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INTEGRATED GLOBAL POSITIONING SYSTEMS (GPS) LABORATORY

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ABSTRACT

The purpose of this research is to develop a user-friendly Integrated GPS lab manual. This manual will help range engineers at NASA to integrate the use of GPS Simulators, GPS receivers, computers, MATLAB software, FUGAWI software and SATELLITE TOOL KIT software. The lab manual will be used in an effort to help NASA engineers predict GPS Coverage of planned operations and analyze GPS coverage of operation post mission.

The Integrated GPS Laboratory was used to do GPS Coverage for two extensive case studies. The first scenario was an airplane trajectory in which an aircraft flew from Cape Canaveral to Los Angeles, California. In the second scenario, a rocket trajectory was done whereas a rocket was launched from Cape Canaveral to one thousand kilo-meters due east in the Atlantic Ocean.

INTEGRATED GPS LABORATORY

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1. INTRODUCTION

In this research an integrated user-friendly GPS lab manual was produced. NASA engineers will use this lab manual in their efforts to estimate trajectories of future Shuttle Launches. The manual is an integration of the use of GPS Simulators, GPS receivers, computers, MATLAB software, FUGAWI software and SATELLITE TOOL KIT (STK) software.

MATLAB Version 6.5 is a high performance software tool for technical computing [1]. This software was used in the research to integrate and differentiate post Shuttle launch data. The data was from the STS103 Shuttle Launch in December 1999. The goal of this part of the research was to examine the accuracy of MATLAB's differentiation and integration capabilities. MATLAB was used to integrate the Shuttle's velocity in order to obtain position. MATLAB was used to differentiate the Shuttle's position in order to get velocity. MATLAB produced errors on the order of 0.0125 % during the test runs.

The CAST –1000 GPS Simulator is a portable satellite simulator [2]. It can simulate 10 GPS satellites simultaneously. It simulates Coarse/Acquisition (C/A) and P codes. It can generate both L1 and L2 frequencies. L1 frequency is 1575.42 MHz and L2 is 1227.60 MHz. It was used in this research to simulate up to 8 satellites on the L1 frequency.

The ASHTECH G12 GPS receiver is a portable hardware device that processes signals from the GPS satellite constellation [3]. This receiver uses twelve discrete parallel channels for C/A code-phase (pseudo-range) measurements and carrier phase measurements on the L1 (1575.42 MHz) band. The receiver was used in this research to provide real-time position, velocity, and time measurements.

SATELLITE TOOL KIT Version 4.3 is a hands-on software tool designed to provide the skills necessary to perform basic aerospace analysis [4]. It can generate paths for a variety of space-, air-, sea-, and land-based objects, such as satellites, aircraft, ships and ground vehicles. It can be used to calculate and visualize a satellite's position and attitude. STK provides 3D animation capabilities and a 2D map background for visualizing the path of these vehicles over time. Ephemeris data from the STS103 's December 1999 Shuttle Launch was loaded into STK from a text file. STK used the data to simulate the trajectory of this Shuttle Launch.

FUGAWI Version 3.0 is a comprehensive program for integrating bit-mapped charts or maps with a GPS receiver [5]. The FUGAWI software is used for visualization of the trajectory of a moving vehicle. The software was used in this research to visualize the ground tracks of an airplane and a rocket.

2. EXPERIMENTAL WORK

2.1 LOADING EPHEMERIS DATA INTO STK

In order to load Ephemeris data into STK, first create a new Scenario by clicking the Scenario icon upon opening STK. Second in the browser menu select the missile icon. The missile object will be created. Click on the missile object so that it will be highlighted in blue. Third click on Properties in the main menu. Fourth select Basics. The Basics menu appears. Fifth under the Propagator drop-down menu select STK External. Sixth browse through the External Ephemeris File to find the STS103 Shuttle Launch data file. Seventh click the apply button. Eighth click the ok button. STK displayed the trajectory of the shuttle launch as orbit tracks in the 3-D visualization window. STK displayed the trajectory of the shuttle launch as ground tracks in the 2-D map window. The plot of the trajectory is shown in the Results section.

2.2 MATLAB COMPUTATIONS

The STS103 Shuttle was launched in December 1999. The Ephemeris report showed the output data for velocity in meters per second and position in meters and time in seconds. The velocity was integrated by MATLAB in order to retrieve the position. The percent errors were less than 0.0125 %. The position was differentiated by MATLAB in order to get the velocity. The percent errors were less than 0.0125 %. MATLAB is an excellent tool to use in integrating and differentiating space data. The MATLAB recipe for differentiation of the Ephemeris data is given in Appendix A. The MATLAB recipe for integration of the Ephemeris data is given in Appendix B. MATLAB outputs used in this research for integration and differentiation are shown in the Results Section.

2.3 TRAJECTORIES PRODUCED FROM INTEGRATED GPS LABORATORY

Two scenarios were created for producing trajectories. The CAST –1000 GPS Simulator, ASHTECH G12 GPS receiver and the FUGAWI 3.0 software were used for these scenarios. An airplane was the vehicle used in the first scenario. A rocket was the vehicle used in the second scenario.

In the first scenario, the aircraft will be stationary for five minutes. Second, the aircraft changed terminal speed to 500 m/s and changed maximum acceleration to 100 m/s^2. Third, the airplane reached a terminal height of 10,000 m. It will climb at a maximum angle of 40°. It reached a maximum climb acceleration of 80 m/s^2. Fourth it cruised for 180 minutes. The airplane traveled from Cape Canaveral, Florida to Los Angeles, California. The latitude setting was 28° and the longitude was -81°. The true initial heading was 290° from the North. The GPS receiver locked onto 7 satellites. The FUGAWI software showed the airplane trajectory. A plot of the airplane trajectory is shown in the Results Section. The lab manual for set-up of the airplane trajectory is given in Appendix C.

In the second scenario, a very fast helicopter was used to simulate the rocket scenario. First the helicopter was stationary for thirty minutes. Second it took off at a terminal velocity of 1000 m/s, at a maximum acceleration of 50 m/s^2. During the takeoff, the course heading was 90° and the course climb angle was 90°. Third it pitched up at a climb angle of 60° at a maximum acceleration of 100 m/s^2. Fourth the helicopter reached a terminal speed of 2000 m/s at a maximum acceleration of 100 m/s^2. Fifth the helicopter cruised for 30 minutes. The GPS receiver locked onto five satellites for the second scenario. The FUGAWI software showed the rocket trajectory. A plot of the rocket trajectory is shown in the Results Section. The lab manual for set-up of the rocket trajectory is given in Appendix D.

3. RESULTS

In Figure 1, the trajectory of the STS103 Shuttle Launch is shown. The STK software produced the trajectory.

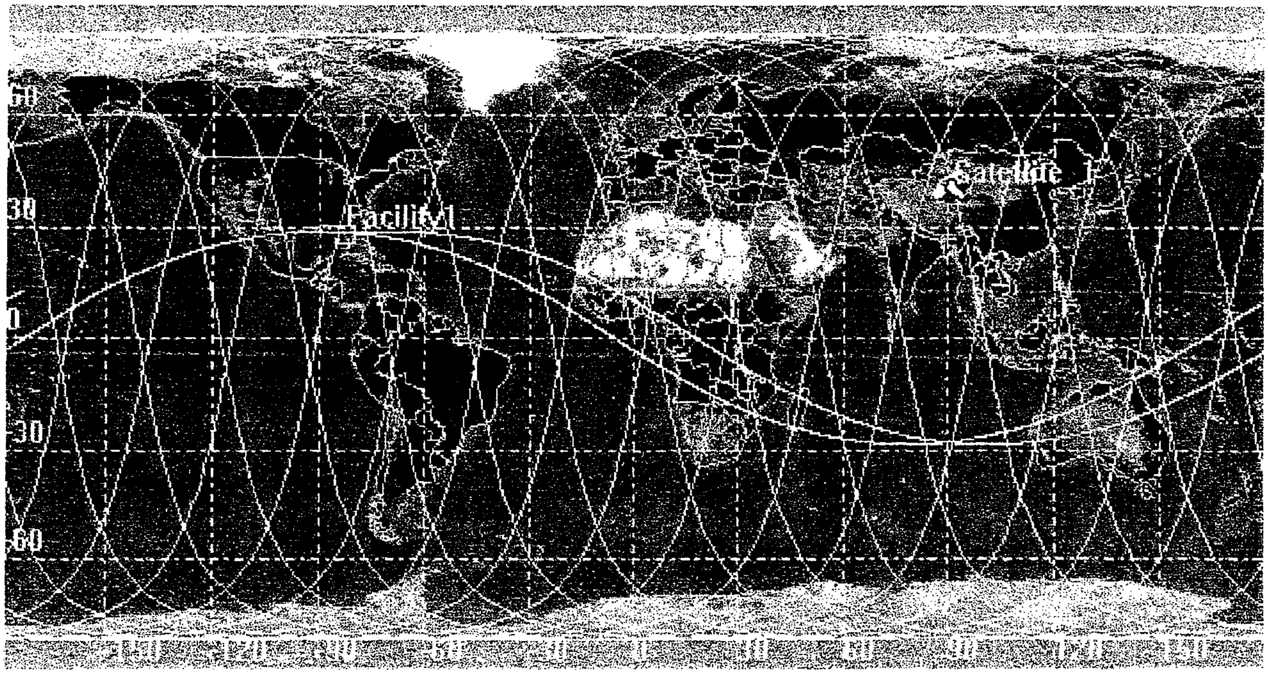

Figure 1: SHUTTLE LAUNCH TRAJECTORY PRODUCED BY STK SOFTWARE

MATLAB was used to produce the waveform in Figure 2. The waveform represents the velocity trajectory of the Shuttle launch STS103 in orbit. The trajectory was produced by the differentiation of the position vector in the x-direction. This output waveform is the velocity vector in the x-direction. Trajectories representing the y-direction and z-direction for velocity were similarly.

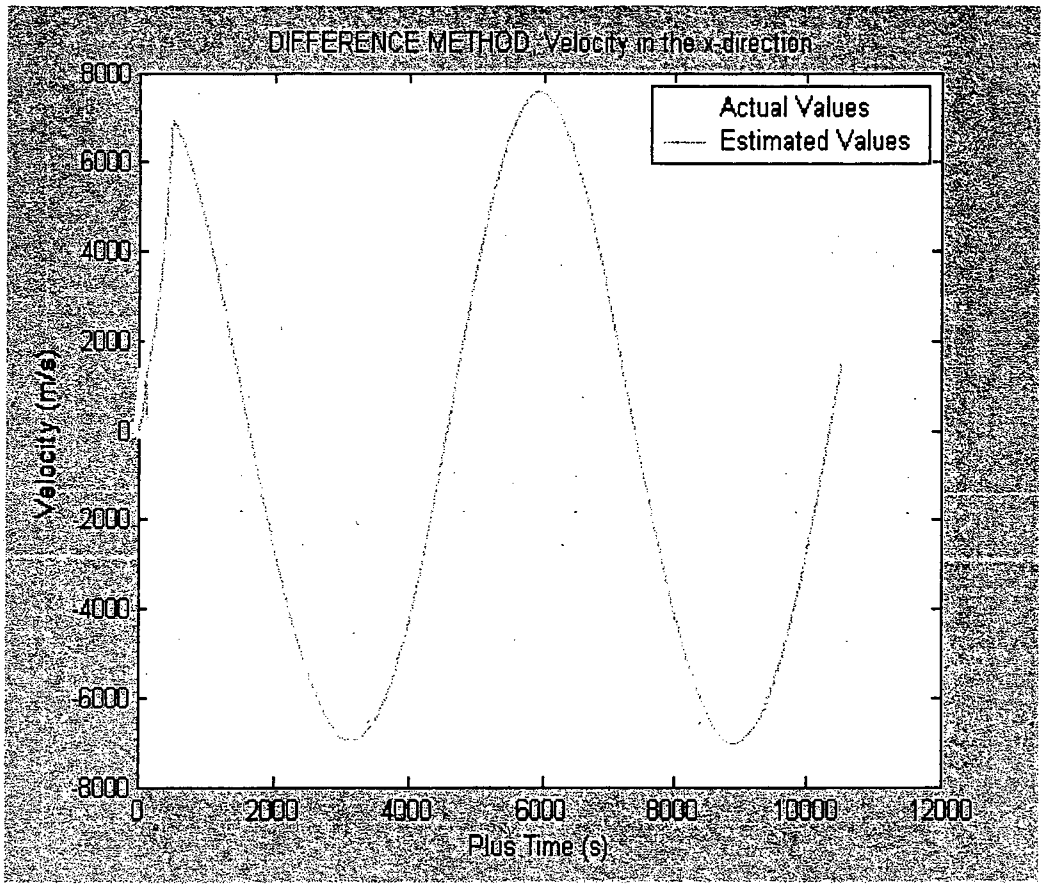

FIGURE 2: VELOCITY TRAJECTORY PRODUCED BY MATLAB

MATLAB was used to produce the waveforms in Figure 3 and Figure 4. The waveform represents the position trajectory of the Shuttle launch STS103 in orbit. The trajectory was produced by the integration of the velocity vector in the y-direction. These output waveforms are the position vectors in the y-direction. Trajectories representing the x-direction and z-directions for position were similarly. MATLAB used the Cumulative Trapezoidal Numerical Integration (CTNI) Method to integrate the velocity data. There is a shift in the two waveforms because CTNI Method started its numerical integration at zero. A MATLAB recipe was written to include a correction factor (CF) to add to the estimated values of the position vectors. Figure 3 shows the integration without CF. Figure 4 shows the integration with CF.

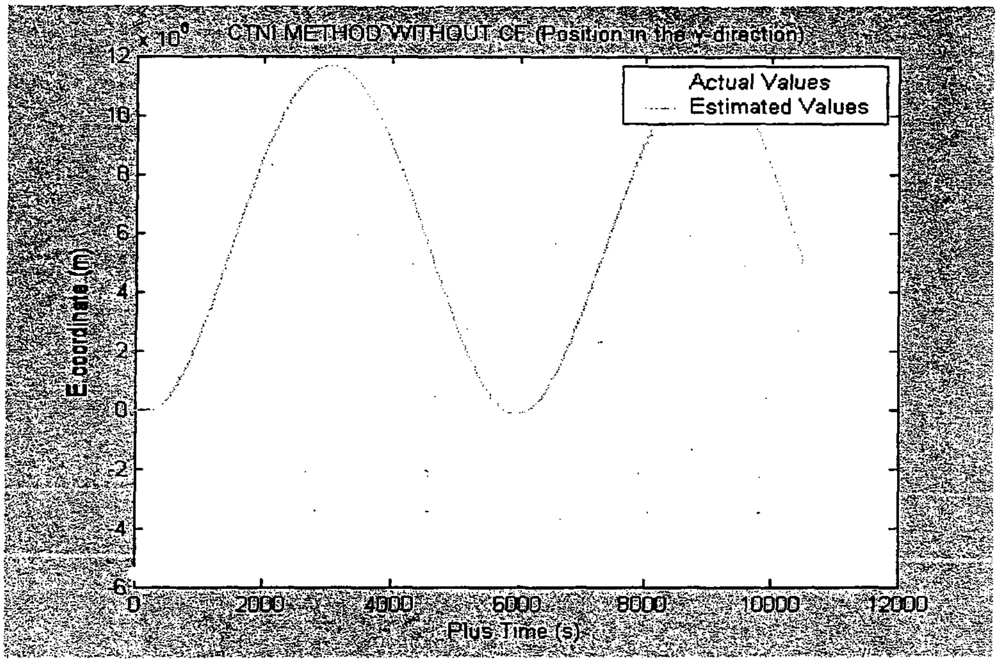

FIGURE 3: POSITION TRAJECTORY WITHOUT CF PRODUCED BY MATLAB

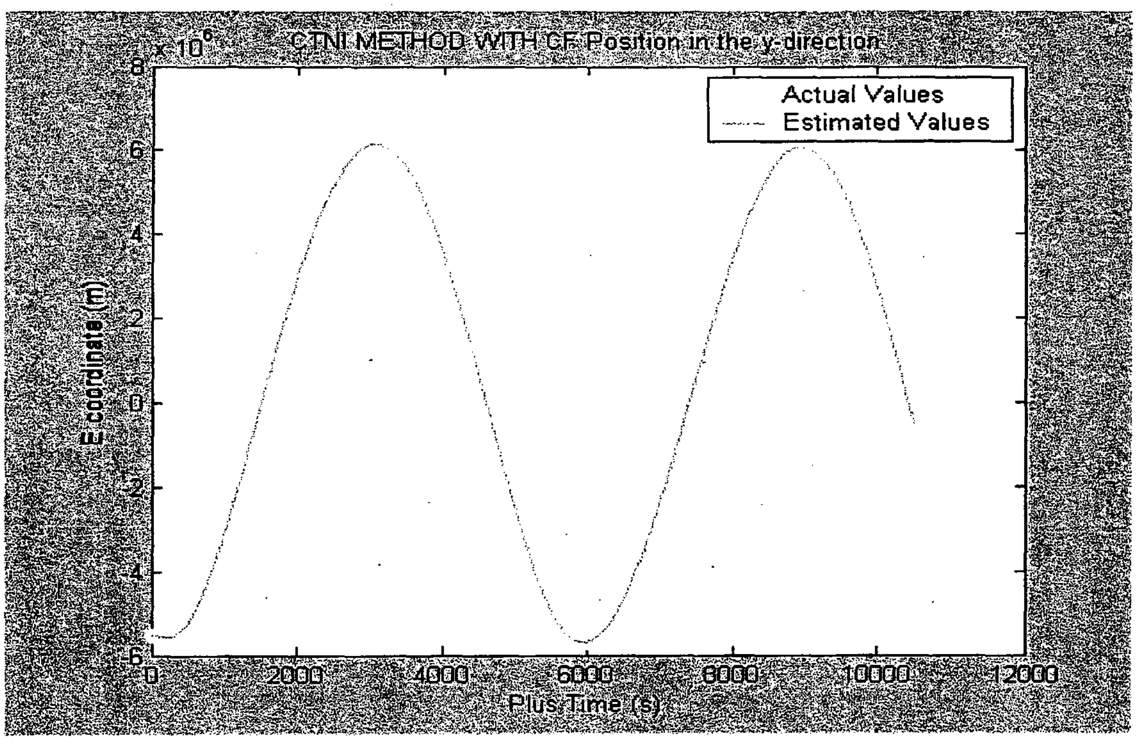

FIGURE 4: POSITION TRAJECTORY WITH CF PRODUCED BY MATLAB

Figure 5 shows the trajectory of the airplane scenario. The airplane started its flight at Cape Canaveral. The final destination was at Los Angeles, California. The trajectory was created by the integrated use of the GPS Simulator, GPS Receiver and the FUGAWI software.

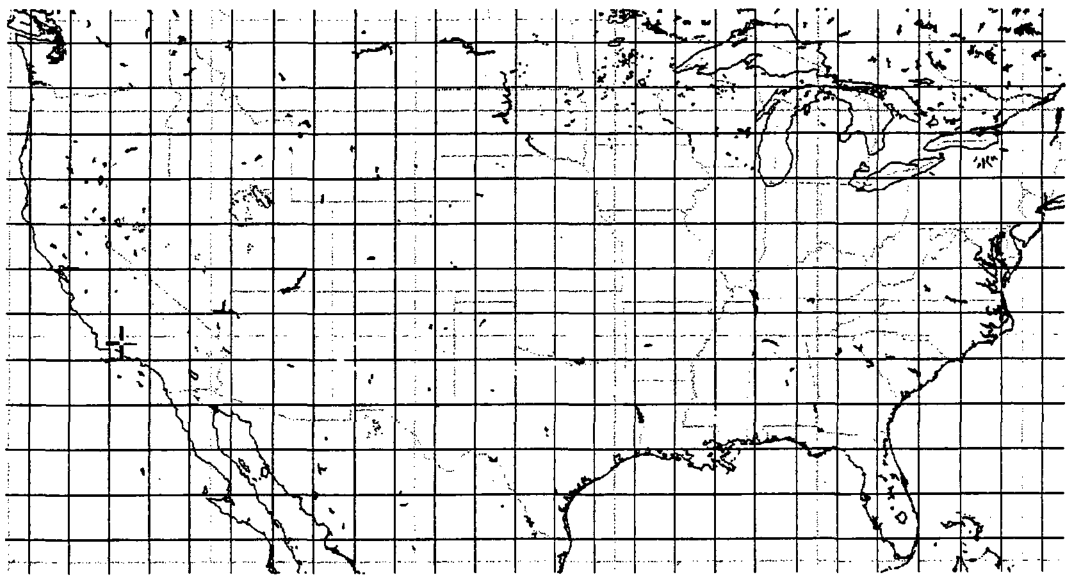

FIGURE 5: AIRPLANE TRAJECTORY

Figure 6 shows the trajectory of the rocket scenario. The rocket started its launch at Cape Canaveral. The final destination of the rocket was 1009.486 km due east in the Atlantic Ocean. The trajectory was created by the integrated use of the GPS Simulator, GPS Receiver and the FUGAWI software.

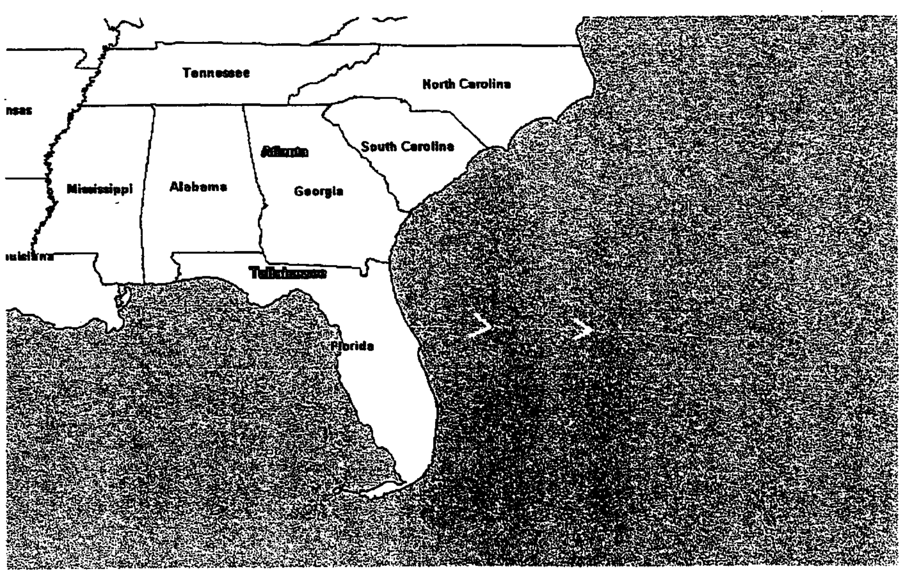

FIGURE 6: ROCKET TRAJECTORY

4. CONCLUSION

A user-friendly GPS lab manual was developed that integrates the use of STK, MATLAB, GPS Simulator, GPS Receiver and Visualization software. Two MATLAB recipes were written to help aid the integration and differentiation. The manual will be used to predict GPS coverage of planned operation. The Integrated GPS Laboratory was used to create two scenarios. One scenario created an airplane trajectory and the second scenario created a rocket scenario. The ability to predict GPS Coverage for future vehicles is the short-term value to NASA/KSC. Reduction in cost of future launch systems and increased flexibility are the long-term values to NASA/KSC.

5. REFERENCES

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5. FUGAWI Navigator's Manual 3.3, Northport Systems Inc., Toronto, Ontario M4T1W5 Canada, January 2002.