Epoch-by-Epoch™ Real-Time GPS Positioning with the L-3 Communications/Interstate Electronics Corporation GPS Receiver

2004 Joint Navigation Conference
Las Vegas, NV

Stephen F. Rounds	IEC
Dr. Yehuda Bock	Geodetics Inc.
Dr. Lydia Bock	Geodetics Inc.
Dr. Jeffrey A. Fayman	Geodetics Inc.

Introduction

- Central Test & Evaluation Investment Program (CTEIP) has funded a program to evaluate the performance of Geodetics' Epoch-by-Epoch™ (EBE) technology
  - Program Elements
    - IEC SAASM-based GPS receiver
    - Ashtech Z12 reference receiver
    - Geodetics EBE software
  - Goal is to evaluate the EBE technology for application to test and evaluation instrumentation applications

Program Goals

- Demonstrate high accuracy position solutions
  - EBE software
  - Measurements from SAASM-based GPS receiver
    - L1 only
    - Pseudorange and carrier phase
  - Reference receiver measurements
  - Simulated IMU measurements
  - Performed using high performance GPS simulator
- Demonstrate instantaneous convergence time after interruption of ground data link (simulated)
- Demonstrate graceful degradation during loss of ground data link

Epoch-by-Epoch™ Positioning / Navigation

- Integer ambiguities are resolved independently at each epoch
- Relative site positions estimated to cm-precision
  - Requires only a single epoch of data from 5 or more SVs
- Estimation of atmospheric effects
  - Extends the allowable range between the rover and reference receiver to several times the typical maximum
- Works with different receiver designs
  - Dual or single frequency
  - C/A or P/Y code

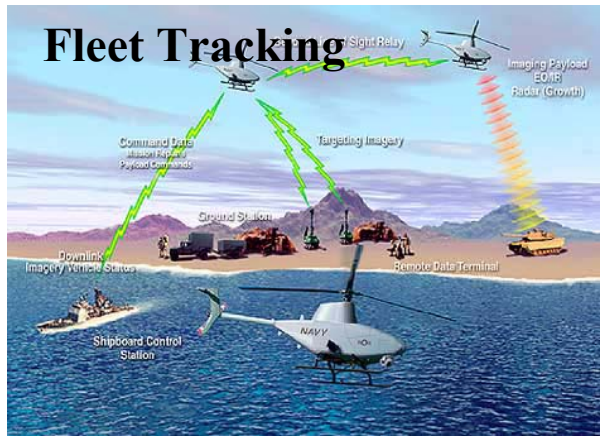
Epoch-by-Epoch™ Positioning / Navigation

- Graceful degradation of position accuracy based on GPS data availability at each epoch
  - Smoothly transitions from EBE-based navigation to autonomous GPS navigation
- Supports multiple reference receivers in networked environment
  - Enhances reliability and extends range
- Supports real-time attitude determination
  - Heading & attitude of moving platform with 2-3 receivers/antennas
  - Precision of about 0.01 degrees
- Precise relative positioning of moving platforms
  - No base station required

Epoch-by-Epoch™ Advantages

- Instantaneous initialization and re-initialization
  - Eliminates 30-45 second re-acquisition typical of other RTK techniques
- Unaffected by cycle-slips and receiver losses of lock
- Easier to detect and reject bad data points compared to batch or other RTK positioning methods
- Operates with single or multiple receivers

Epoch-by-Epoch™ Applications

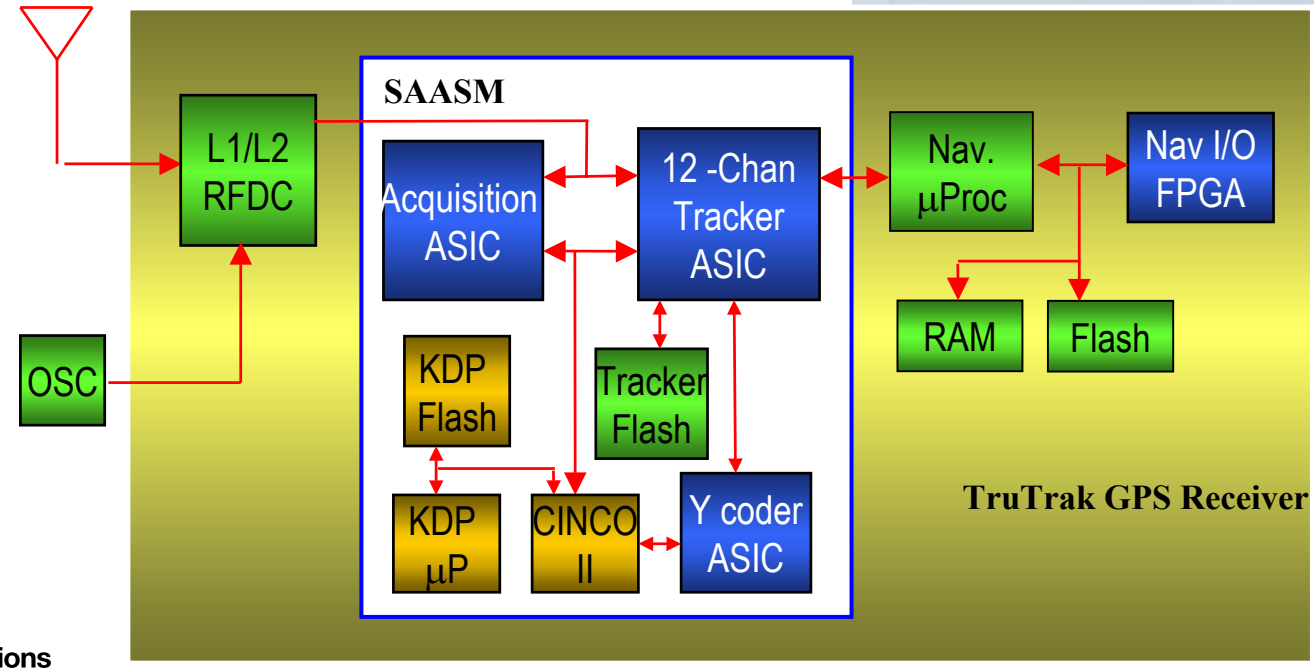


L3 communications
Interstate Electronics Corporation

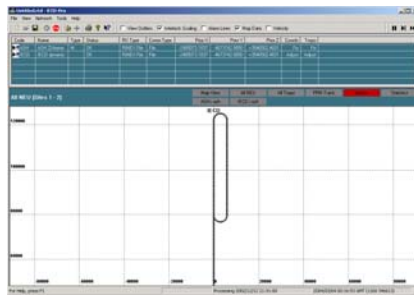
Geodetics
Incorporated

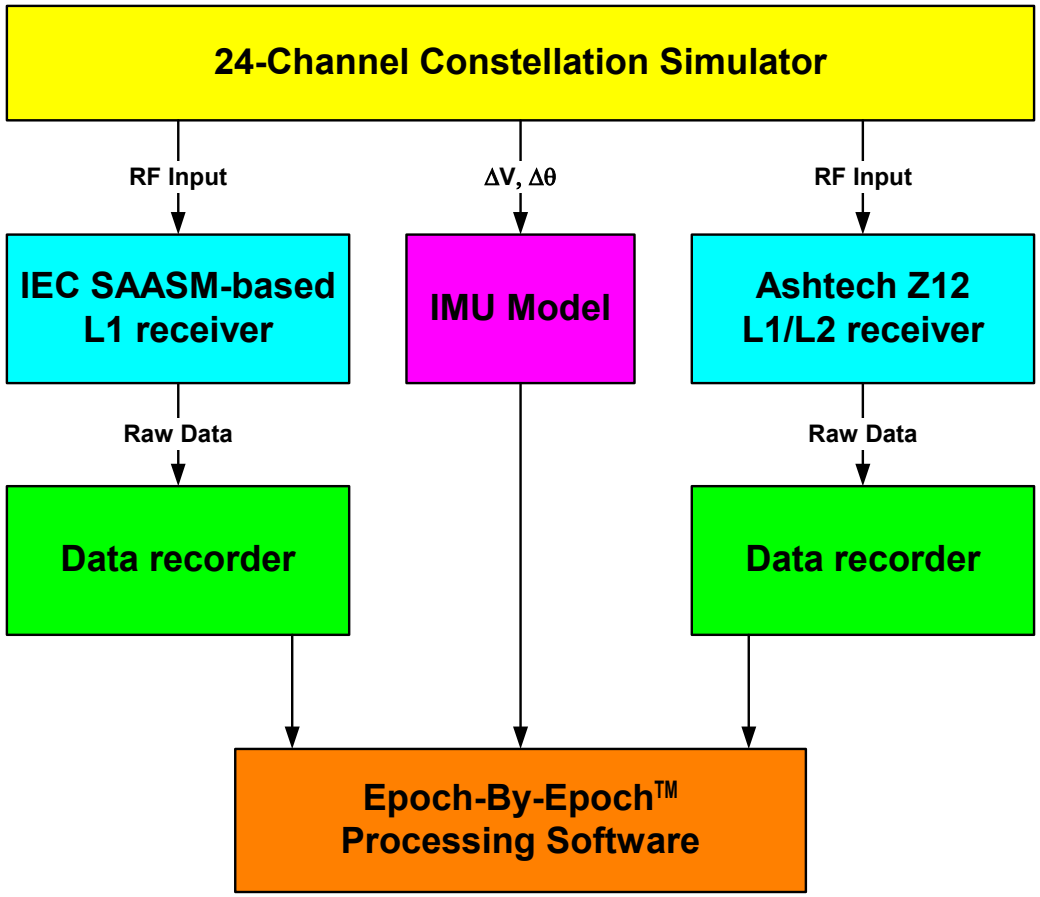
The IEC SAASM Receiver

- **Receiver used was IEC TruTrak Locator**
  - **Currently in high volume production**



EBE/SAASM Test Setup

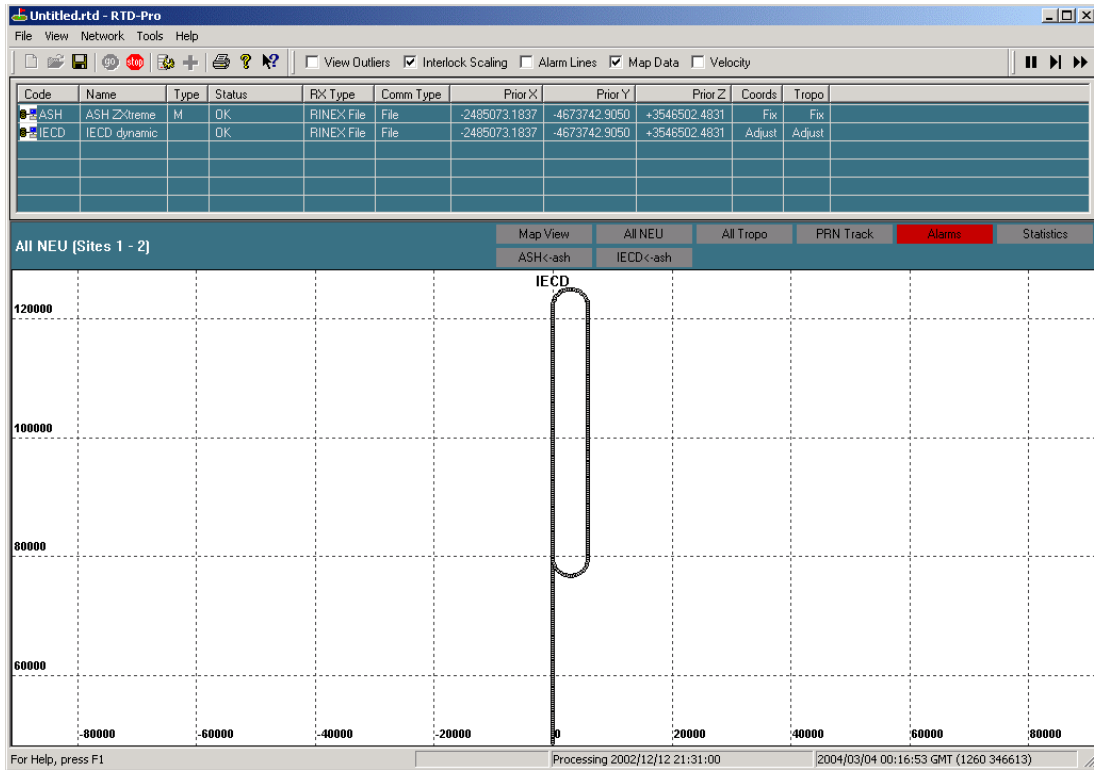




- **Test setup provides a repeatable test scenario**

Test Scenario

- **Mobile receiver**
  - **Multiple laps on oval racetrack**
  - **120 second straight segments**
  - **350 m/sec**
  - **4-g maneuvers**
- **Reference receiver**
  - **Stationary**



EBE Accuracy Results

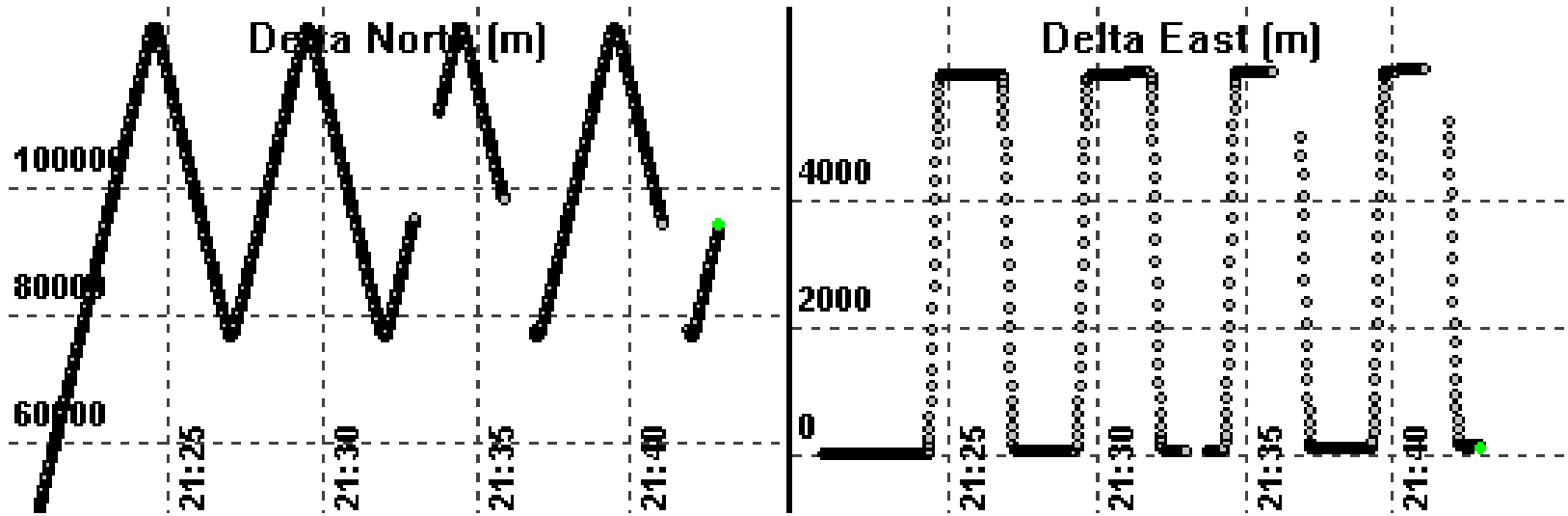
- EBE results were compared with truth data from simulator

Position Errors (m)	North	East	Up
Standard Deviation (1 meter IMU accuracy)	0.18	0.18	0.17
Standard Deviation (2 meter IMU accuracy)	0.32	0.25	0.31

- Results show <0.2 m error
  - Error still only ~0.3 m with poorer IMU
- IMU accuracy is uncertainty in position error growth between epochs

Convergence After Dropout

- Data link dropouts between the reference receiver and the mobile receiver were introduced
  - Looked at error in first EBE position estimate following re-establishment of the link



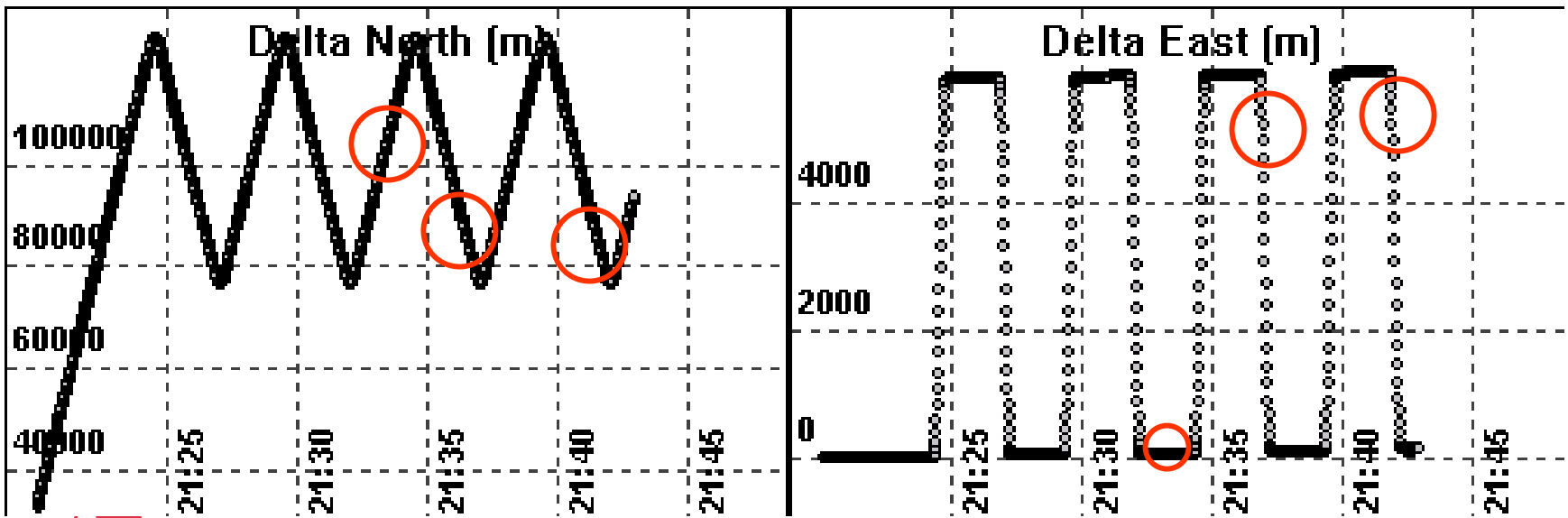
Instantaneous Convergence Results

Gap Duration (sec)	delta-North (m)	delta-East (m)	delta-Up (m)
47	0.34	0.08	0.03
59	-0.68	0.14	-0.47
77	-0.21	0.22	0.33

- Even with gaps approaching a minute or longer, error after re-establishing data link is very small
  - RMS value is 0.34 meters

Graceful Degradation Results

- During those same dropout periods, the mobile receiver GPS data was used to propagate position
- Results show graceful degradation of position error through dropouts



Conclusions

- Measurements from IEC SAASM-based GPS receiver are of geodetic quality
  - Capable of producing very accurate position
  - Further enhancement expected when L2 measurements are also used
- EBE algorithms provide instantaneous convergence after loss of data link
  - Accuracy is 10's of centimeters after 60 second loss
- EBE algorithms provide graceful degradation during loss of data link