Loran-C User Position Software (LUPS) Navigation Performance with PC-104 and DDC Receiver Flight Test Data in the New Jersey Area

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Outline

- Introduction
- LUPS Special Features
- LUPS Configuration Parameters
- Flight Test Results
- Summary
- Recommendations

Introduction

- **This effort is part of the overall program to show that the Loran-C component of a GPS/Loran system can meet horizontal navigation and approach requirements during loss of the GPS signal**
- **LUPS is an all-in-view, weighted least squares Loran-C navigation software which includes**
  - Propagation delay model based on the FCC M3 ground conductivity database
  - Measurement fault detection and exclusion (FDE)
  - Propagation/emission delay and TOA error covariance models
- **LUPS was used to post-process PC-104 and DDC receiver data from the 19 - 22 June 2001 flight tests in the New Jersey to North Carolina coastal areas**

LUPS Special Features (1)

- **Weighted Least Squares Estimation**
  - Weight matrix is the inverse covariance matrix of observation residuals
  - Covariance matrix of observation residuals is the sum of
    - **TOA error covariance matrix**
    - **Propagation delay spatial-error covariance matrix**
    - **Propagation/emission delay temporal-variation covariance matrix**

    with the sum multiplied by the reference variance
  - Navigation output includes
    - **Position estimate**
    - **Position error estimate**
    - **Fault-free protection level**

LUPS Special Features (2)

- **Propagation Delay Model - Millington-Pressey algorithm with edited FCC M3 ground-conductivity database**
- **Fault Detection and Exclusion (FDE) based on Student's t-test. Includes computation of the FDE protection level.**
- **Propagation Delay Spatial-Error Covariance and Propagation/ Emission Delay Temporal-Variation Covariance Models**

LUPS Configuration Parameters (1)

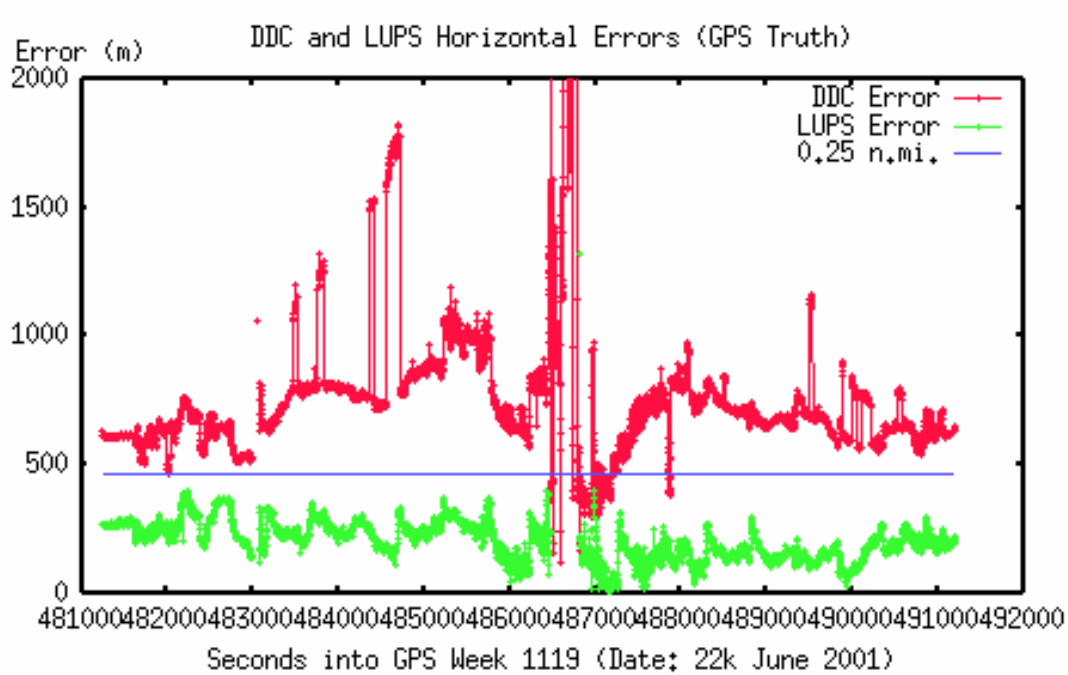
- **Chains tracked**
  - **NEUS GLKS CEC (19 & 20 June, PC-104)**
  - **NEUS SEUS CEC (21 June, PC-104)**
  - **NEUS SEUS CEC (22 June, 481234 - 482992 sec, DDC)**
  - **NEUS SEUS GLKS (22 June, 483056 - 491196 sec, DDC)**
- **Propagation delay spatial-error and propagation/emission delay temporal-variation covariance parameters are from earlier LUPS integration tests**

LUPS Configuration Parameters (2)

- **TOA-noise standard deviation at 0 dB SNR is 50 m for PC-104 and 20 m for DDC data**
- **Standard deviation of "other" error sources is 110 m for PC-104 and 60 m for DDC data**
- **ECD absolute-value threshold = 10 μsec**
- **SNR threshold is -10 dB for PC-104 and -15 dB for DDC data**
- **Reference variance = 1.5 (scale factor applied to all variances and covariances)**

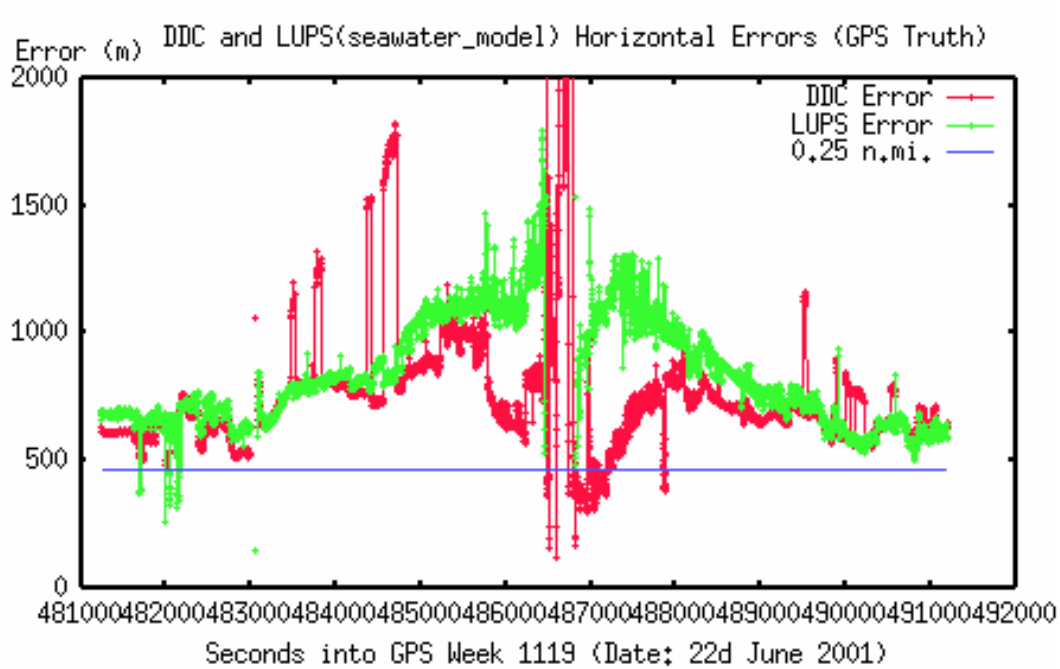
Flight Test Results (1)

- **DDC-native and LUPS horizontal errors on 22 June 2001**



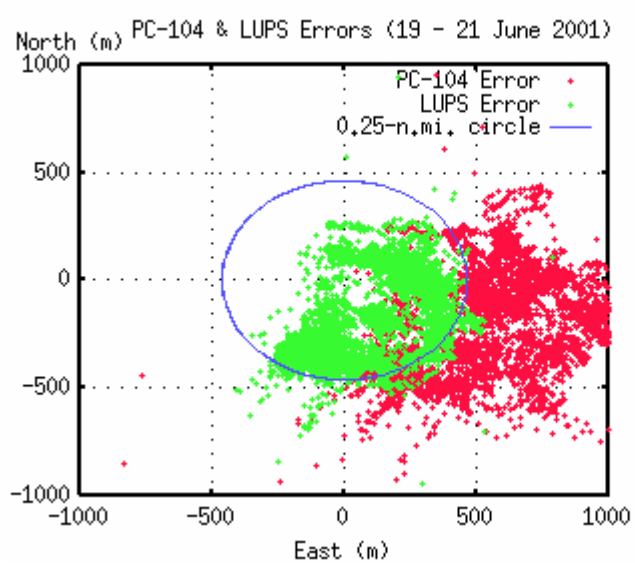
Flight Test Results (2)

- **DDC-native and LUPS horizontal errors on 22 June 2001, using the all-seawater propagation delay model in LUPS**

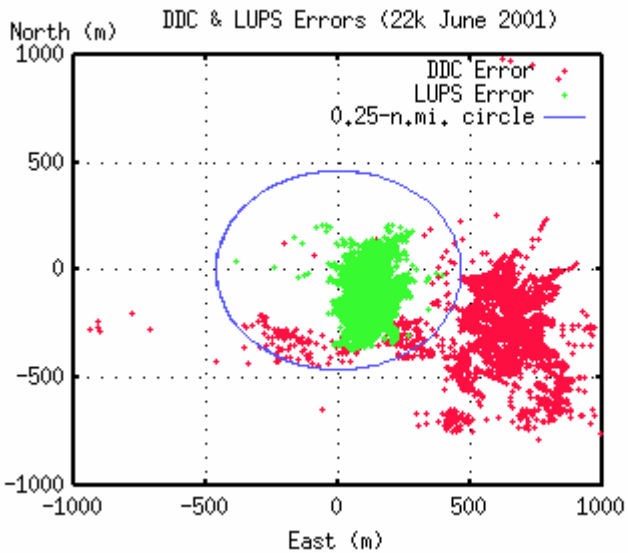


Flight Test Results (3)

- **Receiver-native and LUPS east and north navigation errors**



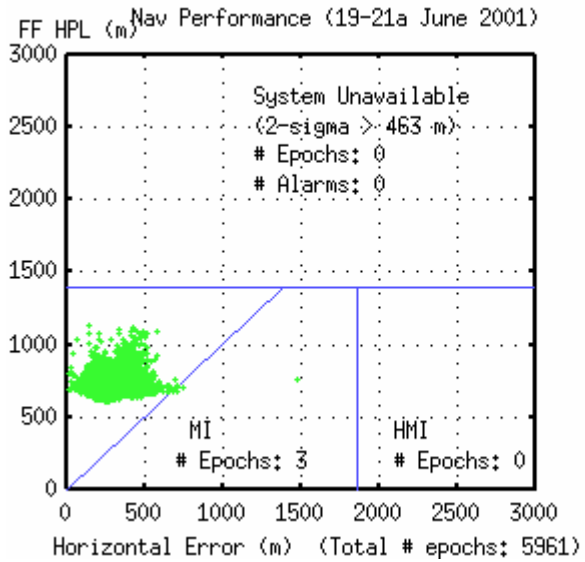
19 - 21 June PC-104 Data

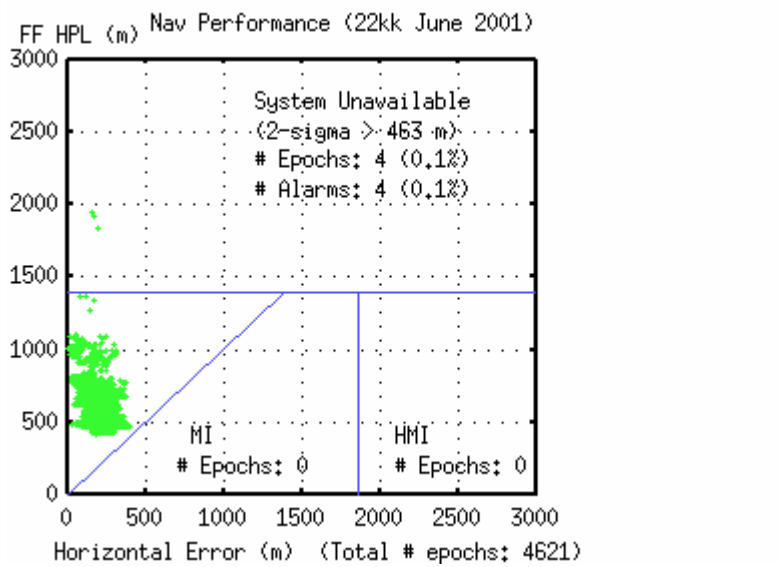


22 June DDC Data

Flight Test Results (4)

- **LUPS navigation performance**





19 - 21 June PC-104 Data

95% Error = 469 m

99.9% Error = 694 m

Ave. # signals = 5.3

22 June DDC Data

95% Error = 322 m

99.9% Error = 399 m

Ave. # signals = 7.6

Summary

- **All-in-view Loran-C can meet the required accuracy, integrity, continuity, and availability requirements with:**
  - Ground-conductivity based propagation delay model
  - Measurement fault detection and exclusion (FDE)
  - Properly calibrated error models in weighted least squares

Recommendations

- **Process more flight test data in various geographic areas**
- **Implement real-time receiver-integrated version of LUPS**
- **Extend LUPS to a hybrid GPS/Loran-C software**
- **Validation and calibration of FDE protection level**