Airborne Platform for the Evaluation of Synthetic Vision Displays and Mounting Configurations

For the
Quarterly Review of the NASA/FAA Joint University Program for Air Transportation Research
Thursday April 3rd, 2003

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Project Sponsor: ***NASA/FAA*** **Joint University Program**

Introduction

- On average one spatial disorientation accident occurred every eleven days from 1987 to 1996.
- VMC into IMC flight continues to be one of the two major areas producing the largest number of GA fatalities.
- General Aviation instrumentation has undergone little change in the past 50 years.
- Major advancements have been made in the areas of inertial navigation and high accuracy GPS.

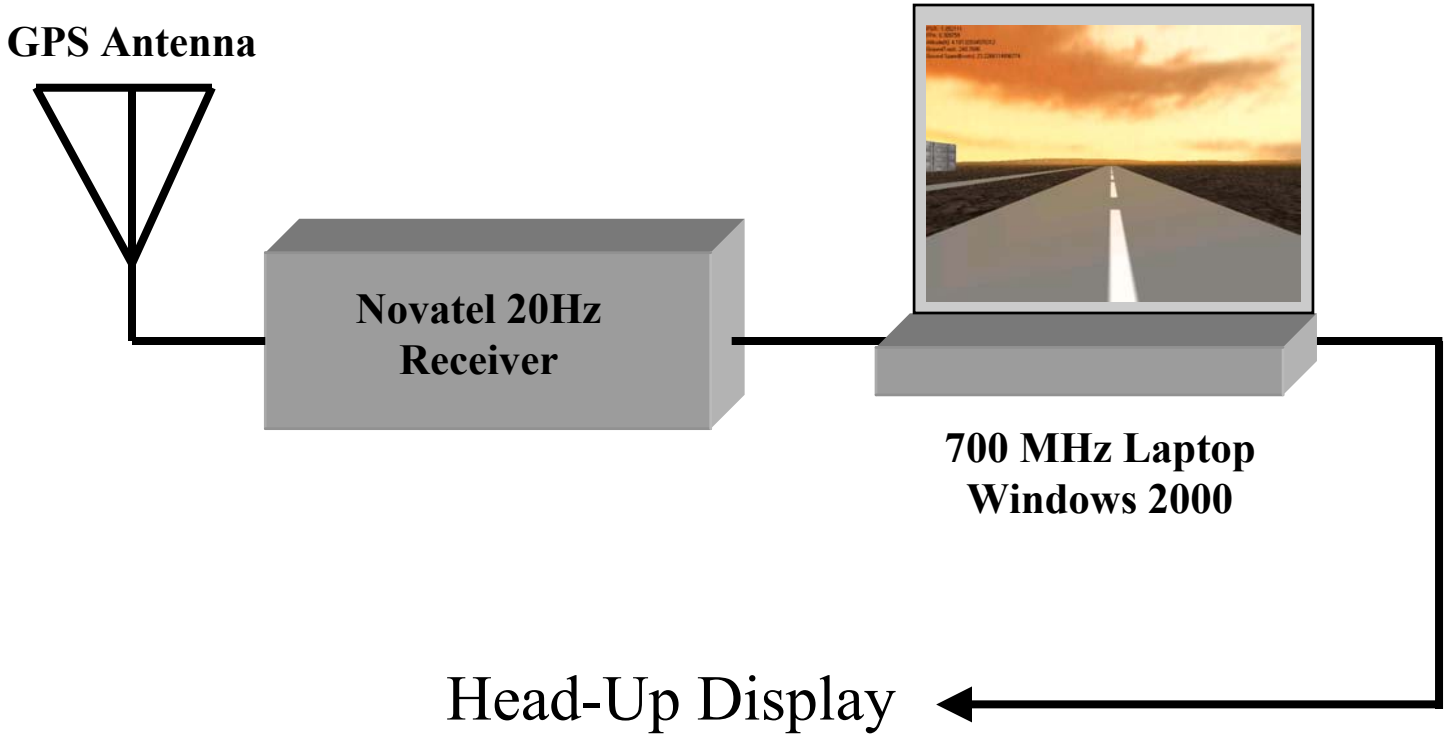
Overview

- Motivation Behind Head-Up Synthetic Vision Display (HUSVD)
- System Overview
- Synthetic Vision System Modifications
- Position Error Analysis
- Certification Issues
- Multiple View and Multiple Configuration HUSVD
- Flight Tests

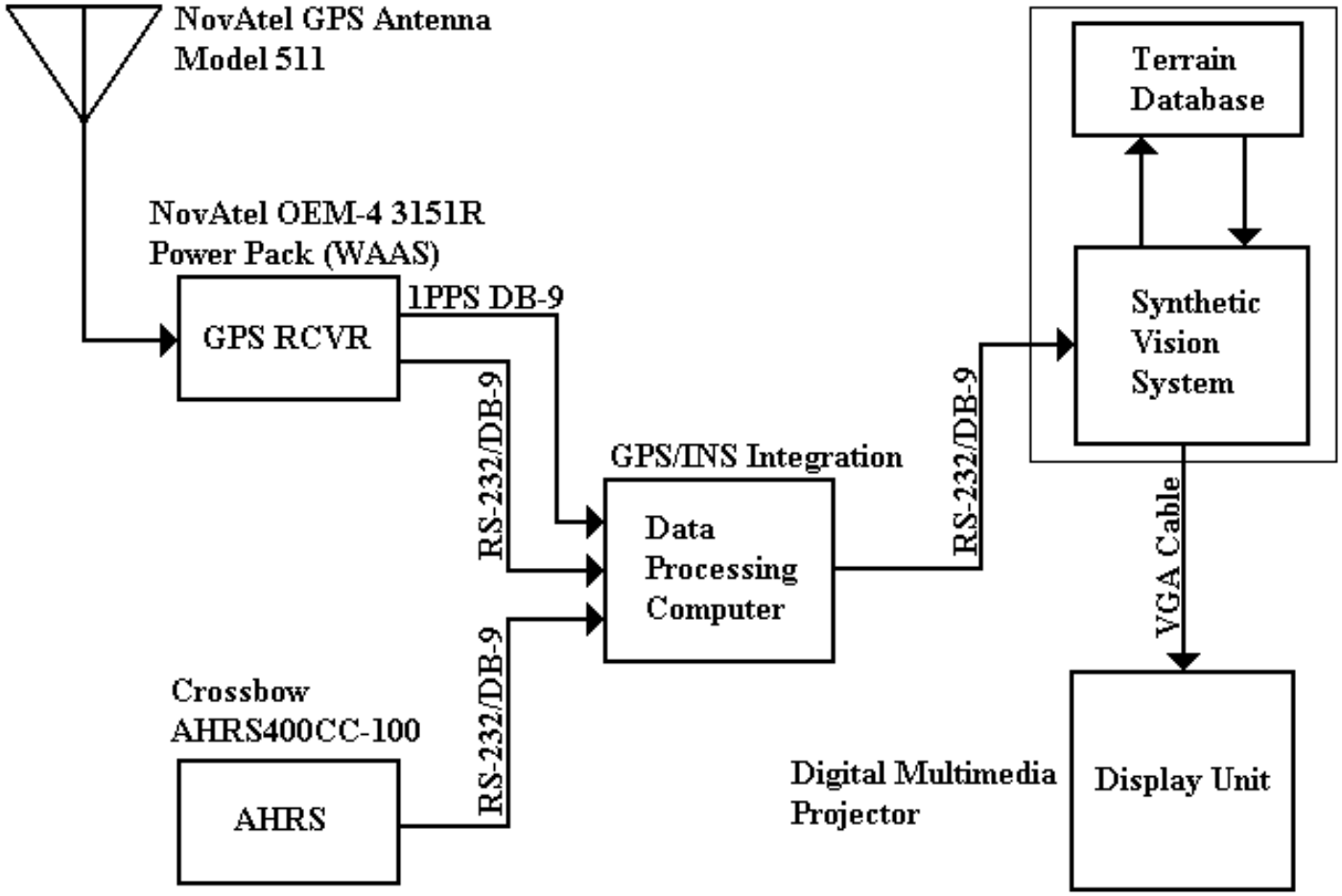
Motivation Behind HUSVD

- Provide Visual Cues in IMC
- Increase Situational Awareness in IMC
- Reduce Pilot Training and Currency Requirements for Flight in IMC
- Reduce Instrument Fixation During the Approach
- Cost-Effective Head-Up Synthetic Vision Display

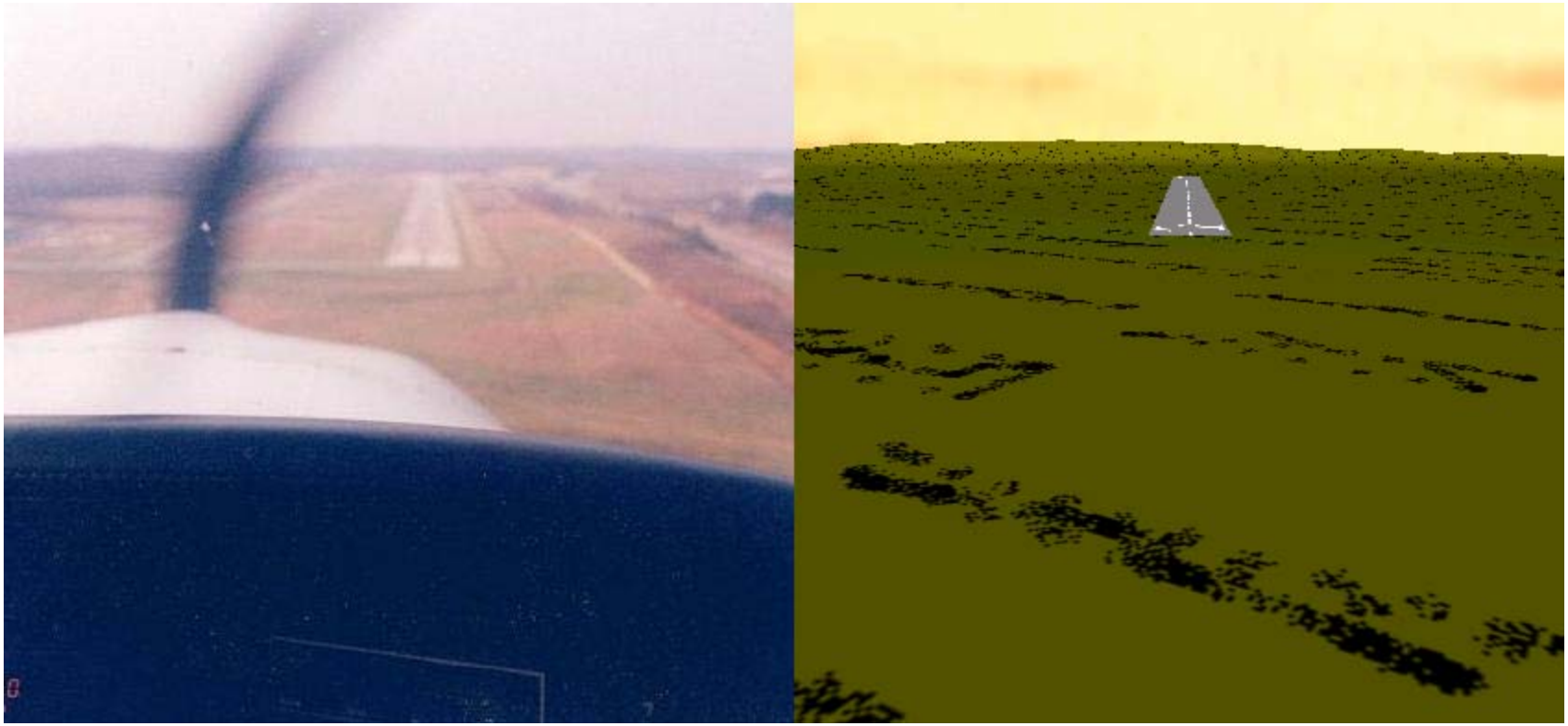
HUSVD Version 1.0



HUSVD Version 2.0

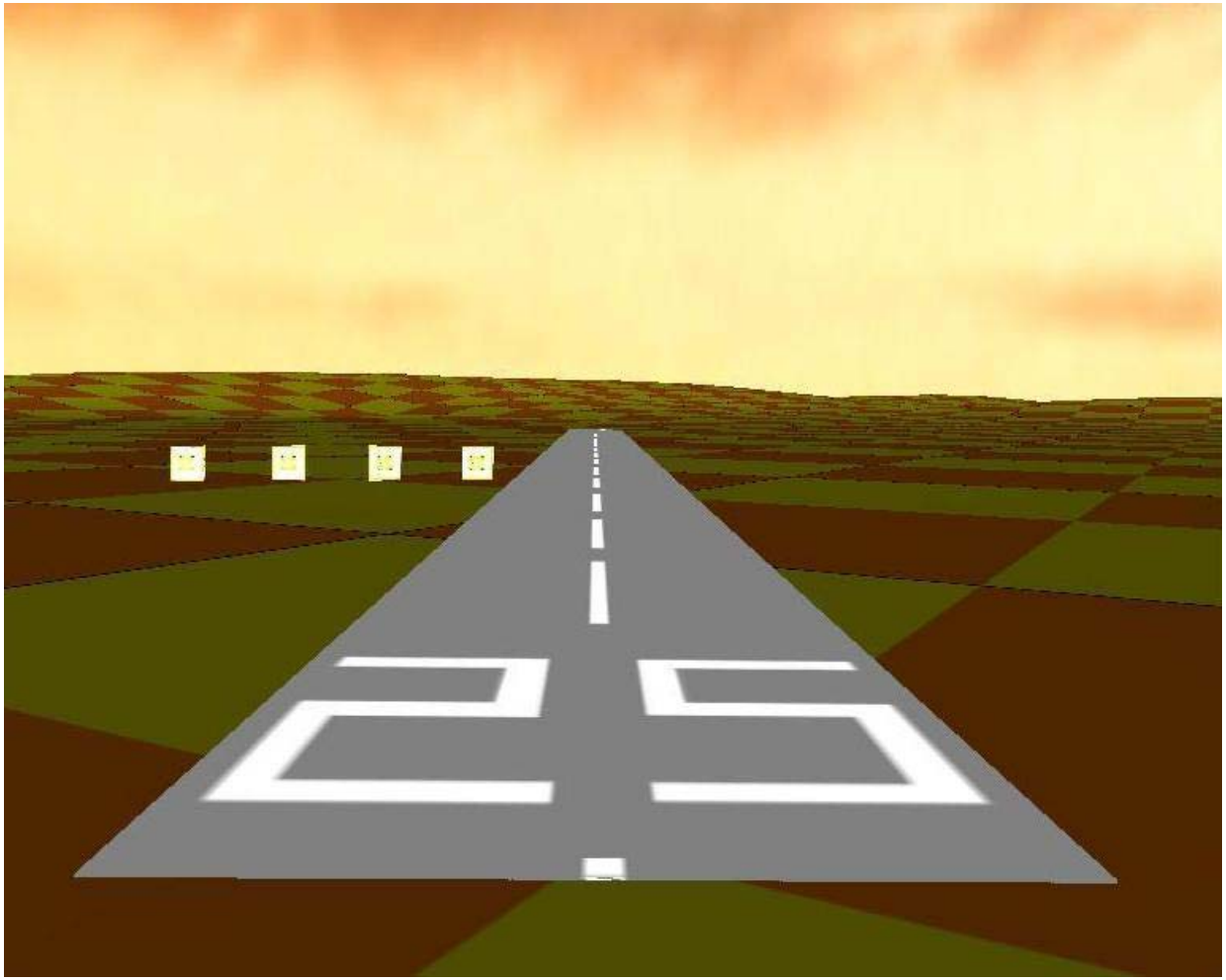


Synthetic Vision Comparison



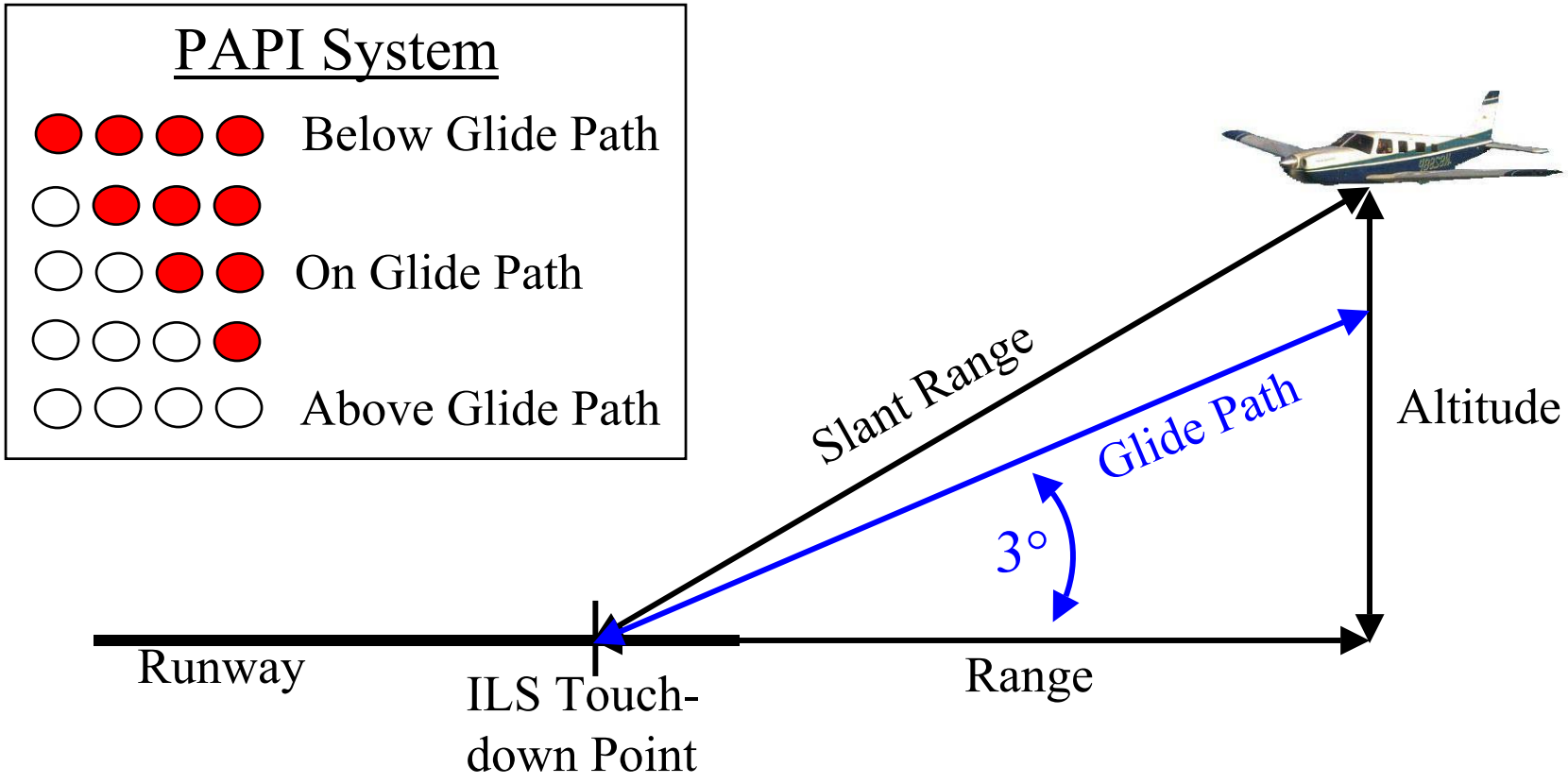
Two separate flight tests on UNI Runway 25. There is a slight altitude difference between the two approaches. The Synthetic Vision is still very compelling.

Synthetic Vision Software



Precision Approach Path Indicator

Calculations Based on Local Level Coordinate System (ENU)



Position Error Analysis

Stocker Center CORS: Observation and Navigation Data Archived Continuously

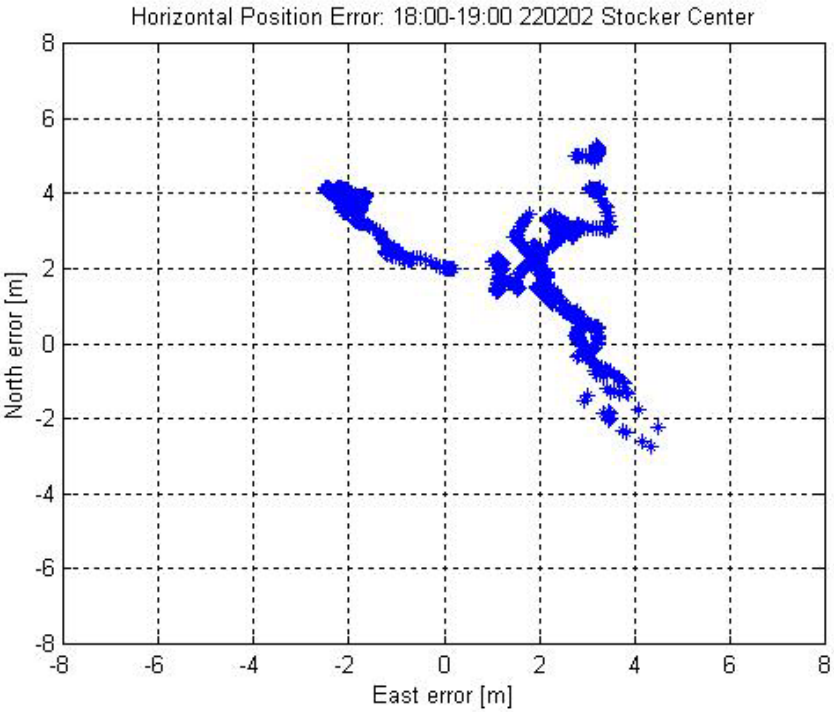
Observation Data: Pseudo-range, Carrier Phase, and Doppler Measurements

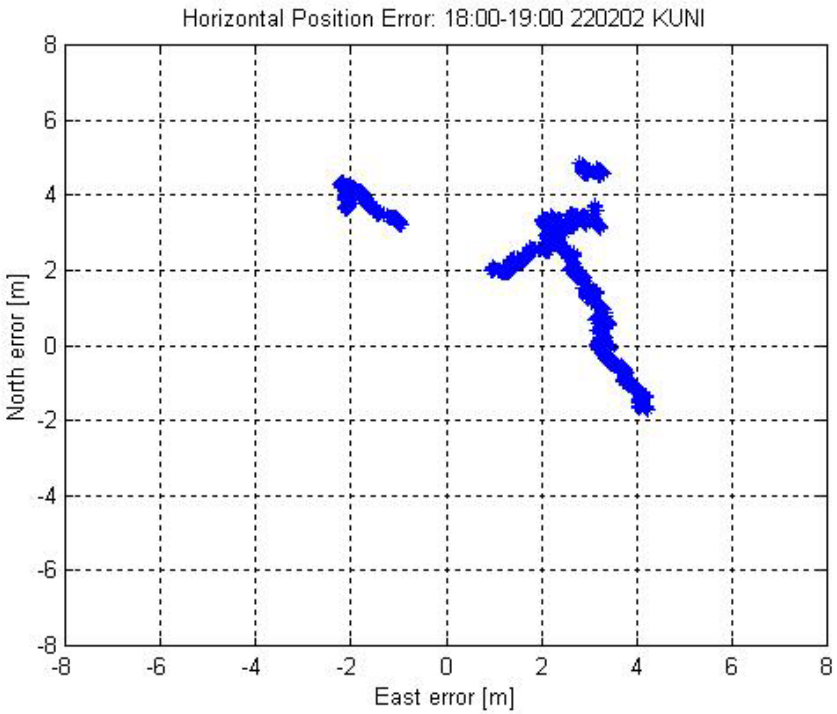
Navigation Data: GPS Satellite Ephemeris Parameters

Ohio University Airport (UNI): Ashtech Receiver Mounted to Avionics Engineering Center's Hangar

Continuously Operating Reference Station (CORS)

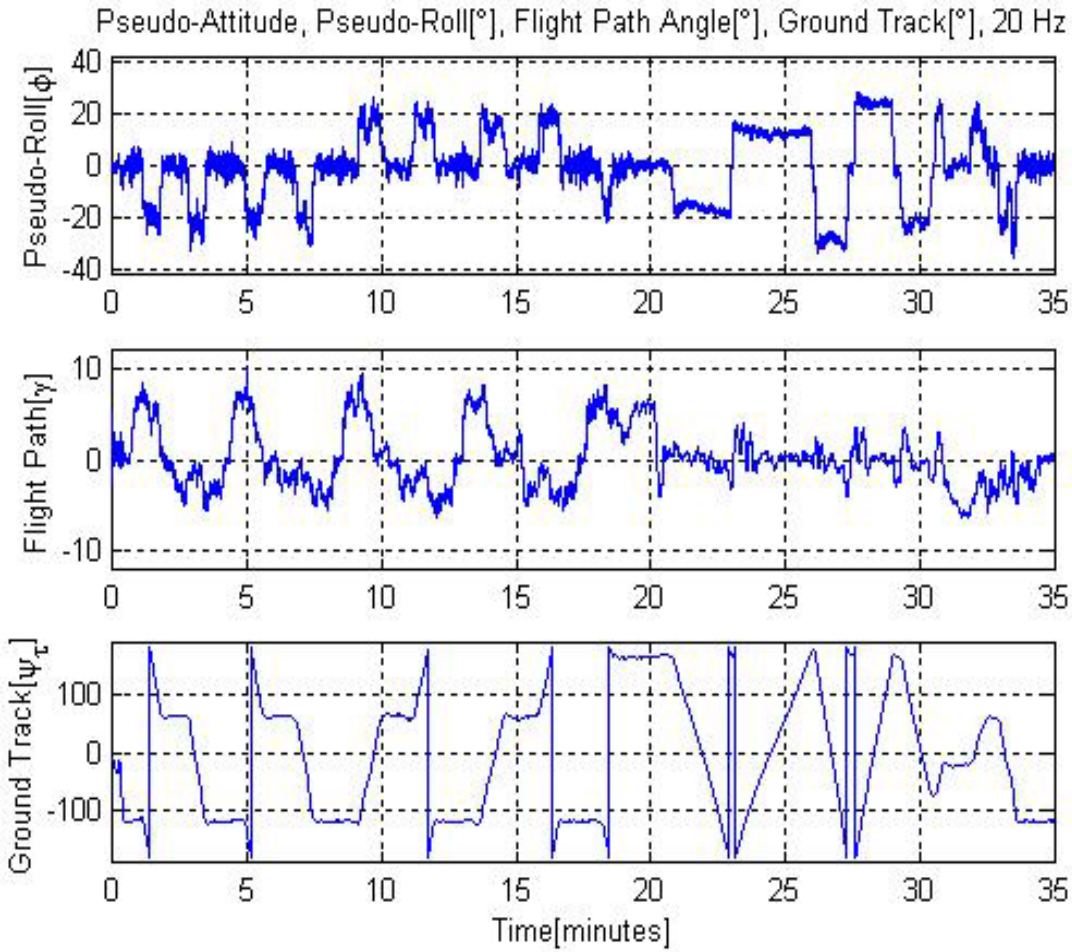
UNI & Stocker CORS Position Error





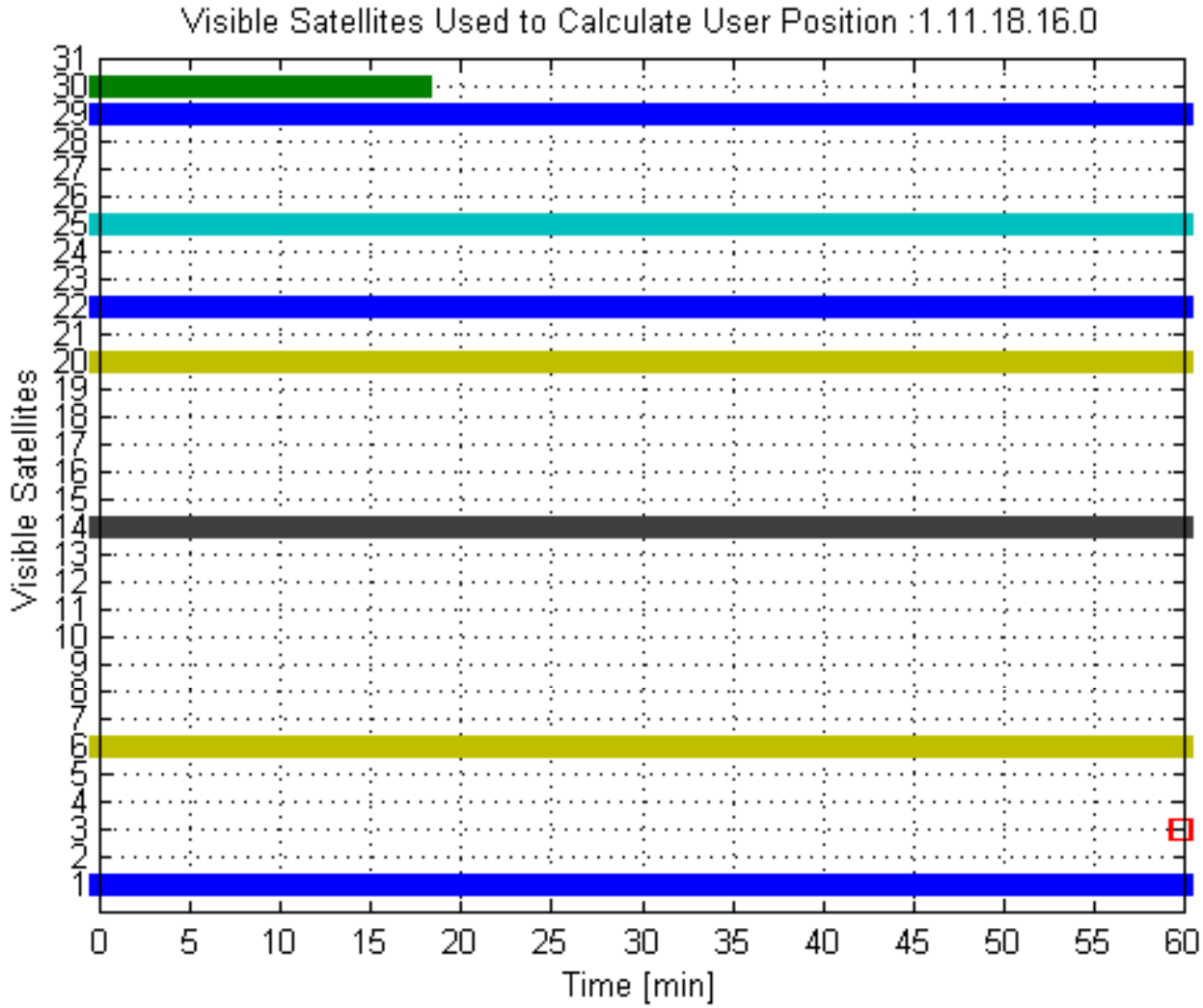
Stationary GPS data, collected at UNI and the Stocker Center CORS, provides a base line for the magnitude of the errors experienced by a dynamic GPS user at UNI. The horizontal position error at Stocker Center (left) is highly correlated to the horizontal position error at UNI (right).

Flight Test 18 November 2001

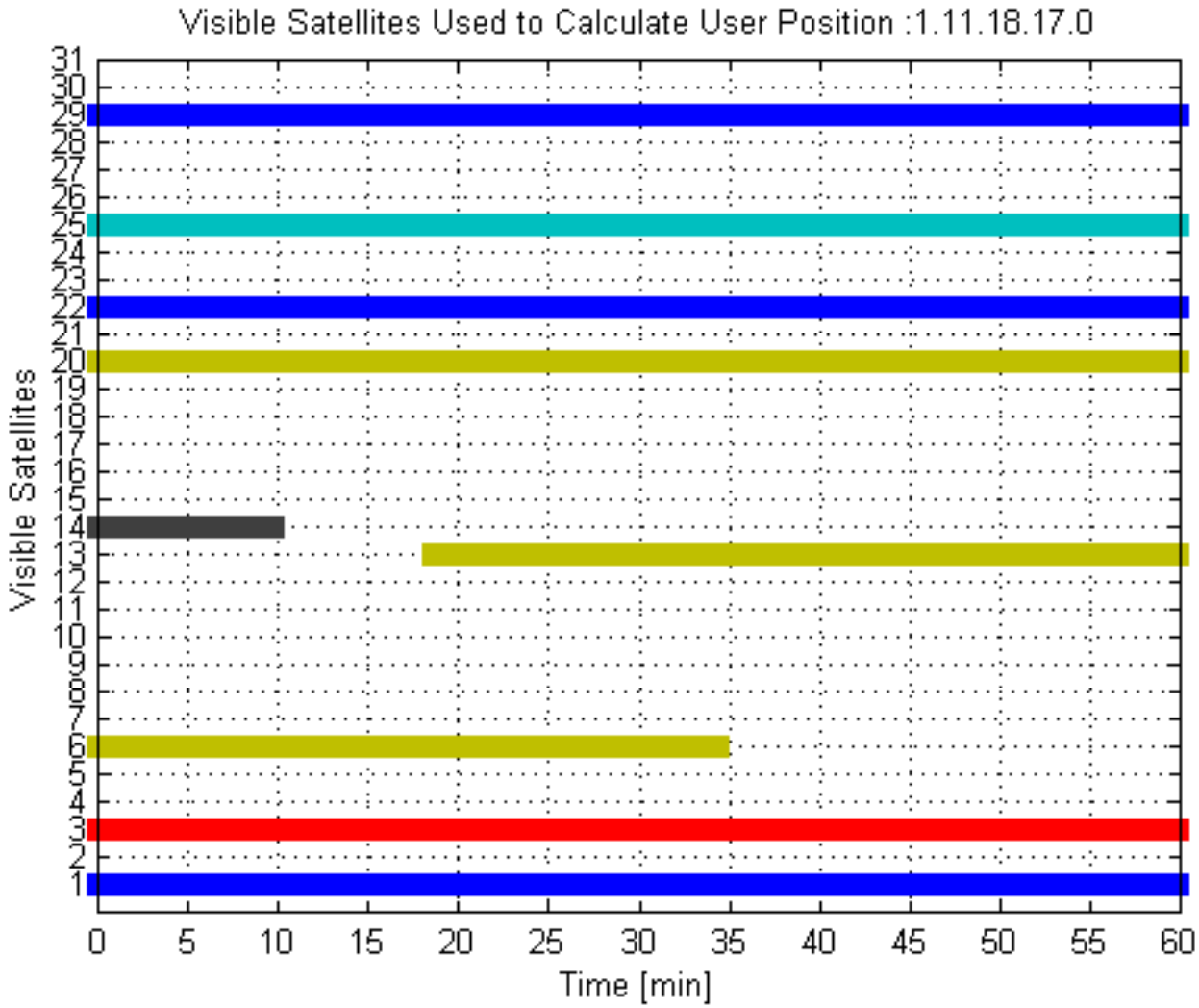


- 12:38:43 Take Off
- 12:42:14 T & G
- 12:42:25 Take Off
- 12:46:22 T & G
- 12:46:33 Take Off
- 12:50:48 T & G
- 12:51:01 Take Off
- 12:55:23 T & G
- 12:55:36 Take Off
- 12:58:50 Maneuvers
- 13:07:25 Return to UNI
- 13:13:26 Final

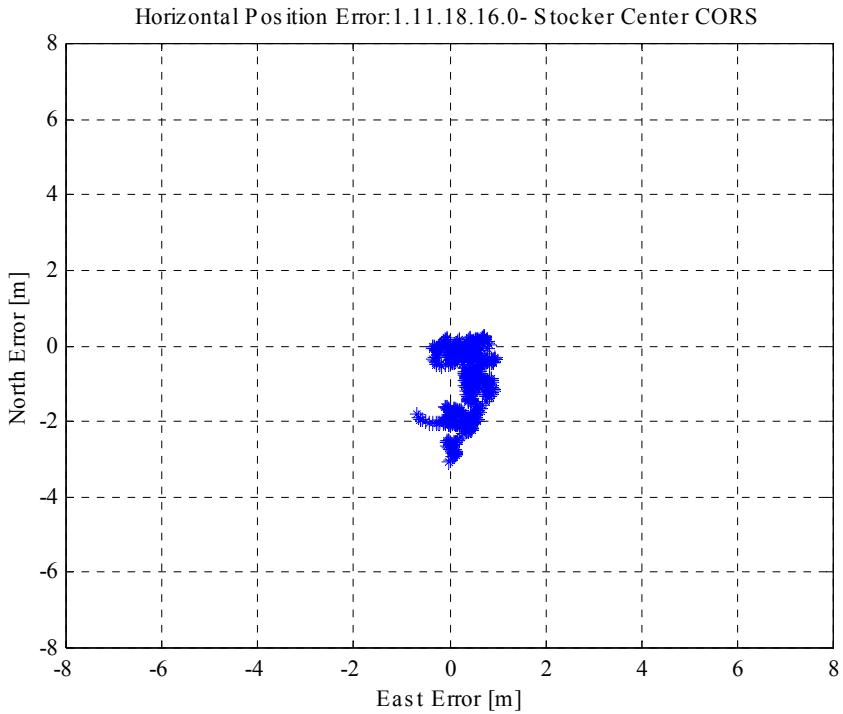
Satellites Visible, 12:00-13:00 Local

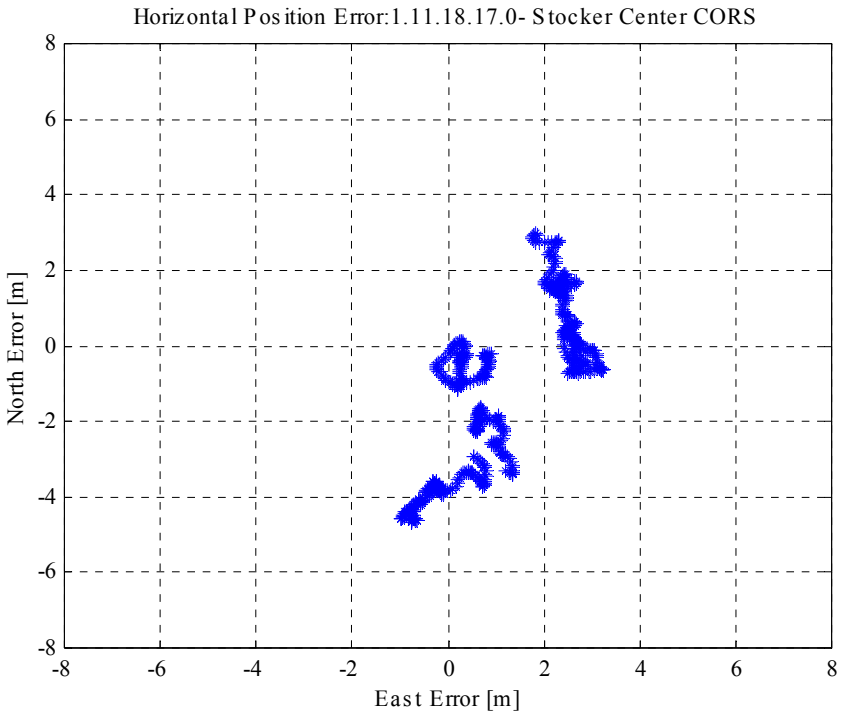


Satellites Visible, 13:00-14:00 Local



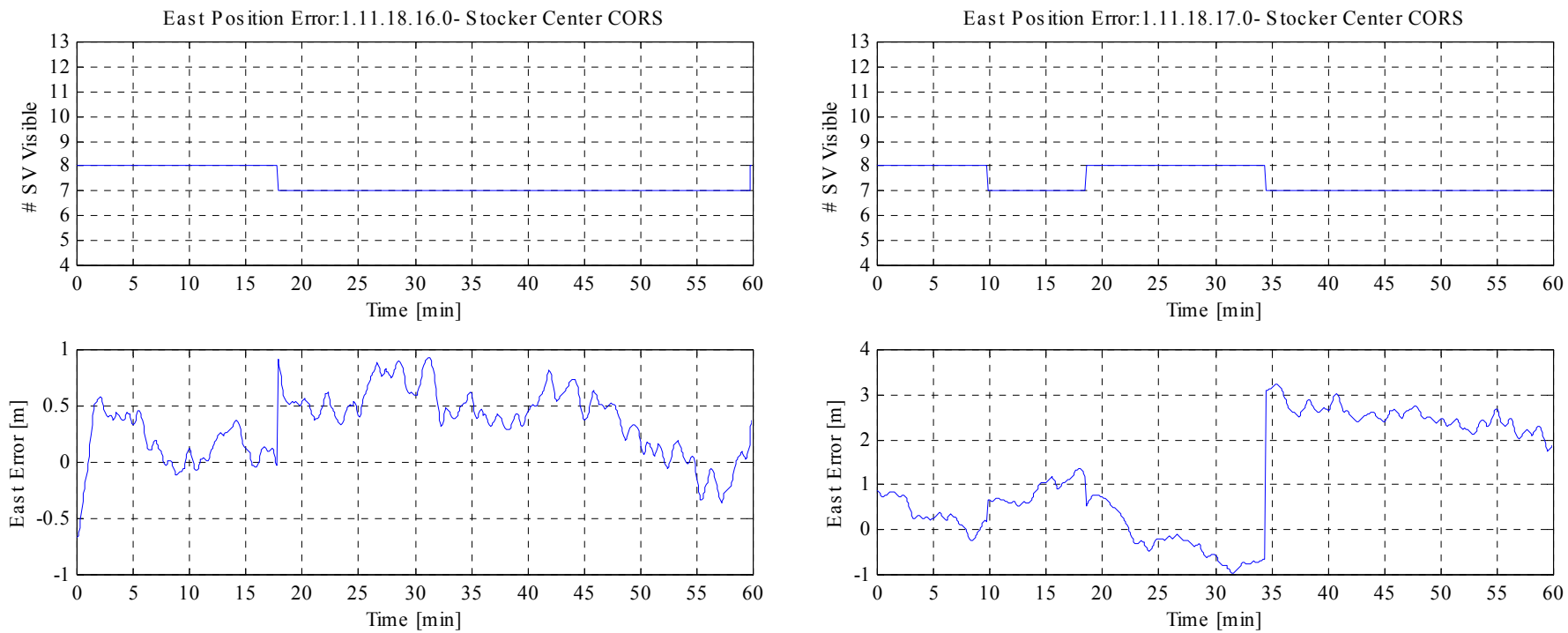
Horizontal Position Error





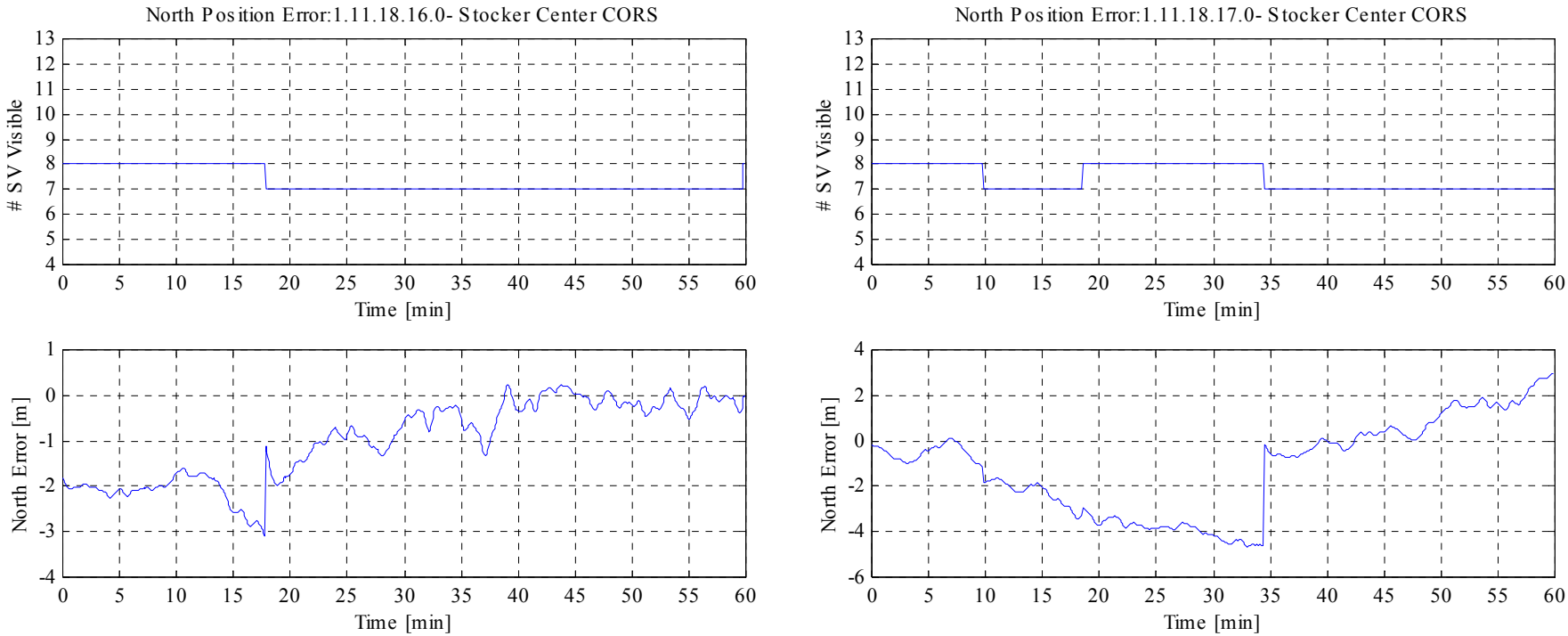
Horizontal position error was calculated over two time intervals, 12:00-13:00 local and 13:00-14:00 local. The horizontal position error for the 12:00 to 13:00 time interval is shown on the left. Both horizontal position error plots represent data collected at the Stocker Center CORS in Athens, Ohio.

East Position Error



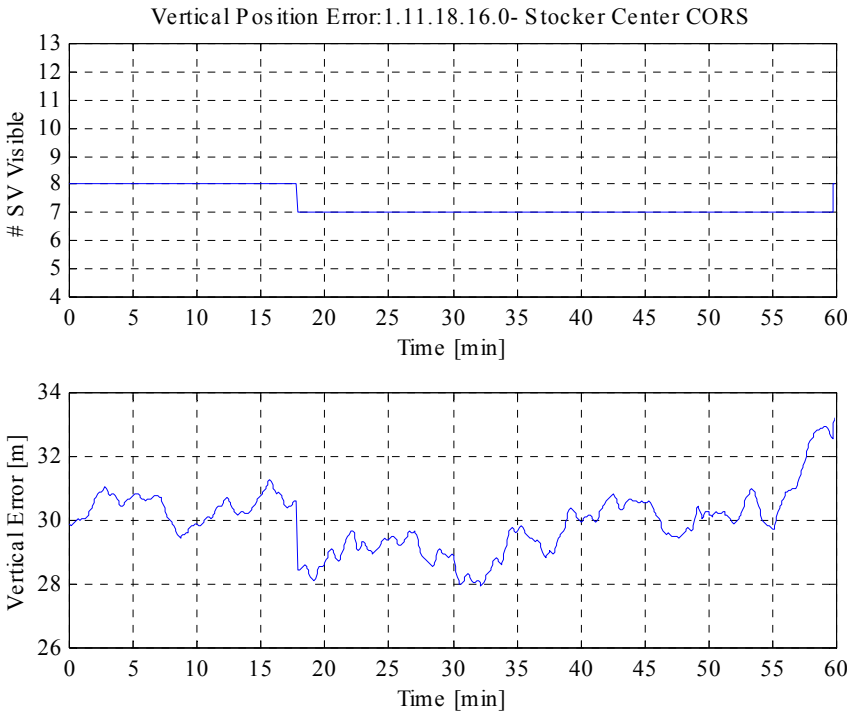
The East position error is calculated over two time intervals, 12:00-13:00 local and 13:00-14:00 local. The position error for the first portion of the flight is shown on the left with the departure time at 38 minutes after the hour. The position error for the final 13 minutes of the flight is shown on the right. The upper portion of each graph provides the number of satellites visible above 5°.

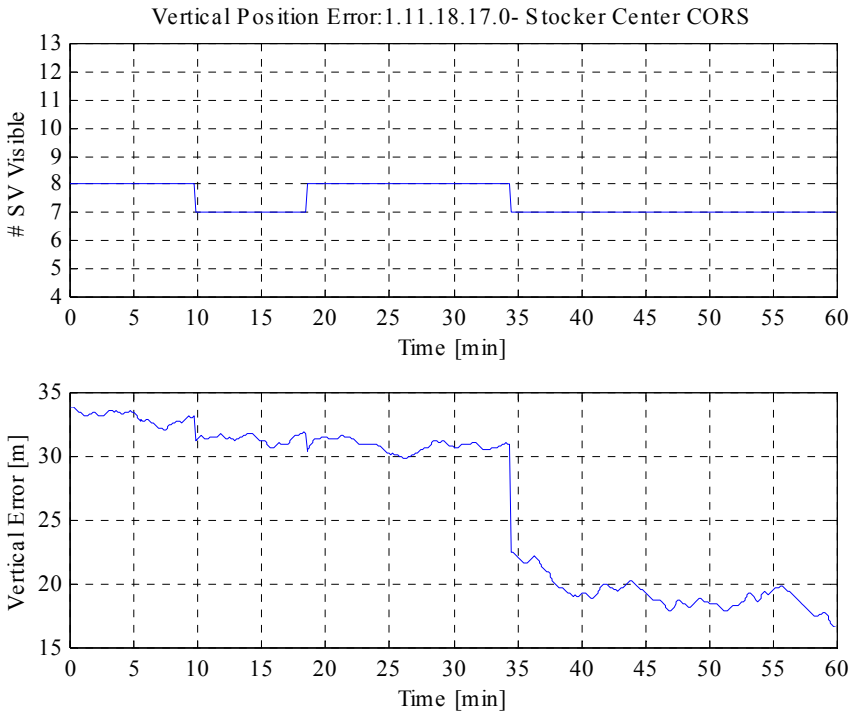
North Position Error



The North position error is calculated over two time intervals, 12:00-13:00 local and 13:00-14:00 local. The North position error for the first portion of the flight is shown on the left with the departure time at 38 minutes after the hour. The North position error for the final 13 minutes of the flight is shown on the right. The upper portion of each graph provides the number of satellites visible above 5°.

Vertical Position Error





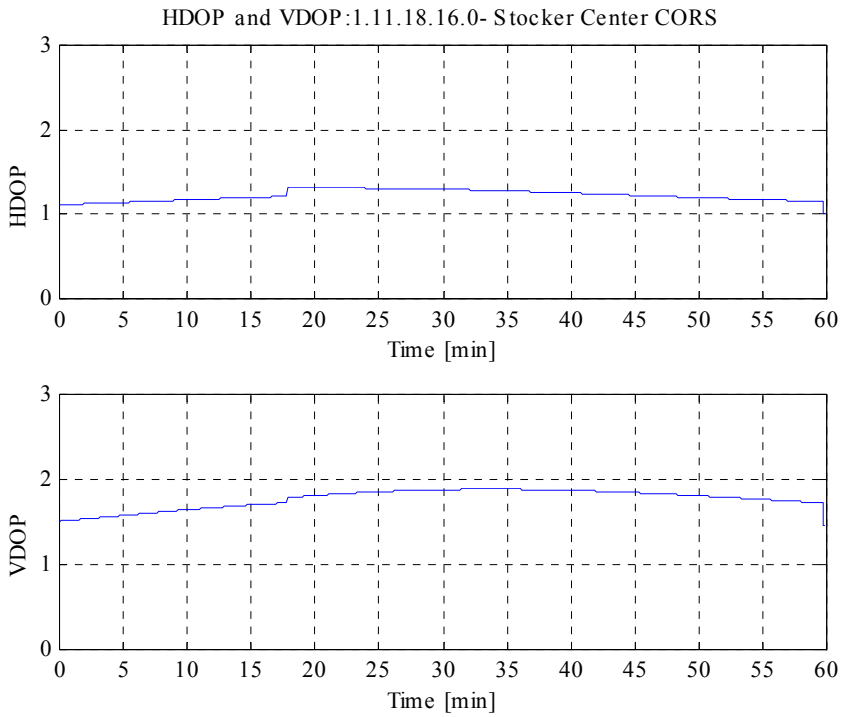
The Vertical position error is calculated over two time intervals, 12:00-13:00 local and 13:00-14:00 local. The Vertical position error for the first portion of the flight is shown on the left with the departure time at 38 minutes after the hour. The Vertical position error for the final 13 minutes of the flight is shown on the right. The upper portion of each graph provides the number of satellites visible above 5°.

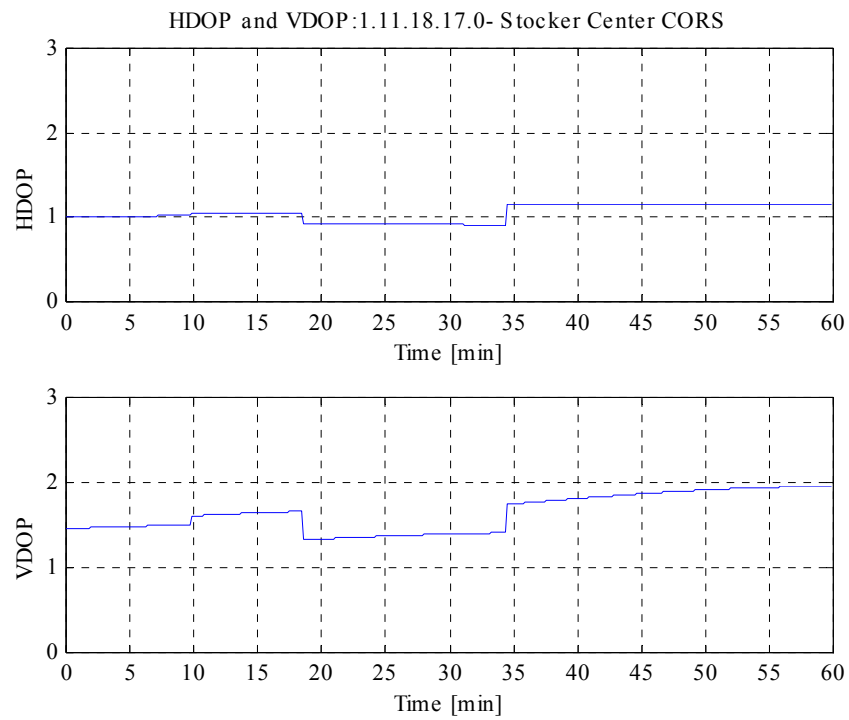
Geometric Dilution of Precision

$$G = (H^T H)^{-1} = \begin{bmatrix} \sigma_E^2 & 1,2 & 1,3 & 1,4 \\ 2,1 & \sigma_N^2 & 2,3 & 2,4 \\ 3,1 & 3,2 & \sigma_U^2 & 3,4 \\ 4,1 & 4,2 & 4,3 & \sigma_{cB}^2 \end{bmatrix}$$

The variance of the East, North, and Up are the (1,1), (2,2), and (3,3) found on the diagonal of the G matrix.

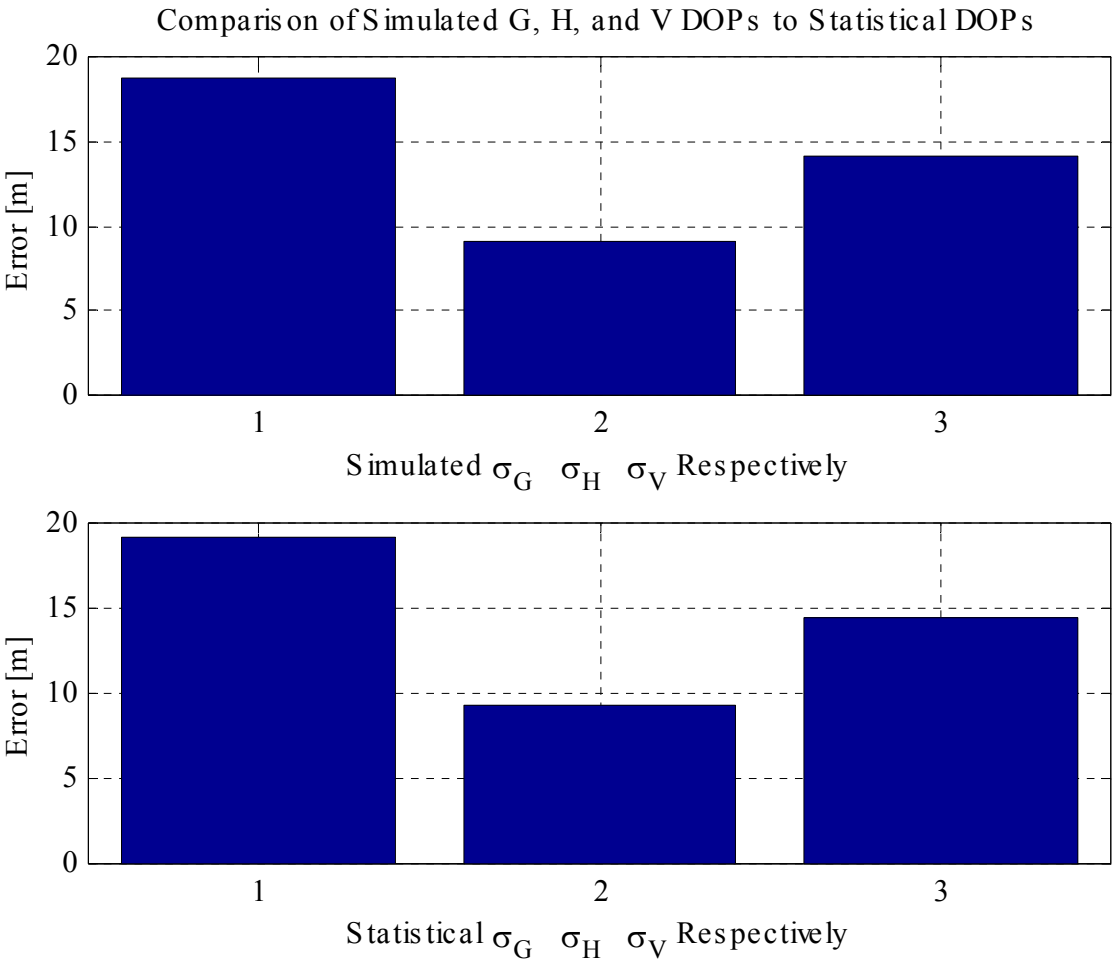
Horizontal & Vertical DOP





The Horizontal and Vertical Dilution of Precision (HDOP & VDOP) are calculated over two time intervals, 12:00-13:00 local and 13:00-14:00 local. The HDOP and VDOP for the first portion of the flight is shown on the left with the departure time at 38 minutes after the hour. The HDOP and VDOP for the final 13 minutes of the flight is shown on the right.

Simulated GDOP

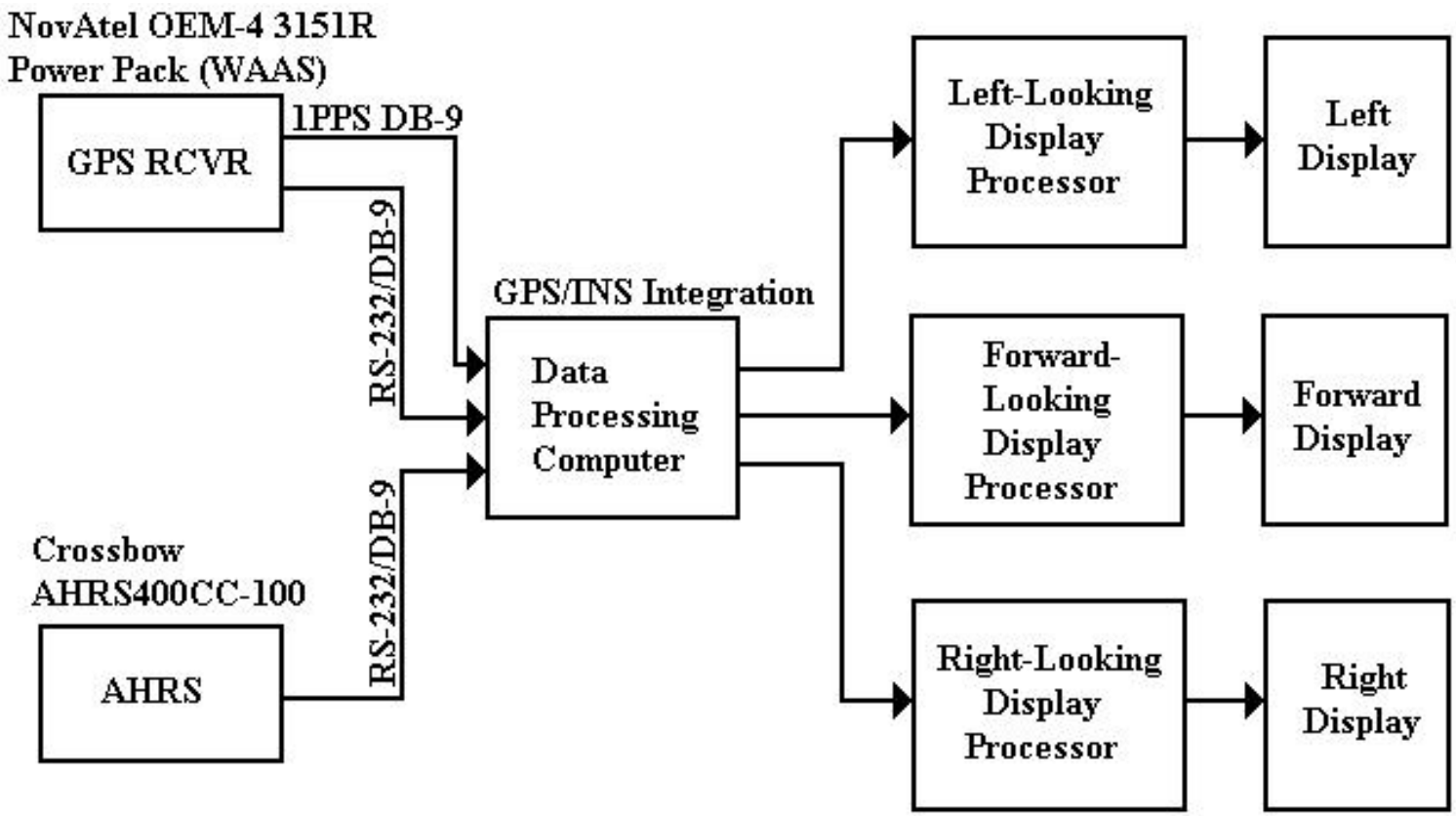


A simulation was performed where a normally distributed random error with a standard deviation of 10 meters was added to the pseudo-range. This simulation was run 1000 times to calculate the GDOP for the user position. The mean was taken for each simulation and used as the GDOP. The GDOP was then calculated using the G matrix and compared graphically to those found in the simulation.

NASA/FAA Certification Issues

- Inconsistent Depth Views, 2-D Versus 3-D
- Pilot Distraction Increasing Work Load
- Quality of Image Under Variable Lighting Conditions
- Resolution and Refresh Rate of Display
- Data Base Errors
- Distortions in Display Alignment
- Degree of Conformity
- Display Latency
- Eye Strain and Fatigue

Multiple View and Multiple Configuration Display System



Tentative Flight Tests Schedule

- 1 May 2003, Integrated GPS/AHRS System, Data Collection and System Evaluation
- 15 May 2003, Full Head-Up Display with New Integrated GPS/AHRS System
- 22 May 2003, Multi-View Display System
- June 2003, Pilot Evaluation

Questions

References

- Kornfeld, R.P., Hansman, R.J., Deyst, J.J., *The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture.* MIT International Center for Air Transportation, Cambridge, MA. Report No. ICAT-99-5, June 1999.
- Jennings, C., Alter, K.W., Barrows, A.K., Per Enge, J., D. Powell, *3-D Perspective Displays for Guidance and Traffic Awareness.* Presented Sep 1999 at the ION GPS Conference, Nashville, TN.
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- Misra, P., P., Enge, *Global Positioning System, Signals, Measurements, and Performance.* Copyright © 2001 by Pratap Misra and Per Enge, ISBN:0-9709544-0-9

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