VOLUMETRIC 3D VISUALIZATION OF TEST AND EVALUATION OPERATIONS

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ABSTRACT

Time-Space-Position-Information (TSPI) visualization systems used today at the Air Force Flight Test Center (AFFTC) and simulation visualization tools used at the Air Armament Center (AAC) utilize two-dimensional (2D) display systems for both real-time and post-mission data analysis. Examples are monitors and large screen projection systems. Some TSPI visualization systems generate three-dimensional (3D) data as output, but the 3D data is translated so that it is compatible with 2D display systems. Currently, 3D volumetric display systems are being utilized by the Federal Aviation Administration (FAA) for monitoring air traffic in 3D without 3D goggles. The aircraft's position information is derived from radar and fed to a volumetric display. The AFFTC and AAC need a similar system for Open Air Range testing utilizing the Global Positioning System (GPS) as the source of position information and Installed Systems Testing utilizing 6 Degree of Freedom (DOF) flight simulation data as the source of position information. This system should be capable of displaying realistic terrain structures, vehicle models and physical test configurations along with text data overlays. The ability to display the mission in real-time on a volumetric 3D display makes it possible for test engineers to observe resource utilization continuously as the mission develops. Quicker turn-around times in the decision process will lead to more efficient

use of limited test resources and will increase the information content of the data being collected.

KEY WORDS

Volumetric 3D Displays, Visualization Systems, Range Operations, Installed Systems Testing, Test and Evaluation.

INTRODUCTION

As flight-testing continues to be the dominant range operation at the AFFTC, new and improved evaluation tools are continuously sought to aid the flight-testing process. New and improved evaluation tools allow for the effective evaluation of flight tests in real-time and post-flight. During real-time tests, these evaluation tools play an important role in flight-testing as they aid the flight test manager in the decision making process. Flight-test missions may or may not be canceled depending on data derived from these evaluation tools. The impact of these decisions may cost in the thousands of dollars in the utilization of test assets and labor. The AAC Preflight Integration of Munitions and Electronic Systems (PRIMES) Test Facility performs installed systems testing using simulated flight test missions within an anechoic chamber. The simulated flight missions are currently created using a 6 DOF simulation. This 3D simulated environment is currently monitored and viewed using conventional 2D display systems. A 3D visualization of the flight simulation would be an invaluable tool to the test engineers conducting the test mission. The introduction of volumetric 3D displays in the flight-test arena and the installed system test arena is viewed as the next generation test and evaluation tool that can enhance both the flight-testing and the installed systems testing processes.

Volumetric 3D displays can aid both flight-testing and installed systems testing by providing the ability to display realistic terrain structures, vehicle models, munitions models, and physical test configurations. Utilizing available 3D terrain data from the National Imagery and Mapping Agency may incorporate realistic terrain information to be able to see the aircraft or target in relation to the surrounding terrain. This may provide more visual information to the test manager, to be able to anticipate dynamic mission scenarios such as line-of-sight blockages, antenna coverage, or even signal multipath phenomena. Existing Computer Aided Design (CAD) models of aircraft may be utilized for display on volumetric 3D displays. Physical test configurations may be displayed as text data overlays to provide additional information to the test manager. These described uses of the 3D volumetric display for range and installed systems test operations are envisioned to improve the test and evaluation process at both the AFFTC and AAC.

CURRENT VISUALIZATION METHODS FOR TEST & EVALUATION (T&E) OPERATIONS

At the AFFTC, range operations are monitored using the Test and Evaluation Command and Control System (TECCS). Developed by Computer Sciences Corporation under the AFFTC Engineering and Technical Support Services (ETSS) contract, TECCS is the primary method of monitoring flight tests within the R2515/R2508 airspace.

Range, azimuth, and elevation data from instrumentation radar and FAA radar is provided to TECCS which then displays the position of the target over a 2D map of the R2508 airspace. TECCS is also capable of displaying downlinked GPS data from the test aircraft. The target is represented by a small triangle along with some text overlays which includes the target's squawk number, heading, velocity, and altitude.

TECCS displays this information on computer monitors and large screen displays. This method takes 3D information and converts it for display on 2D displays.

At the AAC, installed systems testing techniques utilize 6 DOF simulation data to provide X, Y, and Z position information and roll, pitch, and yaw data to the aircraft avionics systems to simulate flight of the aircraft. The simulated flight profile is currently displayed over a 2D map of the simulated airspace.

REQUIRED VISUALIZATION SYSTEM FOR T&E OPERATIONS

To improve on existing display techniques, a display system is required to display 3D information in volumetric space rather than conventional 2D display systems. The added dimension of information from a volumetric 3D display is expected to increase situational awareness of range operations and improve visualization of installed systems testing simulations.

A volumetric 3D display would improve situational awareness for a myriad of range operations such as; range safety, bomb scoring, spin test area monitoring, developing sky screen patterns, mission planning, and overall airspace management. A volumetric 3D display system would also provide a visualization capability for installed system testing simulation environments prior to conducting the actual test mission.

DESIRED VOLUMETRIC 3D DISPLAY CAPABILITIES

HARDWARE

SIZE

The volumetric 3D display must be scaleable to be able to match existing display systems used for flight test analysis today. Volumetric 3D displays that closely resemble the size of a 19” monitor may be used by flight test engineers whereas a volumetric 3D display the size of a 40” screen may be used to show a test in progress to a large group that can sit around the display. This would be ideal when Colonels and Generals want to witness a particular test. A volumetric 3D display would add a greater sense of realism while sitting inside a mission control room.

RESOLUTION

Resolutions comparable to current monitor technology is desirable. A volumetric 3D display comparable to a monitor with a resolution of 800x600 pixels would be usable for test and evaluation purposes.

COLOR

Full color would be ideal to represent data sets and to enhance the aesthetics of the volumetric 3D display. An example for the use of color would be for temperature data. Temperature data from aircraft sensors could be represented on the volumetric 3D display by multiple colors to indicate temperature levels. Green could be used for an acceptable temperature while yellow and red could be used to indicate that there might be a problem with the unit-under-test.

MOTION

Full motion (30 frames per second) would be an ideal capability to get a good sense of what is happening to the test aircraft. As volumetric 3D display technology improves, it would be advantageous to the test and evaluation community to be able to have a high frame rate capability (greater than 30 frames per second) to analyze critical segments of a test, such as bomb or payload drops.

BRIGHTNESS

The ideal scenario would be to be able to use a volumetric 3D display similar to how computer monitors are used.

CONTRAST

Contrast capabilities similar to computer monitors would be ideal to be able to analyze the images displayed.

SOFTWARE

A volumetric display where the aircraft's 3D position in relation to the surrounding terrain, displayed in volumetric space, would be an improvement over the existing 2D display systems used for aircraft test and evaluation.

The capability to replay the test aircraft's position data would aid in the analysis of the aircraft's flying qualities and would be extremely useful for aircraft mishap investigation. The Volumetric 3D Display must be able to accept a variety of 3D formats already in use today. The capability to use text overlays is also desirable to provide additional information on the display subject. The capability to manipulate the test object such as scaling and rotating would aid the analysis of test objects and data.

RESEARCH CONDUCTED

Research on volumetric 3D displays were conducted using Small Business Innovative Research (SBIR) funding. Research on the 3D Volumetric Display topic was done as a joint venture between the AFFTC at Edwards AFB, California and the AAC at Eglin AFB, Florida.

From Phase I and Phase II Air Force SBIR contracts, Genex Technologies, Inc. (GTI) has recently developed a novel design concept of true volumetric three-dimensional display systems. By "volumetric 3D display", we mean that each "voxel" (analogous to a pixel in a 2D image) in the displayed 3D image locates physically at the (x, y, z) spatial position where it is supposed to be. The voxel emits light from that position to form real 3D images in the eyes of viewers. Such true 3D display system provides both physiological and psychological depth cues to human visual system to perceive 3D objects.

Figure 1. GTI's Volumetric 3D Display System.

The current prototype system (as shown in Figure 1) has a cylindrical display volume of 20" in diameter by 5" in height, and is able to show multiple color 3D images with a spatial resolution of 256 by 256 by 128 voxels (8.4 million voxels).

Figure 2 shows two photographs of volumetric 3D images of a signal pattern of aircraft antenna that demonstrates the initial success in volumetric 3D display technology development. The strength of the radiation from a pencil beam antenna is a 3D function, hence can be best visualized using a true volumetric 3D display system. The AFFTC, AAC, and Genex technologies, Inc. are developing a high resolution volumetric 3D display system that allow viewers to see true 3D images with full depth and without using any special eyewear.

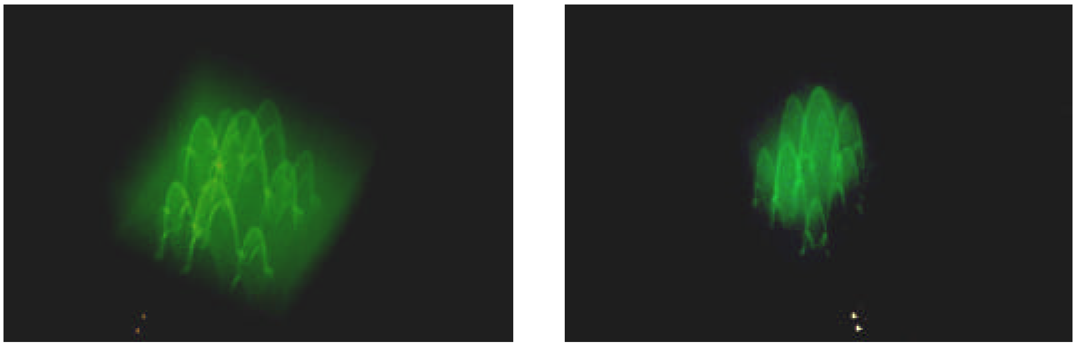

Figure 2.
Visualization of Antenna Signal Patterns Using GTI's Volumetric 3D Display

The two pictures in Figure 2, taken from two different viewing angles, show a 3D signal strength as a function of elevation and azimuth angles displayed on GTI's latest prototype system. With 256 by 256 by 128 spatial resolution and without the need of special eyeglasses, viewers can observe the 3D image in detail. One can walk freely around the monitor to look at the 3D image from any desirable angle he/she chooses, just as if the 3D object is there.

Figure 3 shows a picture of a digital terrain map displayed on a volumetric 3D display system. The 3D terrain data was obtained from the National Geophysical Data Center in Colorado. It is a portion of the elevation map of Northern America continent, with proper scaling of the height values. This 3D display example shows the feasibility of our system in many potential Air Force related applications, such as digital battlefield visualization, command and control of airfield, air traffic control, guidance and navigation, etc.

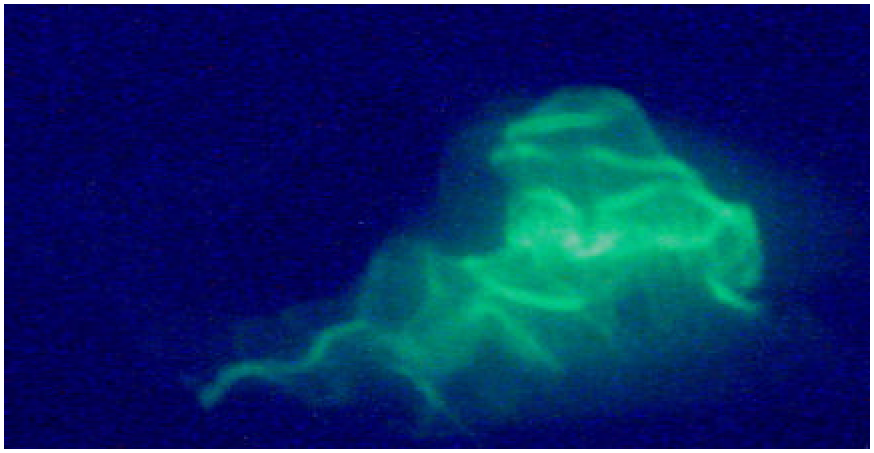
Figure 3. Digital Terrain Displayed by GTI's Volumetric 3D Display.

APPLICATIONS FOR RANGE OPERATIONS

AIRSPACE MONITORING / MANAGEMENT
Real-time monitoring of the test aircraft in relation to the surrounding terrain would be a primary use for the volumetric display. This would improve the situational awareness for the test manager by having a bird's eye view of the test.

RANGE SAFETY
3D aircraft trajectory data may be played back on a volumetric 3D display for analysis, to aid accident investigations. Roll, pitch and yaw data may be better visualized using a volumetric 3D display. These displays would also be ideal for monitoring the entry and exit of test aircraft from the spin test areas.

BOMB SCORING
Volumetric 3D displays may be useful for scoring bombs dropped from test aircraft. The trajectory of a bomb may be estimated and overlaid onto the 3D terrain information to provide bomb scoring capabilities.

MISSION PLANNING
A volumetric 3D display may be used to display antenna patterns from telemetry antennas to aid the planning of a mission. This type of sky screen analysis may provide better information on the coverage of available antennas on range. This will also aid in the allocation of test assets for a mission. This type of improvement in the mission planning capability would reduce the risk of performing a mission with inadequate assets.

FLUTTER AND VIBRATION ANALYSIS
By being able to manipulate the volumetric image, by scaling to different sizes and rotating to different angles, aircraft phenomena such as wing flutter may be evaluated. Recent conversations with National Aeronautics and Space Administration (NASA) engineers indicated that a volumetric 3D display would be useful for flutter and vibration analyses. Vibration patterns, which are similar to antenna patterns, may be better visualized in a volumetric 3D display.

STABILITY AND CONTROL PERFORMANCE ANALYSIS
NASA engineers would benefit greatly with the capability to display the angle of attack, sideslip, and attitude of the test aircraft. The capability to display control surface positions in a volumetric 3D display will also help researchers understand complex vehicle behavior. This type of analysis is typically performed using 3D data on 2D displays. A volumetric 3D display can now integrate all of the 3D data onto one display and with this improved visualization system, NASA engineers can get a more realistic representation of the test data.

CONCLUSIONS

Volumetric 3D displays are expected to increase situational awareness of test and evaluation operations as more information is integrated into one display thus aiding the decision process for Range Control Officers, Operations Duty Officers, and Flight Test Managers. Volumetric 3D displays may augment existing 2D visualization systems to visualize test data in three dimensions. Once this display technology is developed where it is as usable as 2D monitors are used today, it is anticipated that this technology will have a multitude of applications.

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