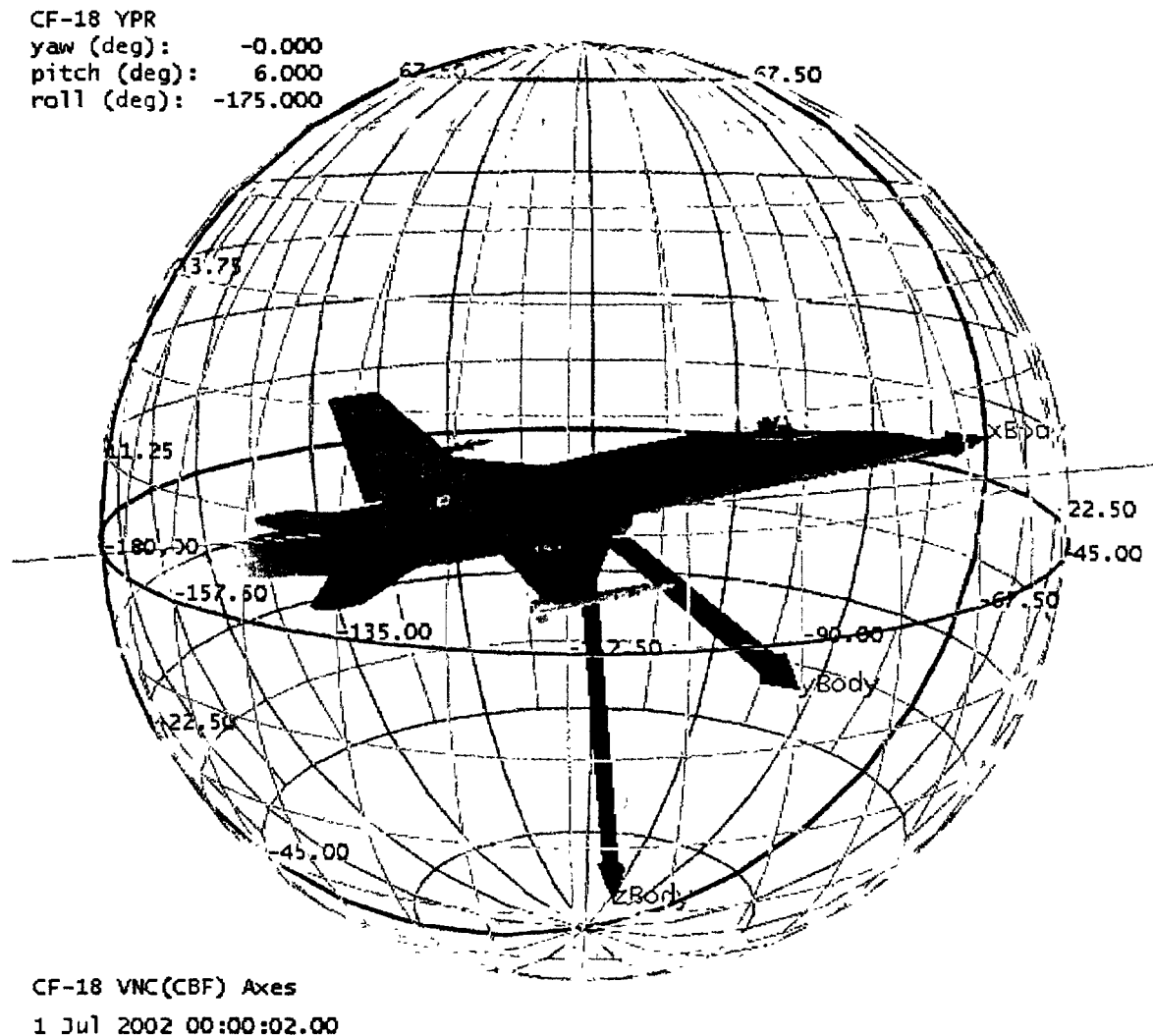


Figure 2: The STK Attitude Sphere for a CF-18

15. Once the waypoint and attitude files are ready, they can be imported to STK. The details of this will be discussed in the next section.

VIRTUAL ENVIRONMENT CONSTRUCTION

16. The scenario start time and end time should be set to the time period of interest in the simulation. This ensures that the environmental factors (daylight etc.) are accurate. These properties are set in the *Time Period* tab of the *Basic Properties* window of the scenario object (Figure 3). It can be accessed by double clicking on the scenario icon in the STK Browser window. The *Epoch* is the time which represents zero seconds in the scenario. This

setting becomes important for scenario properties that are set with respect to the number of seconds from the scenario epoch, such as the attitude profile for aircraft and satellites. Typically the *Epoch* is set to the same time as the *Start* time.

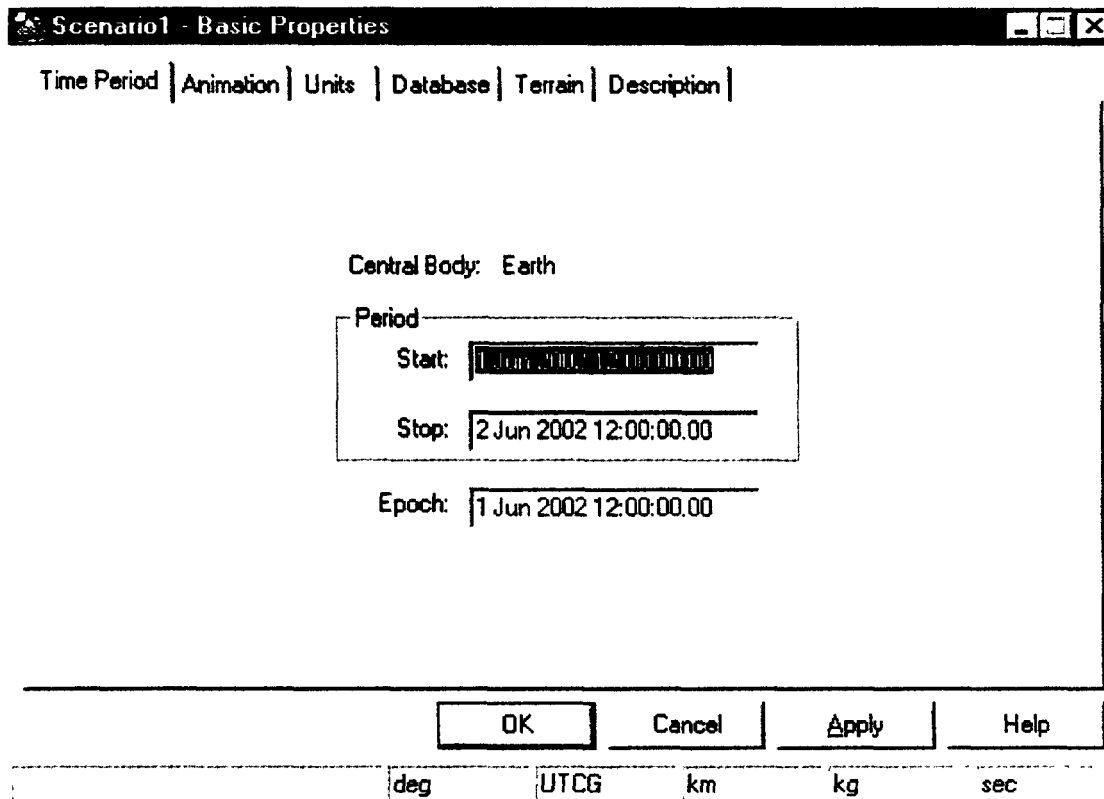


Figure 3: The Time Period Properties of a Scenario Object

17. The *Animation* tab of the *Basic Properties* window is where the settings relating to the scenario animation are found (Figure 4). These settings control the time the Map and VO windows displays begin to animate the scenario. If the animation start time is later than the scenario start time, the Map and VO windows will not begin animating until the scenario has run to the specified time. If the animation start time is set before the scenario start time, the Map and VO windows will never animate. If the intention is to create a real-time movie from the animation, the *Time Step* option in Figure 4 must be set according to the frame rate of STK movie recorder. STK records at 30 frames per second. As will be discussed later, STK will be set to record the animation at every time step. Therefore, in order that the final movie be in real-time, the *Time Step* should be set to 0.033333 (1/30). Although the display in the window trims the number to three decimal places, STK stores the number to considerably higher accuracy. Especially where extreme accuracy is required, or for longer movies, the above number should be entered to at least six decimal places.

Scenario1 - Basic Properties

Time Period | Animation | Units | Database | Terrain | Description

Start Time: 1 Jun 2002 12:00:00.00

☐ End Time : 2 Jun 2002 12:00:00.00

Time Step : 0.333 sec

High Speed : 1.000 sec

OK Cancel Apply Help

deg	UTCG	km	kg	sec
-----	------	----	----	-----

Figure 4: The Animation Properties of a Scenario Object

18. Once an aircraft object has been added to a scenario in the Browser window, double clicking the aircraft icon will open the *Basic Properties* window of the aircraft (Figure 5). Under the *Route* tab, by clicking the *Import from File...* button, it is possible to browse to a previously created waypoint file. Once the file is selected and the *OK* button is pressed, the flight data will be loaded to the aircraft and displayed in the *Route* tab. In the *Attitude* tab, the *Override Basic and Target Pointing Attitude for Specified Times* check box must be selected for importing the attitude file (Figure 6). Beside the *File* box there is a button with three dots on it. This button allows the user to browse to the appropriate attitude file. Clicking on the *Apply* or *OK* button of the *Basic Properties* window will complete the custom file importing process.

CF 18 - Basic Properties

Route | Altitude | Description

Propagator: GreatArc

Import from File...

Start Time: 1 Jun 2002 12:00:00.00Stop Time: 15 Jun 2002 00:00:00.00

Latitude	Longitude	Altitude	Speed	Accel	Time	Turn Radius
0.00000000 de	0.00000000 d	3.048 km	0.077 km/sec	0.000 km/hr	15 Jun 2002 10:00:00.00	0.000 km

☒ Update Map Graphics

Smooth Rate

Edit Mode

☒ Add New Point

☐ Change Current Point

Insert Point

Delete Point

Copy Point

☐ Use Terrain Data

Grnd Elev: 00500 ft

Grnd Elev:

+

-

Turn Radius: 0

OK

Cancel

Apply

Help

degUTCgkmkgsec

Figure 5: The Route Properties of an Aircraft Object

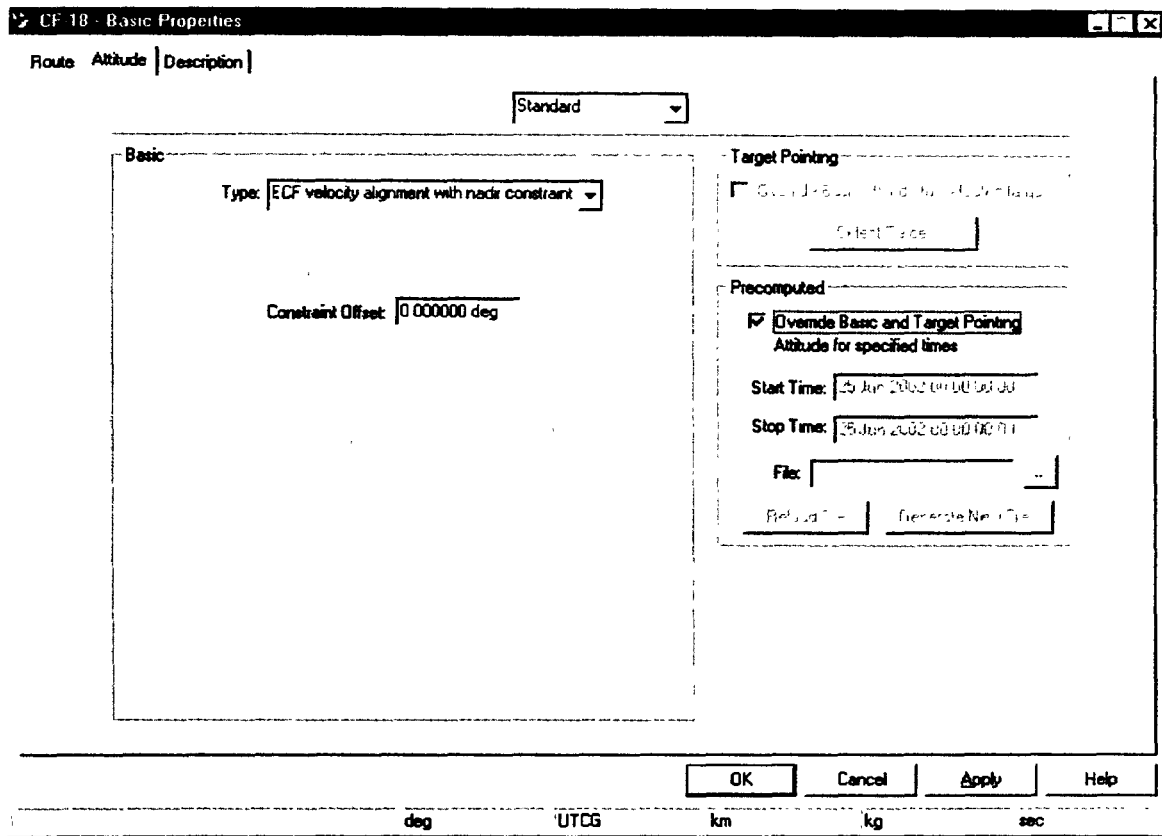


Figure 6: The Attitude Properties of an Aircraft Object

19. Since an airborne bomb is a projectile object, an STK *Missile* object is used to model it. The *Basic Properties* window of the missile object contains all the parameters to ensure the “bomb” behaves appropriately (Figure 7). First, it is very important that the *Propagator* be set to *Ballistic*. This ensures that STK knows that the object is a bomb in free fall (i.e. a ballistic projectile). The *Start Time* of the object is simply the time at which the object begins its descent. The *Launch Latitude – Geodetic*, *Launch Longitude* and *Launch Altitude* should be set to the exact location of the aircraft at the time specified by the beginning of the missile object. This can be found by referring to the *Basic Properties* of the aircraft object (*Route* tab). The fourth option (third pull down menu) should be set to *Fixed Apogee Alt.* This allows the maximum altitude of the bomb to be set by the user. This value should be set with the same value as the *Launch Altitude* to ensure that the bomb always propagates downward. The final three options are self-explanatory; they allow the impact position to be set. If terrain data is not used, it will be necessary to provide the *actual* altitude of the target as the *Impact Altitude* if precise timing of the bomb is a concern. Note that the *Stop Time* will be automatically calculated according to the values provided. There does exist an option to provide a fixed time of flight for the bomb, however this option is not recommended as the

accuracy of the other inputs will suffer.

Bomb Basic Properties

Trajectory | Altitude | Description

Propagator:

Start Time: Stop Time: Step size:

Launch Latitude - Geodetic	0.000000 deg
Launch Longitude	0.000000 deg
Launch Altitude	0.000000 km
Fixed Apogee Alt	12.387301 km
Impact Latitude - Geodetic	20.000000 deg
Impact Longitude	20.000000 deg
Impact Altitude	0.000000 km

deg UTC km kg sec

OK Cancel Apply Help

Figure 7: The Basic Properties of a Missile Object

20. If a visualization of the bombs target is required, a facility object may be created and then located at the point of impact. In the *3D Graphics Properties* of the facility under the *Model* tab, the options for the visualization of the target are available. With the *Show* check box selected and the *Model List* option chosen, the *Edit List* button becomes available (Figure 8). The *Model List* window that is shown allows selection of various models that will represent this facility as well as the scenario times at which the facility appearance switches from one model to the next. For instance, Figure 8 indicates that the facility object appears to be a facility model and changes to a target model 35 minutes later.

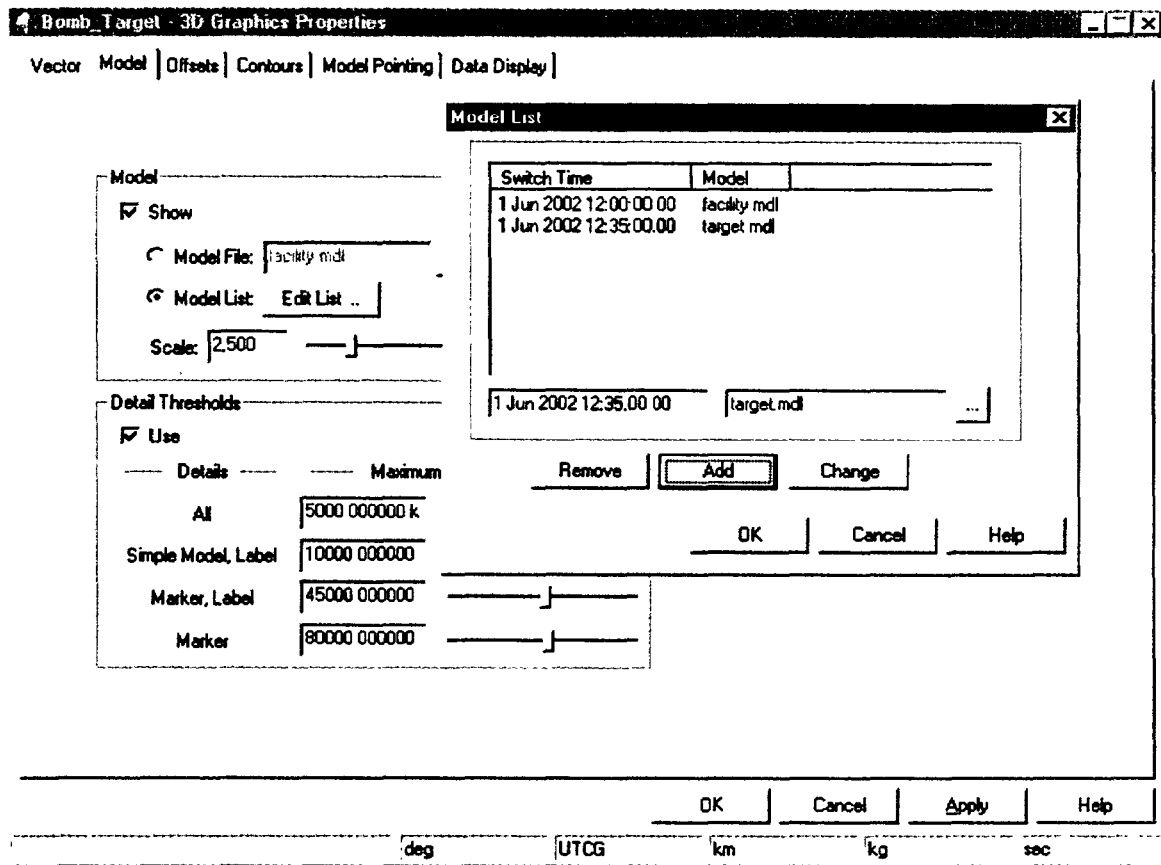


Figure 8: The 3D Graphics Properties of a Facility Object

21. In STK, the Earth is treated as a spheroid without any surface details. In other words, the altitude measured in above-ground-level (AGL) is identical to the corresponding altitude in above-sea-level (ASL). Thus any ground-based facility has a default altitude of zero. This problem can be coped with by raising the altitude of the facility appropriately, and STK can take care of the rest of the calculations. From the computational point of view, this is a sufficient solution to the problem but it is not so in visualization. One can notice that the raised facility is located above the “ground”, which is a zero-altitude surface, in the VO window. Since the goal is to make a movie from the reconstructed scenario, this visualization defect must be corrected. The solution is to include the terrain landscape into the virtual world.

22. The STK Terrain module allows users to import digital terrain data into a scenario object [2]. The format of the terrain data can be in MUSE raster format (*.dte), digital elevation model format (*.dem), NIMA mean elevation data format (*.dmed), DTED terrain cell (*.dt0, *.dt1, *.dt2, *.dt3, *.dt4, *.dt5), and AGI world terrain format (*.hdr). The AGI

world terrain data can be ordered from AGI while ordering the Terrain module, and is used in this project. Different terrain data has different resolution. The higher the resolution the data is, the longer it takes for STK to import the set and to perform any terrain-related calculation. Once the terrain data is available, one can import it into STK by double-clicking the scenario object icon in the Browser window. In the scenario object's *Basic Properties* window, one can choose the *Terrain* tab to start importing the data. Figure 9 shows the window in which the AGI terrain data has been loaded.

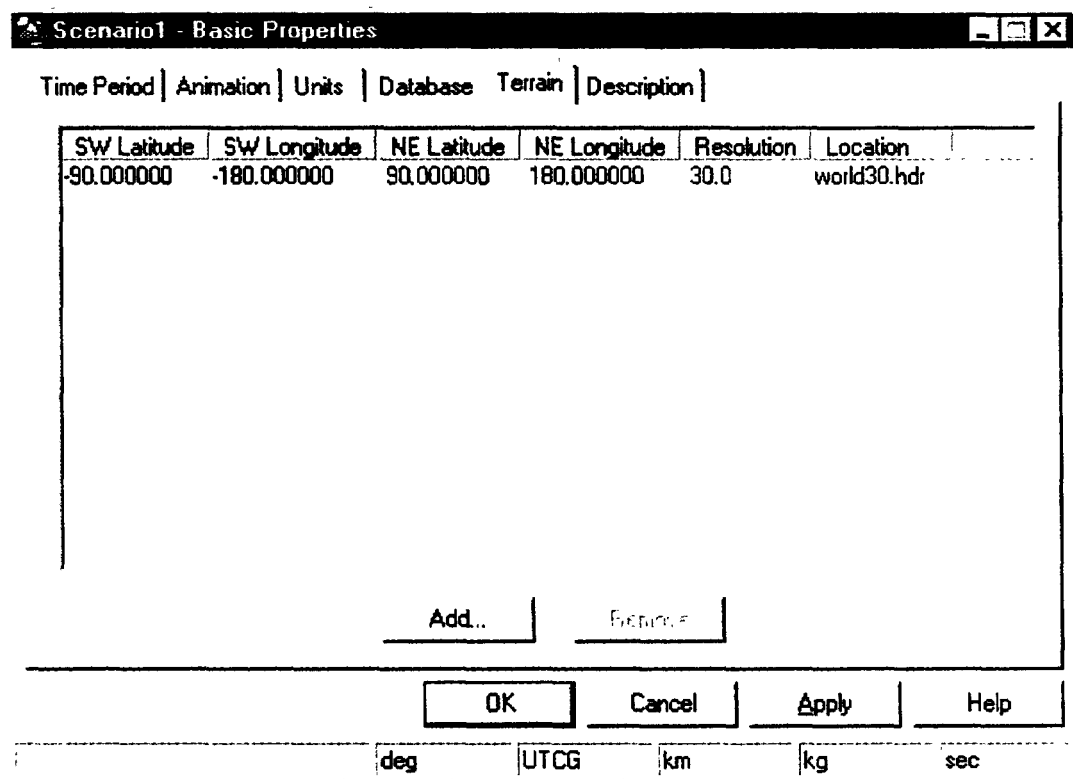


Figure 9: The Terrain Properties of a Scenario Object

23. It is not easy to notice if the terrain data is loaded in the scenario or not because the globe in the VO window shows little difference before and after loading the data. Figure 10 shows an STK facility object trying to use terrain data for the altitude of the facility. In one case the data is available (first window in Figure 10) but not in the other case. (This is indicated by the non-zero number in the circled altitude box of the first figure.) This provides a simple way to check if the importation of the terrain data is successful or not. After using the terrain data⁴, one will notice that the facility is in the air. The readers are reminded that

⁴ Loading the terrain data via the window in Figure 9 does not make all objects in the scenario use the data. The *OK* or *Apply* button (e.g. see Figure 10) of each object must be clicked in order to use the data.

the data is only a set of elevation values of points on the surface of the spheroid. It is not imagery or something that is directly visible. In order to see the surface of the terrain, imagery is needed to cover the area. STK then stretches the imagery appropriately according to the terrain data in order to manifest the terrain details.

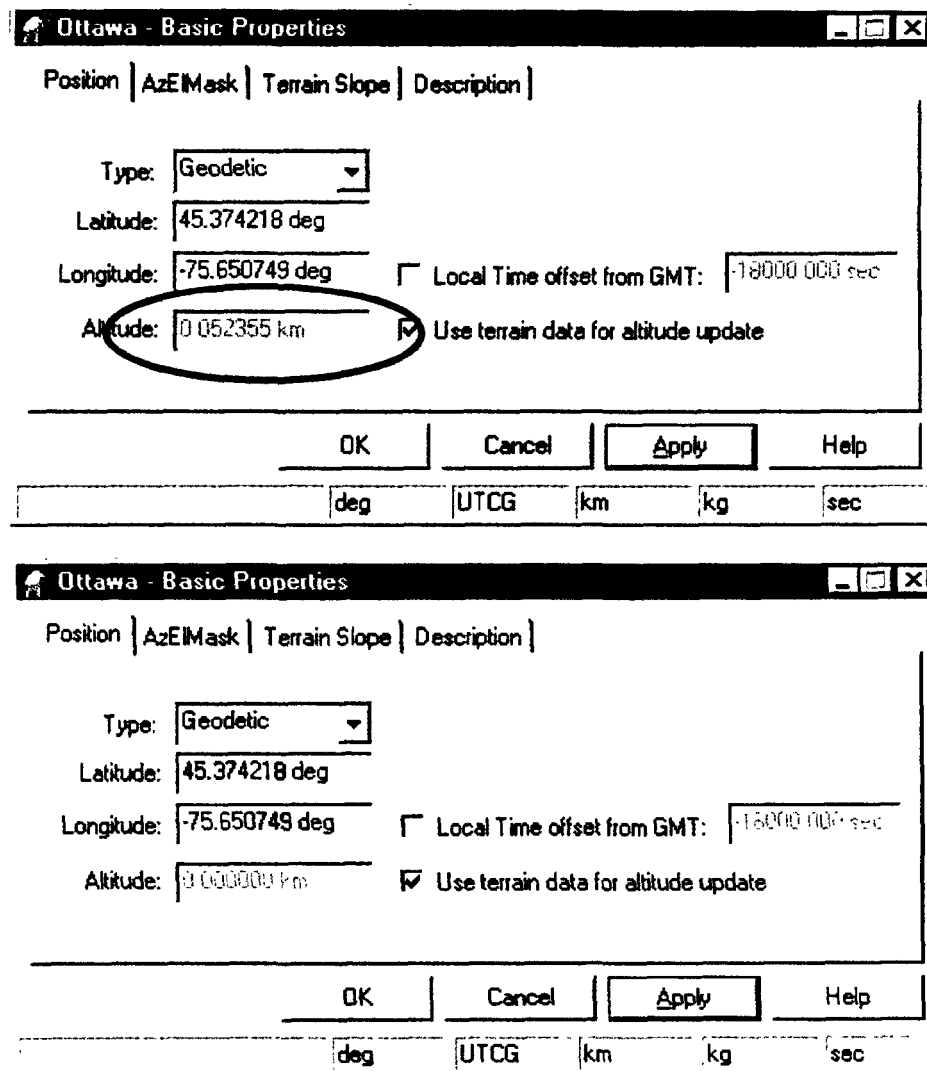


Figure 10: A Facility Can (Top) and Cannot (Bottom) Allocate some Terrain Data

Terrain Converter for Scenario - Scenario1

Terrain Region

North Lat: 46.000000 deg

West Lon: -76.000000 deg East Lon: -75.000000 deg

South Lat: 45.000000 deg

Output

Format: AGI Image (txm)

Size Options

Size	Width	Height
1024 x 1024	1024	1024

Color Options

	Hue	Saturation	Value
Min Elevation HSV:	0.7000	0.8000	0.4000
Max Elevation HSV:	0.0000	0.2000	1.0000

Directory: Program Files\AGI\stk\4.3\STKData\VO\Textures ...

Filename: Ottawa

Convert

Cancel **Help**

Figure 11: The Terrain Converter

24. The imagery for covering the terrain surface must be an STK texture file. This file has an extension of “*.txm”. It contains not only the imagery but the latitude and longitude of the four corners of the picture as well. If such file is readily available, one can immediately paste it onto the surface of the globe. The procedure will be explained in the next paragraph. On the other hand, if no texture file is available, the users can generate a simple one by the *Terrain Converter*. This tool uses the terrain data to create a texture file that uses color spectrum to indicate the contour of the surface. Figure 11 shows this tool, which can be called up by highlighting the scenario object icon in the Browser window and choosing the *Terrain Converter* option in the *Tools* button in the toolbar. The *Terrain Converter* window allows a user to specify a rectangular region on which imagery will be put. (The region

cannot be too big; it depends upon the hardware capability.) Figure 11 suggests that the tool uses the lowest and highest points within the region as the range of altitude in which the color spectrum is spread. Thus it is possible that two texture files of adjacent regions show color discontinuity along the boundary because of different altitude range in the two regions. It is ideal if the users can provide appropriate imagery for the region of interest. In case such imagery is not in a texture file format, STK's *Image Converter* provides a tool to turn an imagery file into a texture file. Calling up this tool is similar to the procedure of calling up the *Terrain Converter*. Details of the two converters can be found in [3] or in the STK help manual.

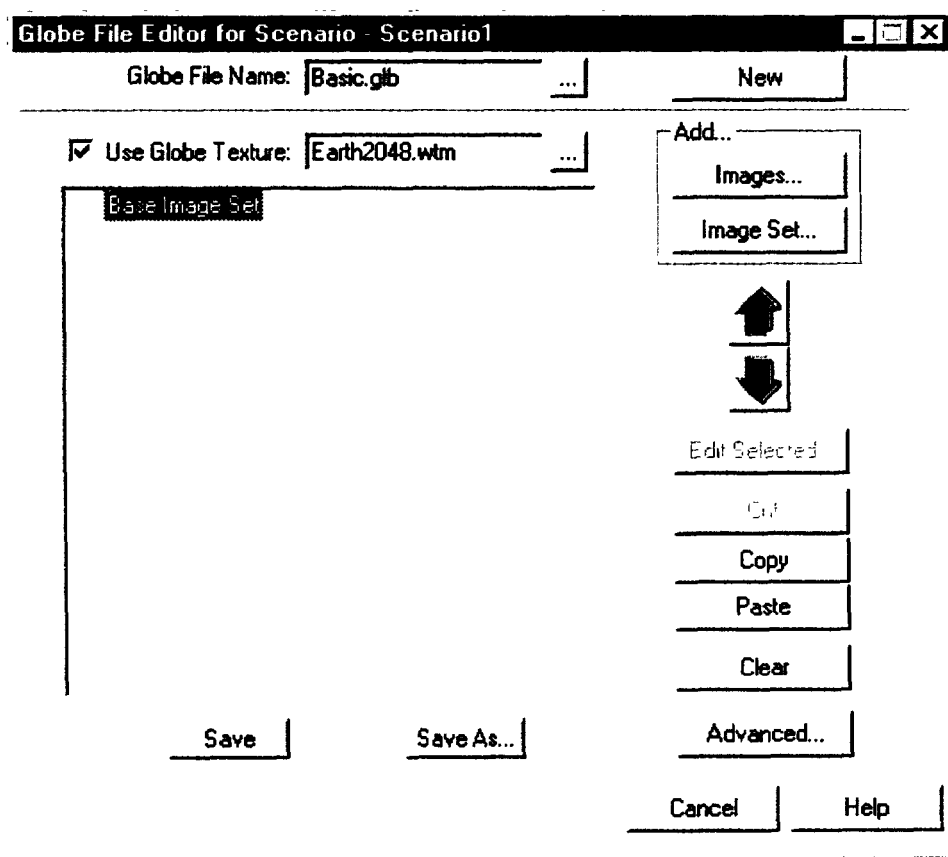


Figure 12: The Globe File Editor

25. A texture file imagery can be pasted on the surface of the globe by using STK's *Globe File Editor*, which is shown in Figure 12. This tool can be accessed through the *Tools* button of the Browser window when the scenario object icon is highlighted. It allows the users to select the images that will be put on the surface of the globe. Images can be selected after clicking the *Images* button in the window. After the selection has been completed, users must click the *Save* button in order to put the images on the globe.

26. Figure 13 shows the window that appears after clicking the *Images* button in the *Globe File Editor* in Figure 12. It is evident from Figure 13 that the directory “D:\Program Files\AGI\stk\4.3\STKData\VO\Textures” has only one texture file, namely “Ottawa.txm”. Notice that the *Convert Images* button at the upper right corner activates the tool *Image Converter*, which was briefly mentioned before.

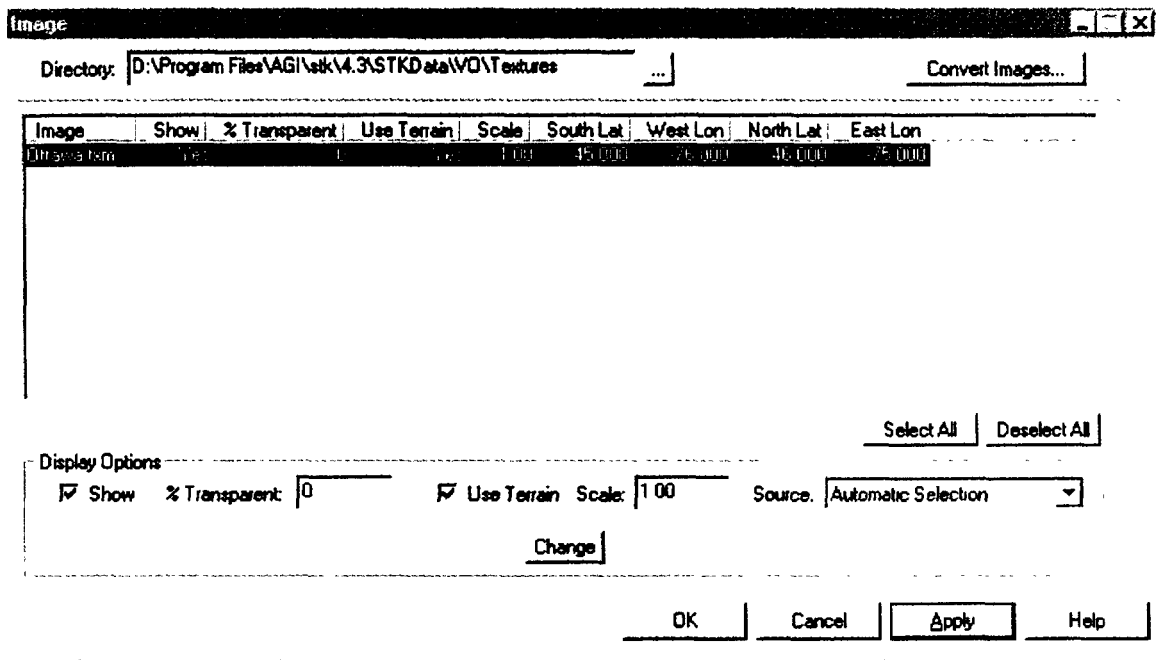


Figure 13: Add Images to the Globe File Editor

27. The lower right diagram in Figure 14 shows the result of imagery laid over the globe with terrain data. If the terrain data is removed, the 3-dimensional perspective of the landscape also vanishes, as is shown in the lower left diagram. If the texture file of imagery is absent, there is no way to tell whether the terrain data is present or not, as is shown in the top two diagrams in Figure 14. By comparing the two diagrams at the bottom, one realizes that the surface of the ground in the right one is raised above the spheroid of zero-altitude. As a result, any facility object in a scenario with terrain data and texture files will appear on the ground instead of hanging in the air.

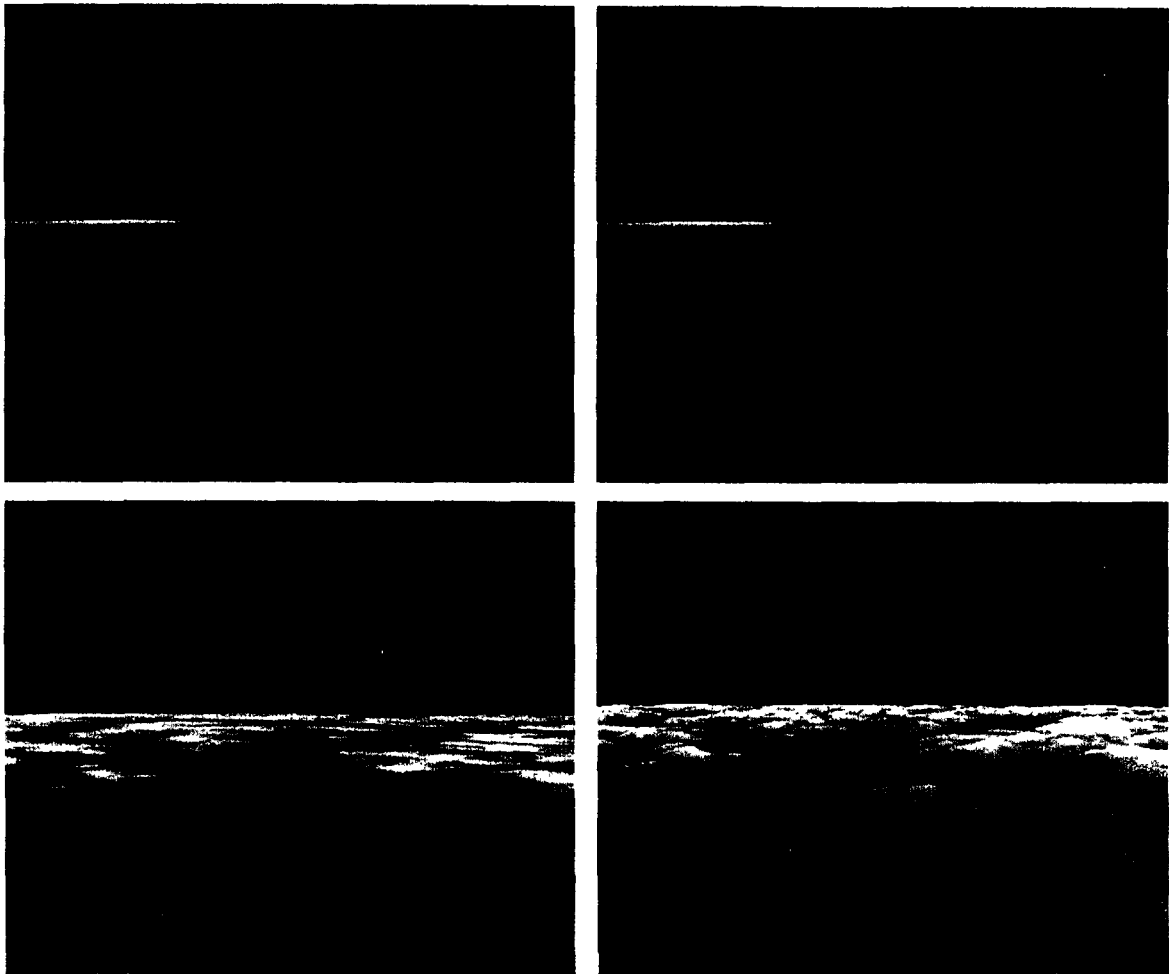


Figure 14: VO View of the Terrain Data and Imagery

**Upper left: With no terrain data or imagery; Upper right: With only terrain data;
Lower left: With only imagery; Lower right: With terrain data and imagery.**

28. The previous discussion about terrain is irrelevant if one does not have the STK Terrain module and the terrain data in the region of interest. If these tools are unavailable, a facility always appears to be hung in the air if its actual altitude is used. One way to deceive the viewers is to lower every object, including the aircraft and bomb, by a fixed distance that equals the altitude (ASL) of the facility. In this way, the facility will appear to be on the “ground”, and the separation between the facility and the aircraft in the virtual world agrees with the corresponding separation in the real world.

SCENARIO PRESENTATION

29. In the toolbar of the STK Map window and the VO window, one can find a *Play* button for scenario animation. Thus it is easy to animate a scenario by just clicking this button. However it requires some skills to animate and present the scenario elegantly. For example, it may be desirable to include some instantaneous data display on the window, or perhaps show some “camera movement” in the completed movie. In this section, some standard skills for presenting the scenario will be discussed. This section also includes the discussion of producing a movie clip. The discussion here focuses on the 3-dimensional scenario presentation through the VO window. However much of the discussion can apply to the Map window for 2-dimensional scenario presentation as well.

Object Appearance

30. If a scenario has an aircraft object, one could find the vehicle in the VO window. However it is very likely that the type of aircraft shown is not the correct one. More importantly, sometimes the size of the aircraft appears to be ridiculously huge. The solution to these issues can be found from the aircraft object’s *3D Graphics Properties* window. While the aircraft object is highlighted, clicking the *Tools* button in the Browser window will disclose a list of options, in which one can find the *3D Graphics Properties*. Choosing this option will bring out the window which is shown in Figure 15. The *Model* tab allows the user to choose the type of aircraft for display and the display size. Readers are reminded that the size of the aircraft is expressed in logarithmic scale. That is to say a scale of 0, as shown in Figure 15, yields the actual size of the aircraft. A scale of 1.00 will magnify the model 10 times larger than the actual one. Sometimes the size of a model is purposely increased beyond its actual size in order to exaggerate the object in the VO window.

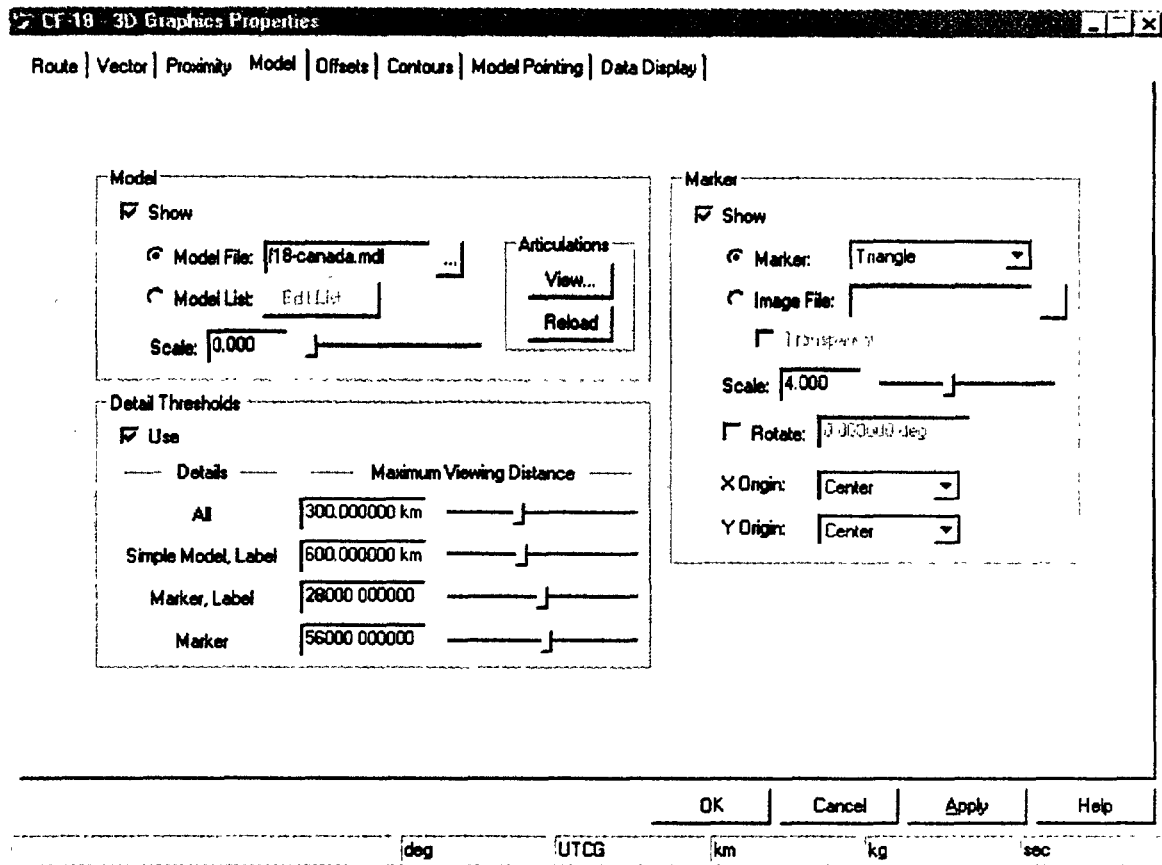


Figure 15: The 3D Model Properties of an Aircraft Object

On-screen Data Display

31. STK can display some data on the VO window (e.g. Figure 2), or conversely can show no data at all (e.g. Figure 14). The manipulation of data display can be found in the *3D Graphics Properties* button of the toolbar in the VO window. The *Annotation* tab of the *3D Graphics Properties* window, as shown in Figure 16, allows the users to put scenario data like animation time, time step, reference frame, etc. on the VO window. The *Overlays* tab allows one to remove the AGI logo, or to attach a DND logo on the VO window. Users are encouraged to explore the other tabs in this window in order to customize the appearance of the VO window.

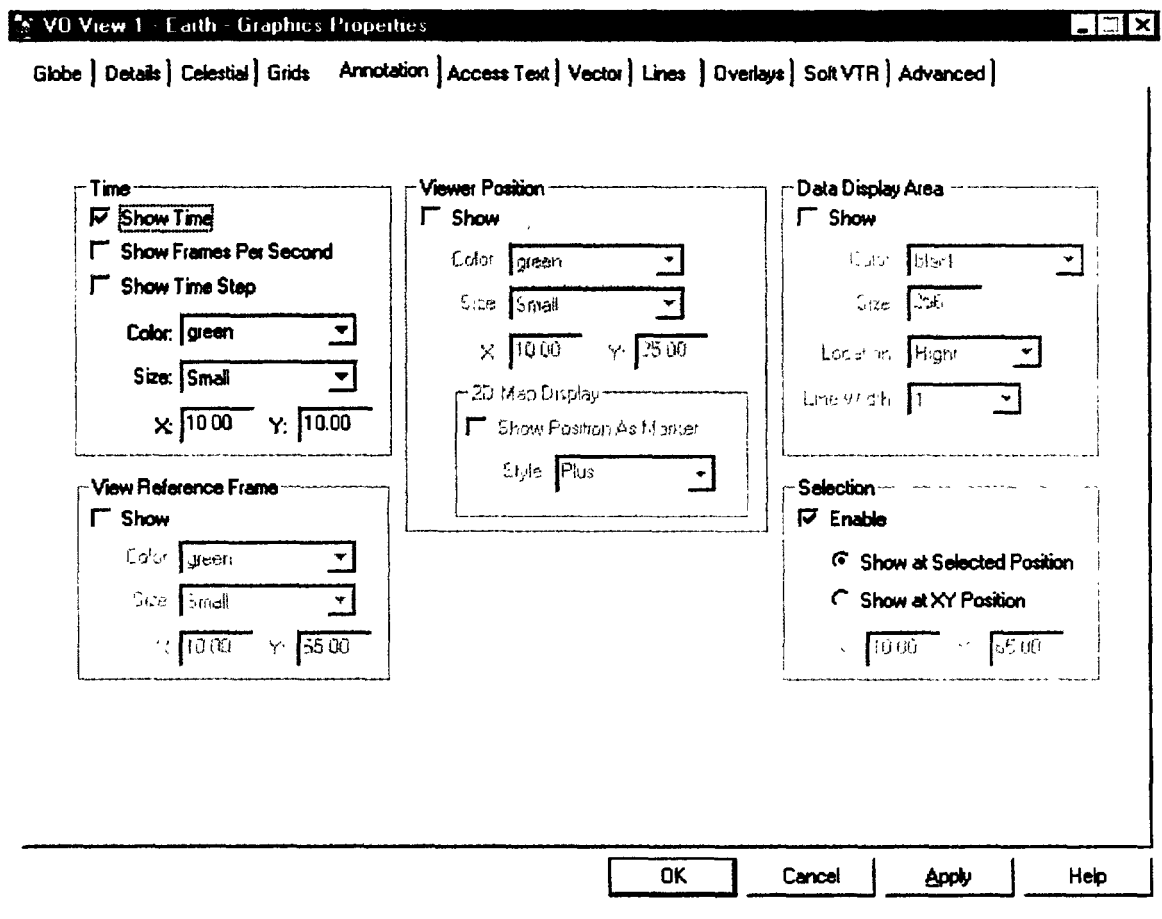


Figure 16: Annotation Properties of a VO Window

32. In order to show the data of an object, say an aircraft, on the VO window, one must start from the aircraft object's *3D Graphics Properties* window. It can be found by choosing the appropriate option after right-clicking the icon of the aircraft object in the Browser window. The *Data Display* tab of the window is shown in Figure 17. Two data sets *LLA Position* and *Velocity Heading* are shown in the diagram. If the user wants to choose the first set, simply highlight the set and click the *Show* checkbox and then the *Change* button. Finally clicking the *OK* or *Apply* button will have the chosen data shown in the VO window. The position of the data display in the VO window can be adjusted via this tab as well.

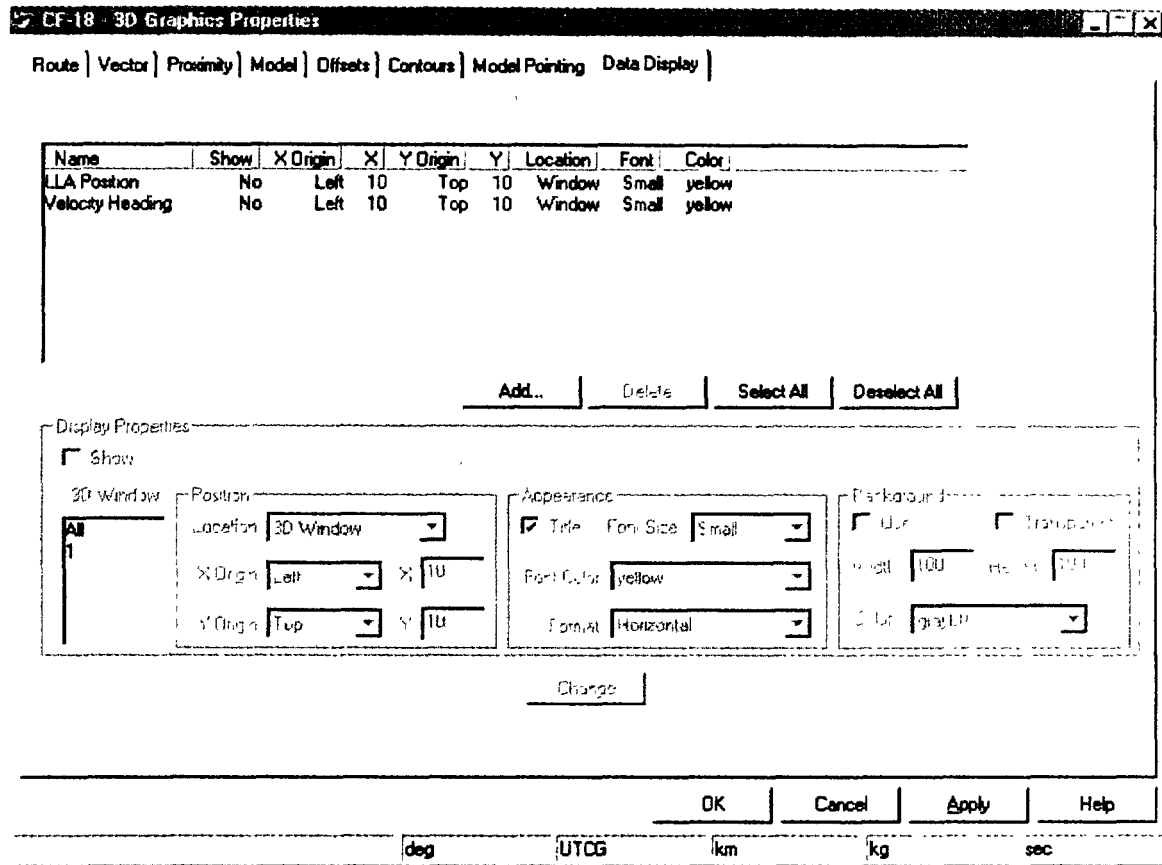


Figure 17: Data Display Properties of an Aircraft Object

33. In the example shown in Figure 17, only two sets of data are available. Indeed many other sets are available. They can be found by clicking the *Add* button below the list of sets. This button calls up another window, which is shown in Figure 18. Simply highlight a new set and click the *Add* button in Figure 18 will put the new set in the list of Figure 17. In fact the list in Figure 18 is a list of report styles available to the aircraft. Recall that STK can generate some reports of any object in a scenario. Different report styles usually contain different kind of data. Thus the *Data Display* tab of Figure 17 simply selects the data listed in a particular report style and shows it in the VO window.

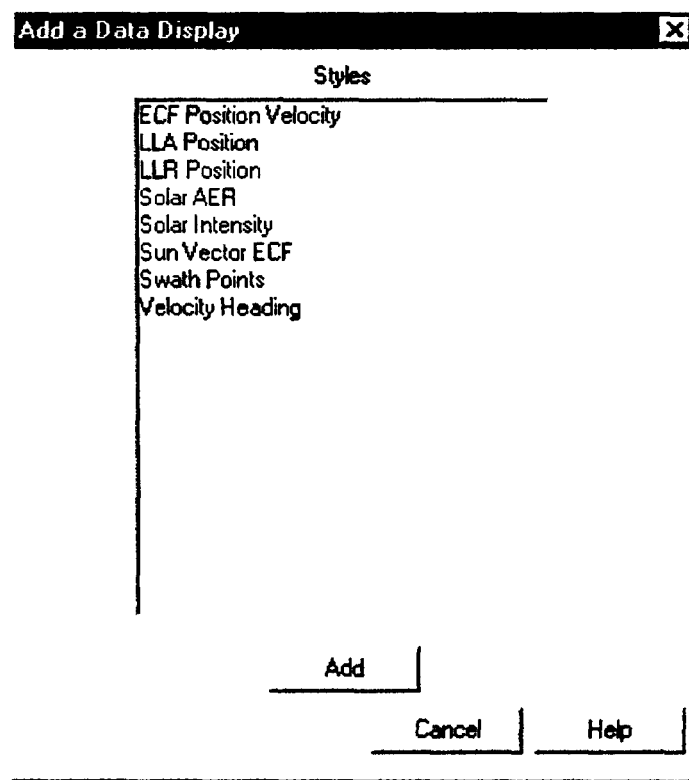


Figure 18: Add a Data Display Window

34. In case one would like to put the instantaneous YPR values on the VO window like the one in Figure 2, a problem arises. Figure 18 does not have any style that has the YPR values. As a result, one must create a new report style that contains the data. In order to create a new report style, the aircraft object's *Report* window must be opened. It is shown in Figure 19. The procedure of opening this window is similar to the one of opening the *3D Graphics Properties* window of the aircraft object. One can create a new report style by clicking the *New* button in the window of Figure 19. STK will give a default name to the new style but one can change the name by typing the new name in the textbox and clicking the *Change* button. This completes creating a new report style but the new style has no data specification at all.

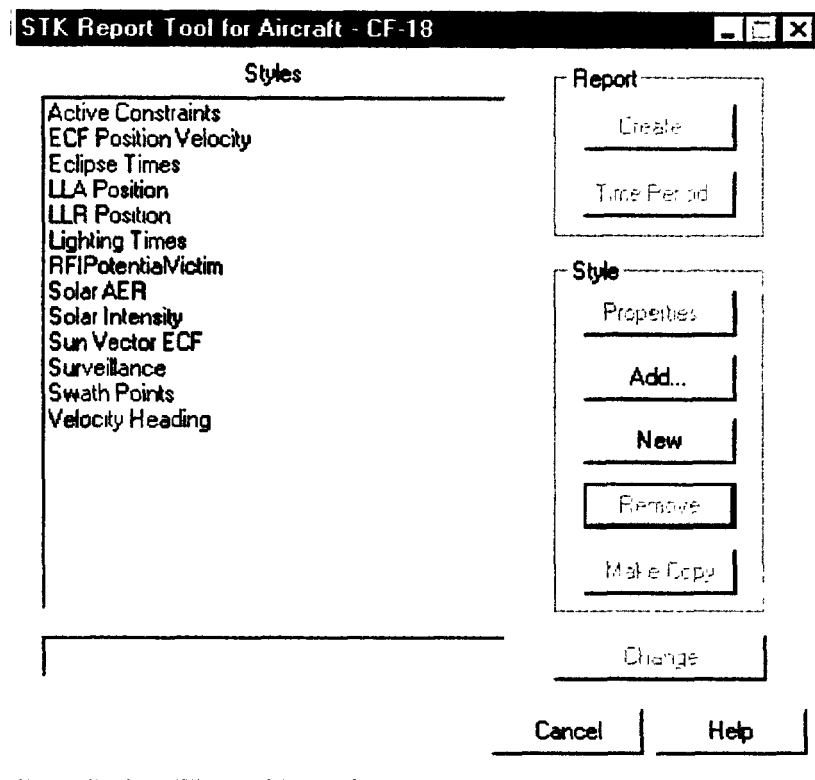


Figure 19: Report Window of an Aircraft Object

35. The new report style's data content can be specified by calling up another window. It can be done by clicking the *Properties* button in the window of Figure 19 while the new report style is highlighted. This *Properties* window is shown in Figure 20. This diagram shows that the yaw, pitch and roll in the VNC(CBF) frame has been put in the new report style *YPR*. Therefore by including the new style in the *3D Graphics Properties* window of Figure 17, the YPR values can be shown in the VO window.

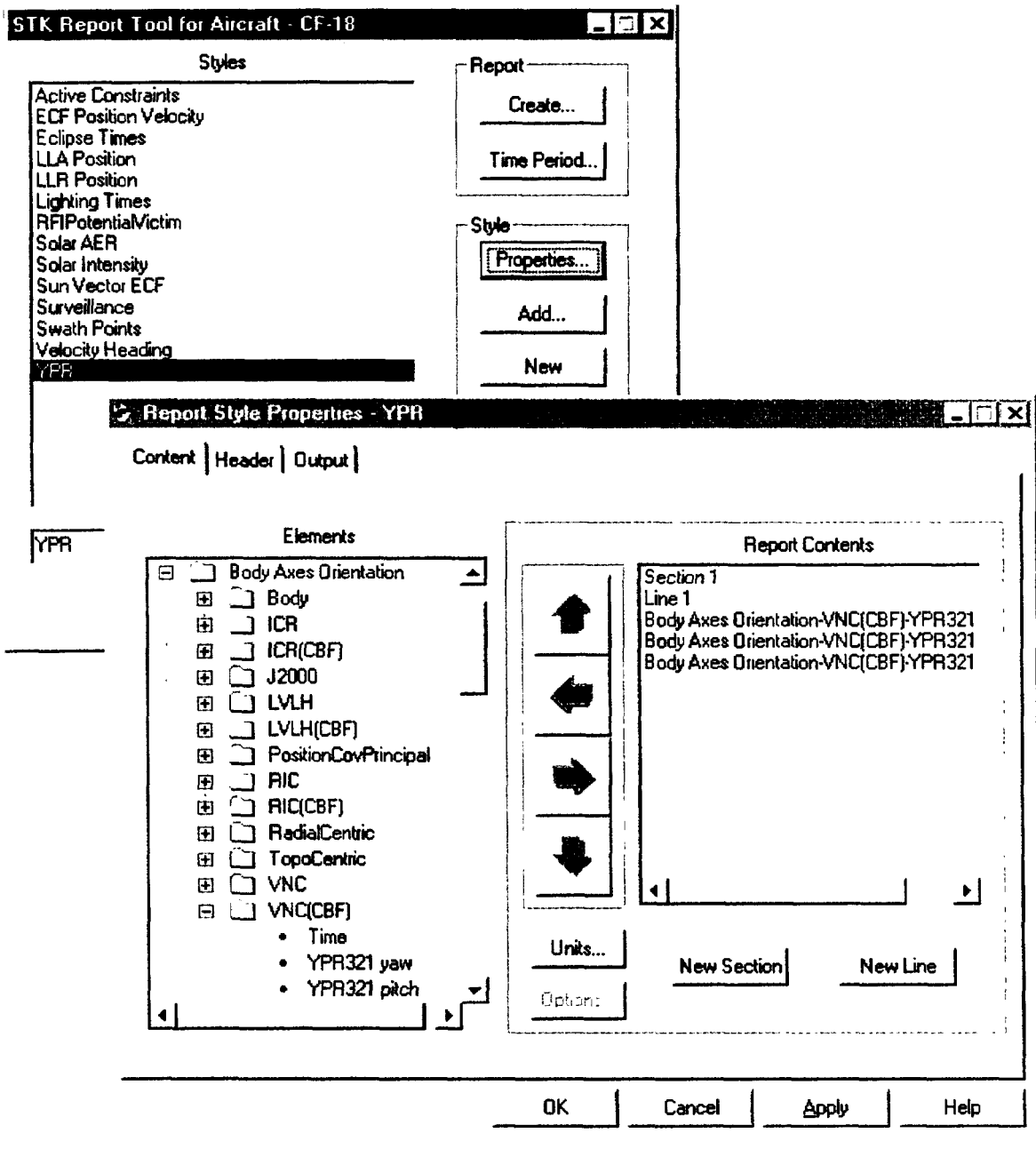


Figure 20: Report Style Properties Window of the Aircraft Object

View Path Editor

36. The *View Path Editor* enables the user to create a three dimensional path along which the view, or “camera”, in the VO window will follow. Not only will the position of the camera follow this path, but also the orientation of the view is maintained.

37. If the *View Path Editor* button is not in the VO window toolbar, the following steps must be performed. With the scenario icon highlighted in the STK Browser window, go to the *Tools* menu in the toolbar and then choose the *3D windows Toolbar Options*. This is shown in Figure 21. When the options window opens, highlight the *View Path Options* item, check the *Show* checkbox, and press the *Change* button. Finally clicking the *OK* button will activate the changes. Note that a VO window must be opened to do this procedure.

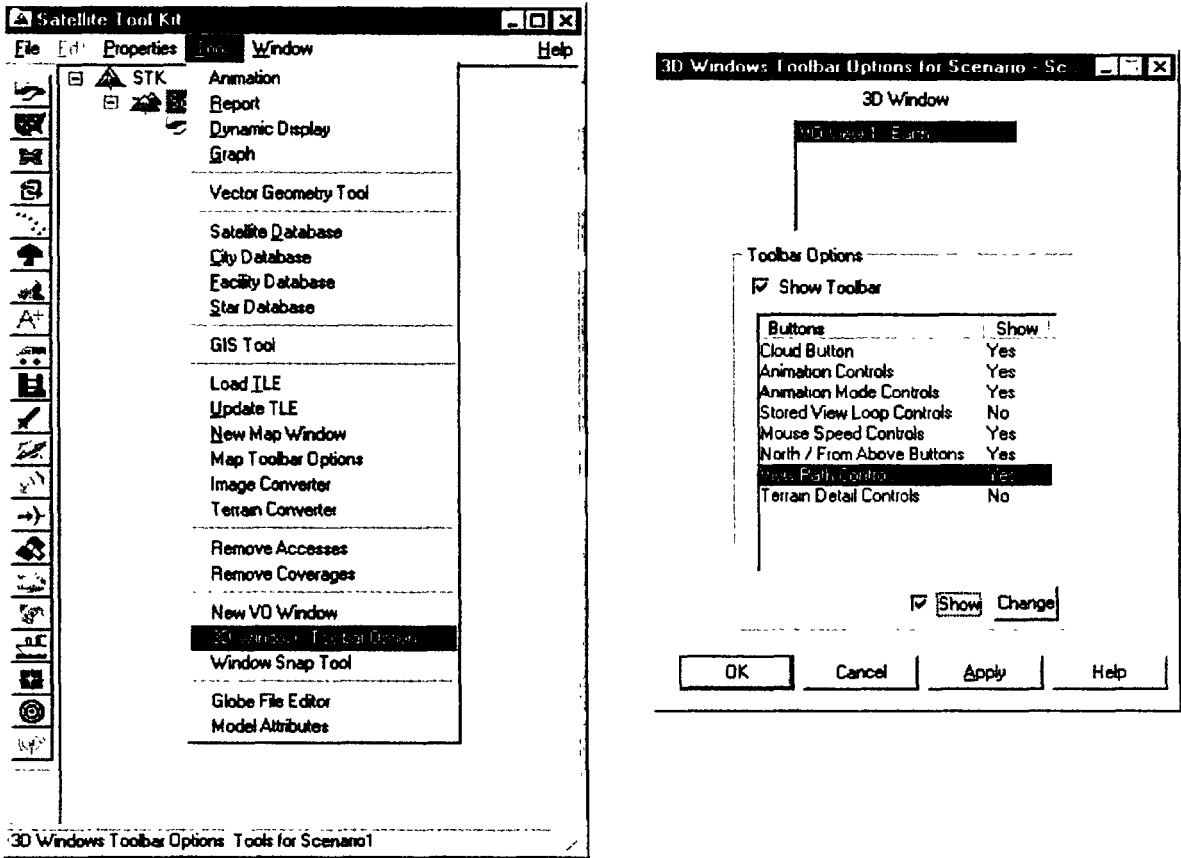


Figure 21: Adding the View Path Button to the VO Window Toolbar

38. Some set up is required before the view path is actually created. In the *Path* section of the *View Path Editor*, press the *New* button to create a new path (Figure 22). Underneath the list of view paths is a textbox to rename the new path. This will help avoid confusion when multiple paths are created. In the *Path Attributes* section, the recommended *Type* is *Splined*. This ensures that the path editor remembers the position and orientation of the view that is selected. The alternative is to have a *Tethered* path. This option fixes the orientation of the camera to a particular object in the simulated world so that the object is always in the center

of the field of view. The *Auto-Smooth Path* checkbox should be checked to ensure that the view is smooth during the transitions from position to position.

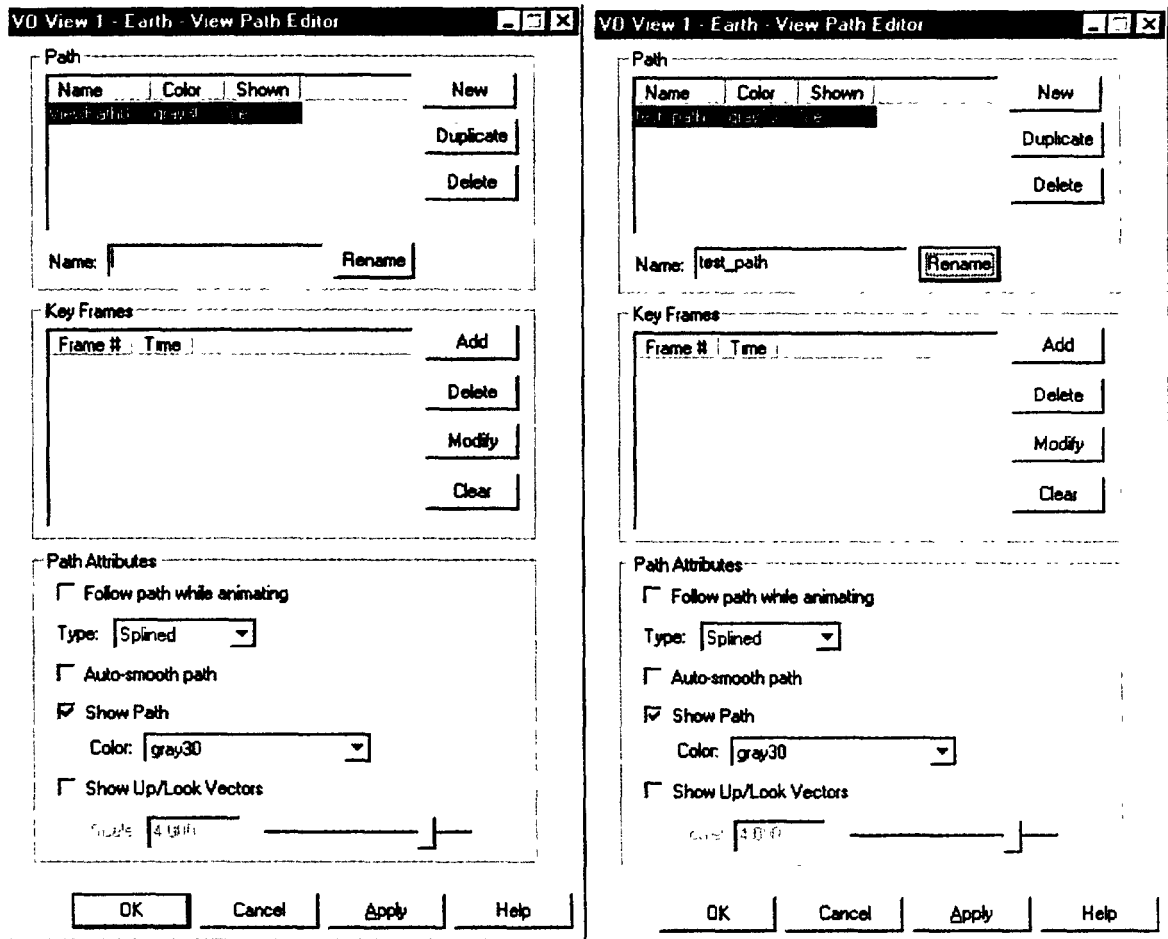


Figure 22: The View Path Editor Windows

39. The creation of the view path is as simple as playing the scenario for a short period of time (two to six seconds), pausing the scenario while the view is orientated in the manner desired, and pressing the *Add* button in the *View Path Editor* to create a new frame. Several of these frames at different times allow STK to “move the camera” accordingly. To ensure the interpolation between frames derives the intended path, it is a good idea to keep the time *and* distance between frames on the view path small. This is especially true if the “camera movement” is complicated. As an example, STK recommends at least five selected frames to do a smooth fly-around of an object in a given time period.

40. To have the animation follow the newly created view path, the *Follow Path While Animating* checkbox must be checked. When it is checked, the frames on the view path are no longer modifiable. If multiple view paths have been created, whichever one is highlighted in the list will be the one STK follows during animation. All the view paths that are created will be saved along with the scenario. Figure 23 shows a view path that the animation will follow. Notice that the frames are no longer editable.

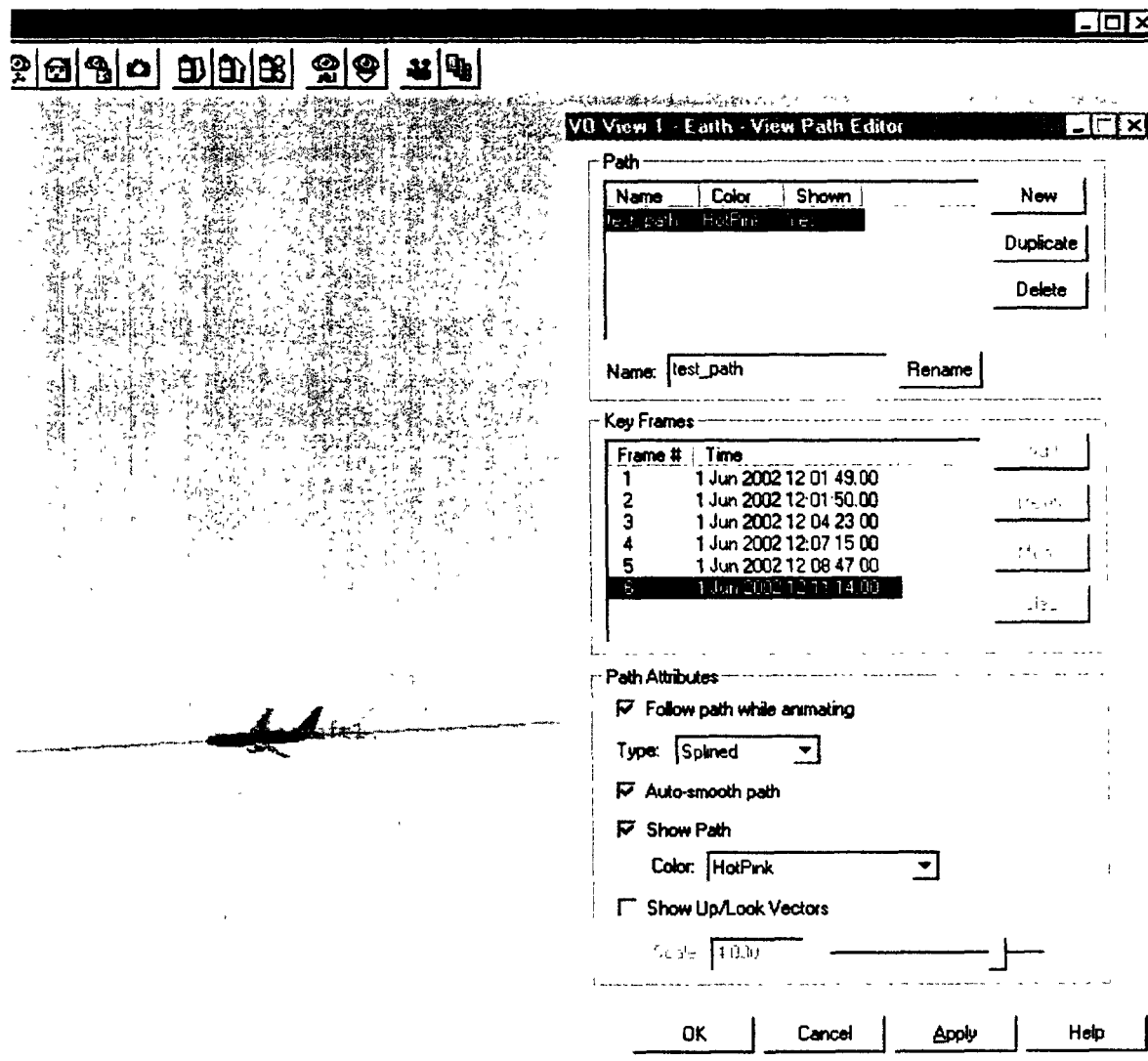


Figure 23: The View Path Editor Selected to Follow a Newly Created Path.
 Notice the unavailability of the editing buttons.

Soft VTR

41. The *Soft VTR* window provides all the necessary tools for capturing images or movies from the animation. STK gives the option of outputting the animation as a series of what are essentially screen captures. These can then be *glued* together to form a movie by software such as MATLAB. Generally however, it is preferable to have STK output an AVI directly.

42. Assuming the desired output is an AVI movie file, the process is begun by opening the *Soft VTR* window. It can be accessed by choosing the *Soft VTR* tab in the *3D Graphics Properties* button of the VO window (Figure 24). Recording starts by selecting the *Record Every Animation Time Step* radio button. At most four of the default options need to be changed. The *Directory* should be chosen carefully as this will be where the completed movie is placed. Depending on the other options chosen, the completed movie can be very large; a few Gb would not be unusual. Therefore the user must ensure that the directory has enough disk space for the movie. The *File Name Prefix* is simply the name of the completed file. The *File Format* should be *AVI Animation (AVI)*. The *Preload Textures* checkbox should be selected. This helps to increase recording performance and motion smoothness by loading some graphics into the memory ahead of time.

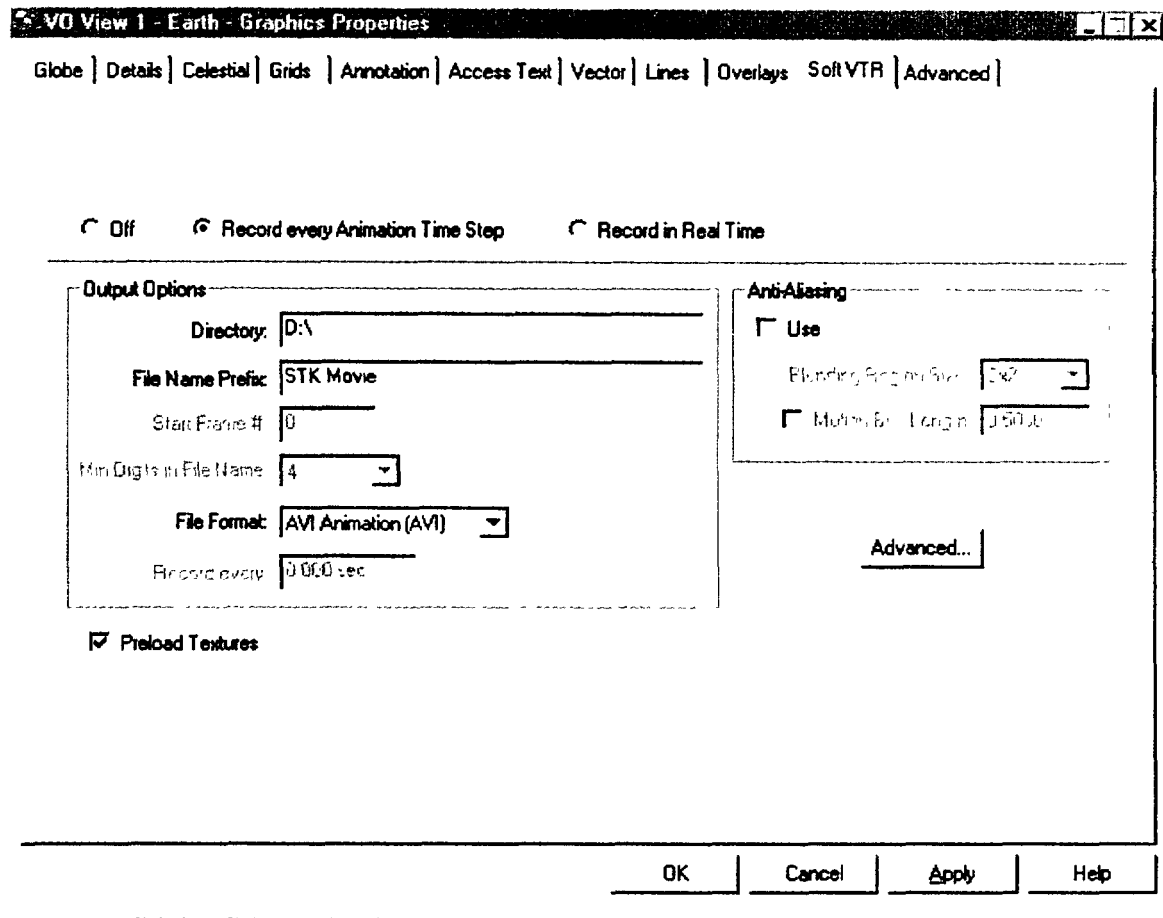


Figure 24: The Soft VTR Properties of a VO Window

43. The following trick may be appealing to some users. In the *Advanced* tab of the *3D Graphics Properties* window (next to the *Soft VTR* tab), there is a checkbox labeled *Hide Cursor*. When activated, this prevents the mouse pointer from being rendered while it is in the animation screen of the VO window. The *3D Graphics Properties* window must now be positioned so that no part of it overlays the VO window itself. If it or any other window is present over any portion of the VO window during movie recording, the other window will be included in the movie. For this reason it is a good idea to position all active windows such that they are not overlapping with the VO window. As well, it is a good idea to disable any screensavers which might activate during the movie recording.

44. When all is ready, click the *Apply* button in the *Soft VTR* tab window. Another window now appears which provides options for choosing compression algorithms and quality levels. The window is shown in Figure 25. The *Microsoft Video 1* with a compression quality of 95 provides a good balance between file size and image quality. After the selection

has been made, the *OK* button must be pushed. The scenario may now be animated. When the animation completes, one must push the *Stop* or *Pause* button in the VO window. On the *Soft VTR* tab window, select the *Off* radio button and click the *OK* or *Apply* button. The newly created movie will now be released by STK and should be viewable through an appropriate player (e.g. Windows Media Player).

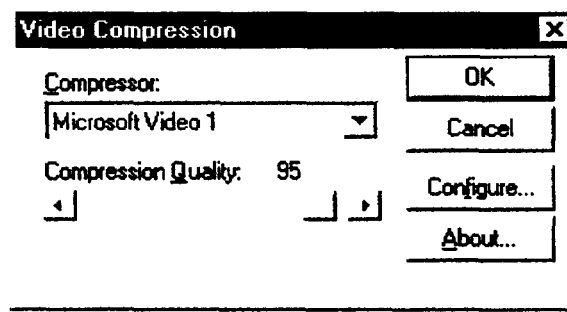


Figure 25: The Video Compression Window

45. Caution should be given when recording movies of the VO animation. The file size of these movies can quickly become extremely large, depending on the compression quality chosen and the length of the animation. Without any compression, a four-minute movie was found to be approximately 4 Gb.

VIDEO AND AUDIO MIXING

46. STK is not capable of doing video editing of any kind. Additional software was needed to mix an audio track onto the completed videos. The software used was MGI Video Wave 4. It is very capable software available at reasonable prices. The ideal software to use is Adobe Premiere 6. This software is considerably more expensive but has many more advanced features that may add to a production.

47. MPEG2 compression was the format used in the final video production. This was found to have the best compromise between final image quality and file size. It can also be read by the latest version of Windows Media Player, which is available free of charge for any Windows-based computer. The final file size was typically between 150 and 200 Mb.

48. It should be noted that there was a significant degradation in the quality of the image in the mixed video. Time was unfortunately not available to test all the available compression standards so this degradation may be less in an alternate format. Ultimately, a choice will need to be made about image quality versus file size.

III - DISCUSSION

49. As stated, this Research Note gives a detailed description of the process involved in using AGI's Satellite Tool Kit (STK) visualization tools to produce a movie providing detailed situational awareness of a reconstructed air force operation for the purposes of post-operation analysis. The intent of this paper is to serve as a manual to streamline this process for future endeavours of this nature.

50. The time from delivery of the raw data to JSORT to the final delivery to the sponsor of several animated movies with audio from the cockpit was five working days. This included extensive editorial input from the sponsor prior to release of the final product. Given the collective experience of the authors that is captured in this paper, this time can be considerably reduced to the point where the only true time sink will be the analyst's and/or the sponsor's preoccupation with perfecting the movie.

51. This paper assumes that the reader has a basic familiarity with STK. The STK modules needed for this work are STK Pro, 3-D Advanced Visualization Option (STK AVO) and the STK Terrain module. Additionally, the STK/Connect module for MATLAB interface and the STK Attitude module would be useful tools to consider for a more robust analytical capability. For audio and video mixing, MGI Video Wave 4 software was used. For a higher quality product the use of Adobe Premiere 6 is recommended.

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2. <http://www.stk.com/resources/help/Help/stk/terrain.htm>
3. <http://www.stk.com/resources/help/Help/stk43/stk/images.htm>

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AGI's Satellite Tool Kit (STK) visualization tools were used recently to provide detailed situational awareness of a reconstructed air force operation for the purposes of a post-operation analysis. The end products were several animations or movies mixed with audio from the cockpit of one of the aircraft under scrutiny. This research note provides a detailed description of the process involved in developing these animations. It is intended as a manual to streamline the process for future endeavors of this nature.

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