Integrated GPS/WAAS/eLoran System for Aviation

by

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Loran Evaluation Program and Future of eLoran

- This effort is part of FAA program evaluating eLoran's ability to meet Required Navigation Performance (RNP) 0.3 criteria for accuracy, availability, integrity and continuity requirements for Non-Precision Approaches (NPAs)
- Results of technical evaluations and Volpe benefit/cost study on eLoran were turned over to DOT on March 31
- FAA/USCG technical evaluations and Volpe benefit/cost study were positive
- DOT has indicated they are planning to issue long-term Loran policy statement shortly

Participants

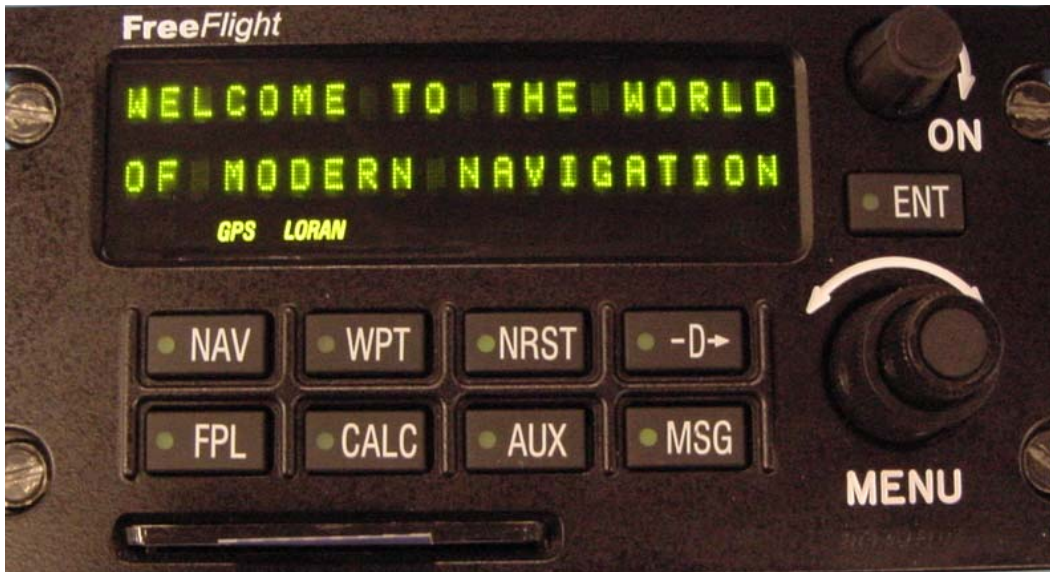
- Locus
  - e-Loran receivers
  - H-field and GPS/Loran antennas
  - ASF collection and generation system
- Free Flight Systems
  - Avionics for general aviation (GA), business and regional aircraft, etc.
  - Has FAA certified GPS/WAAS receiver
- Avionics Engineering Center
  - ASF data collection
  - Flight tests and data analysis
- Federal Aviation Administration
  - Program administration and funding

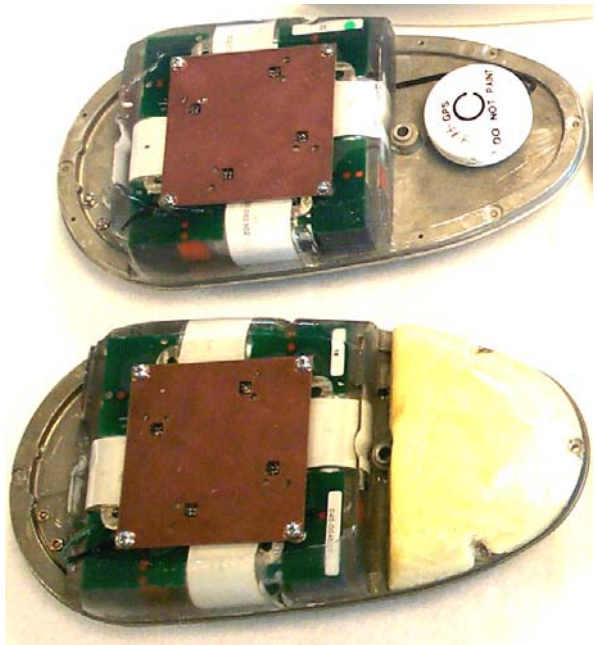
Outline

- Locus/FreeFlight Integration Program
- ASF Collection and Generation System
- Flight Test Results
- Revised eLoran Minimum Operational Performance Standards (MOPS)
- Summary

Phase 1 Program

- 2 unit prototype - minimal integration
- ASF flashcard – real time corrections
- FFS Model 2101 Approach Plus GPS/WAAS receiver for display/control





- Combined GPS/Loran antenna in ADF radome for flight trials

Phase 2 Integration Program

- Develop single unit prototype receiver in 2101 enclosure
  - Locus:
    - Design custom interface/power supply board
    - Develop EMI interference mitigation technology to enable receiver operation within 2101
  - FreeFlight:
    - Develop software to integrate GPS and Loran position and integrity data, including the simulated loss of WAAS, GPS RAIM, and GPS
    - Develop prototype enclosure and all associated mechanicals/interfaces, etc.

- Develop single unit GPS/Loran antenna
  - Locus:
    - Develop new H-field preamp
    - Combine GPS and Loran antennas

Phase 2 Integration Program

- FFS 2101 Software Modifications:
  - Compute Loran estimated accuracy – 2-sigma (95%) based on station geometry and residual error of measurements.
  - Compute Loran and GPS/WAAS estimated position uncertainty (EPU) and provide UNABLE RNP annunciation in compliance with DO-283 guidelines. Operator selects Autopilot, Flight Director, or CDI input.
  - Compute Loran velocity by differentiating and filtering 1 Hz Loran position data.
  - Selection of most accurate sensor and operator deselection of GPS/WAAS.
  - Compute RNP integrity based on simple position-based integrity scheme and enable operator to simulate loss of GPS/WAAS integrity (WAAS or RAIM) and subsequent reliance on Loran position for integrity.

Phase 2 Integration Program

- Integration program ongoing, hardware in August, delivery in November

ASF flashcard mount

Dimensions:
4.88” H (124 mm)
5.74” W (146 mm)
8.14” D (207 mm)

Combined GPS/Loran Prototype with ASF Flashcard

ASF Measurement System

- UPS
- 2 SatMates (e and H-field)
- 12 channel GPS/WAAS
- Rugged laptop computer with ASF software utility
- Rugged enclosure
- Flashcard for easy data storage and comparisons during tests
- Log uncorrected and ASF-corrected Loran data for further analysis and comparison

"Quasi-ASFs" Derivation and Flight Test Procedures

- Collect ~ 1 hour Loran and GPS data at airport
- Software utility:
  - calculates position offset of Loran vs. GPS
  - subtracts measured TOA from calculated TOA to obtain ASF
  - generates single set of ASF tables for that airport
  - ASFs are for stations used in nav solution
- Second utility reads ASFs and burns flashcard
- Insert flashcard and begin airport flight trials
- SatMate calculates position using TOA ASFs and general nav conductivity of 5 Siemens (sea water)

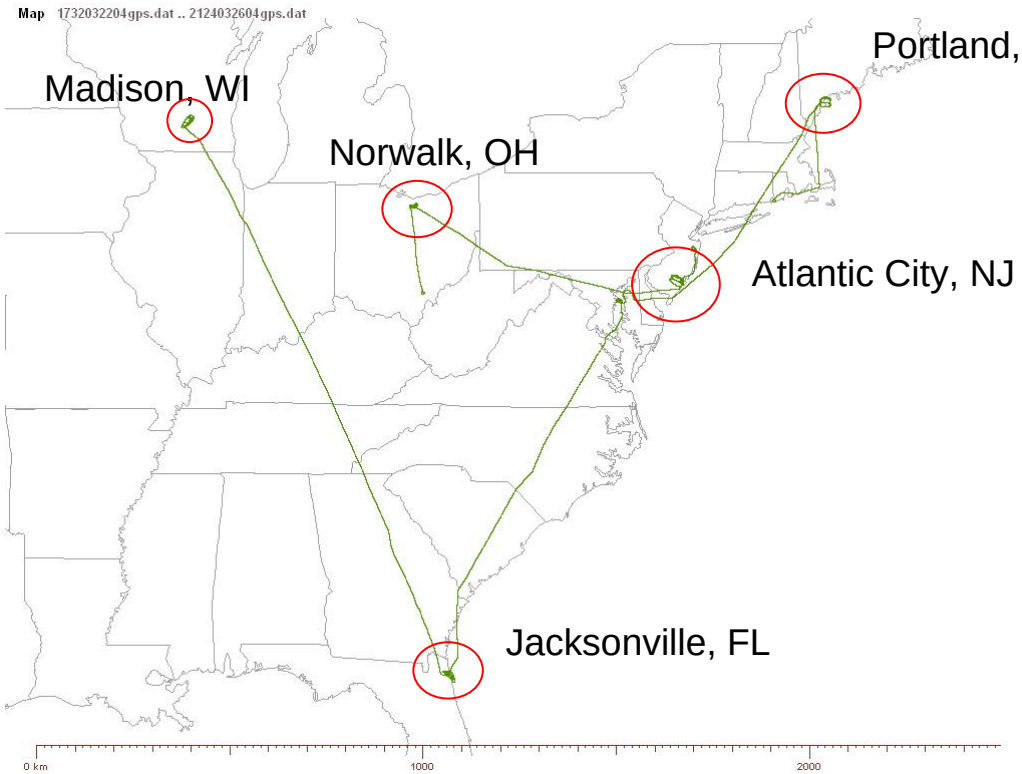
Example ASF File for an Airport

Averaged quasi-ASF values:
#ASF 8970M -0.906us [13500]
#ASF 8970X 0.429us [13498]
#ASF 8970Y 0.685us [13500]
#ASF 9960M 0.39us [13500]
#ASF 9960W 27.5us [8]
#ASF 9960Z -0.83us [13500]
#ASF 9960X 2.18us [13314]
#ASF 8970W 2.88us [13486]
#ASF 7980M -0.589us [13456]
#ASF 7980W -1.4us [13470]
#ASF 8970Z 0.118us [13468]
#ASF 7980Z -0.271us [13444]
#ASF 8290M 0.324us [13450]
#ASF 8290W 0.665us [13456]
#ASF 8290X 0.24us [13364]
#ASF 9610X 0.495us [12358]
#ASF 9610Y 0.523us [11932]
#ASF 9960Y 2.56us [13220]
#ASF 9610M -1.49us [13064]
#ASF 9610V -0.846us [13064]
#ASF 9610Z 0.261us [13064]
#ASF 7980X -0.544us [11690]
#ASF 7980Y 0.799us [6610]

ASF System in Operation

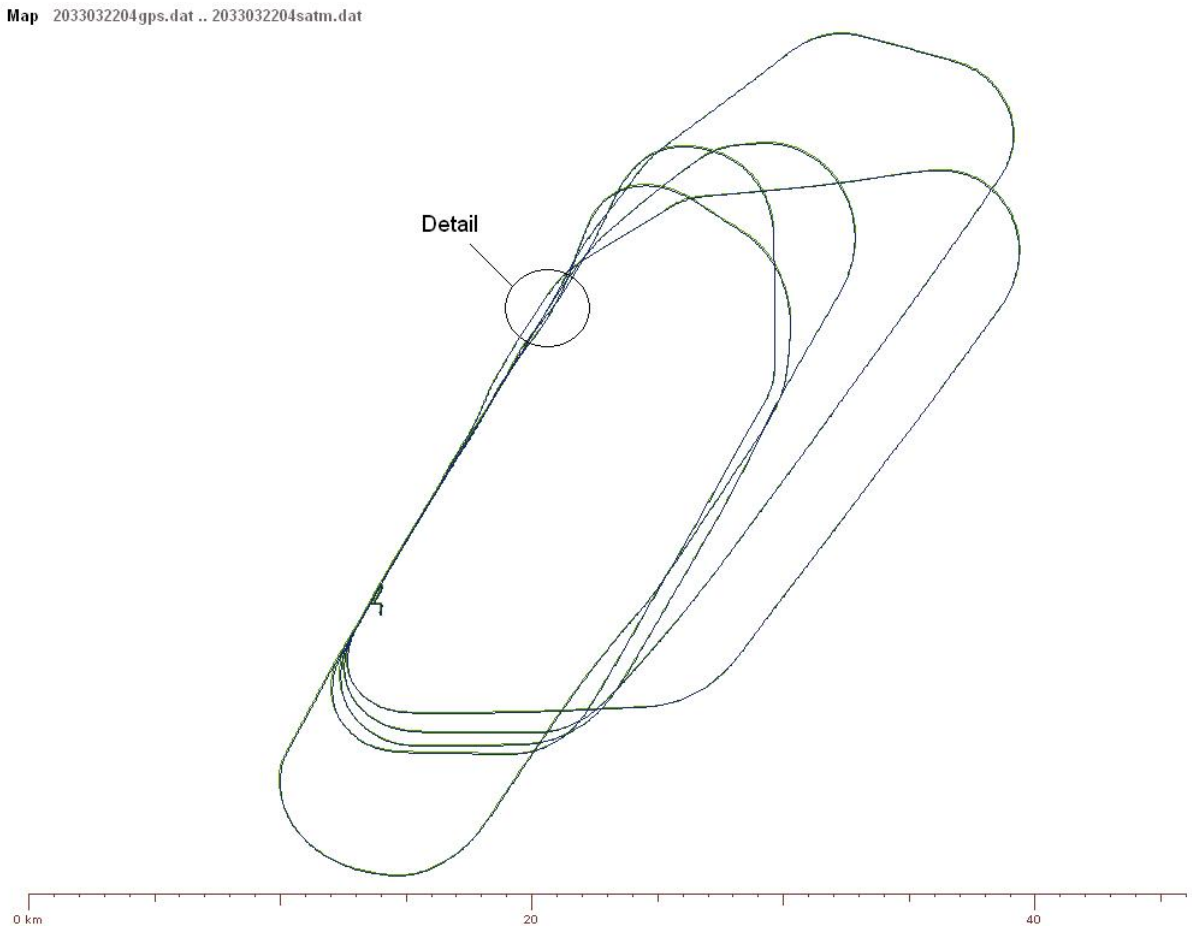
- ASF system
- Tripod held GPS, e-field, and H-field Loran antennas
- Shown here in operation at Jacksonville, Florida - Craig Airport

March 2004 Flight Tests

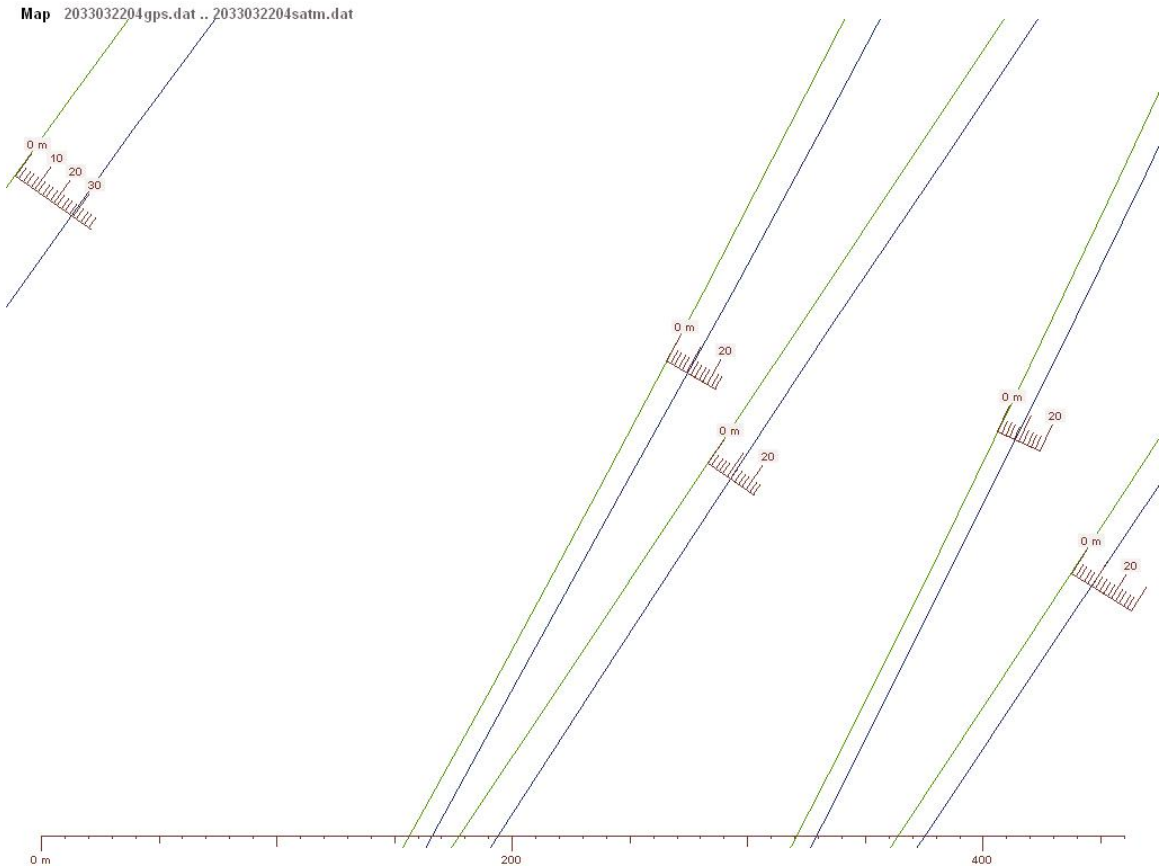


Ongoing flight tests performed by Ohio University's Avionics Engineering Center (AEC) using King Air, C-90SE twin turboprop

March 2004 Flights
ASFs from Same Day

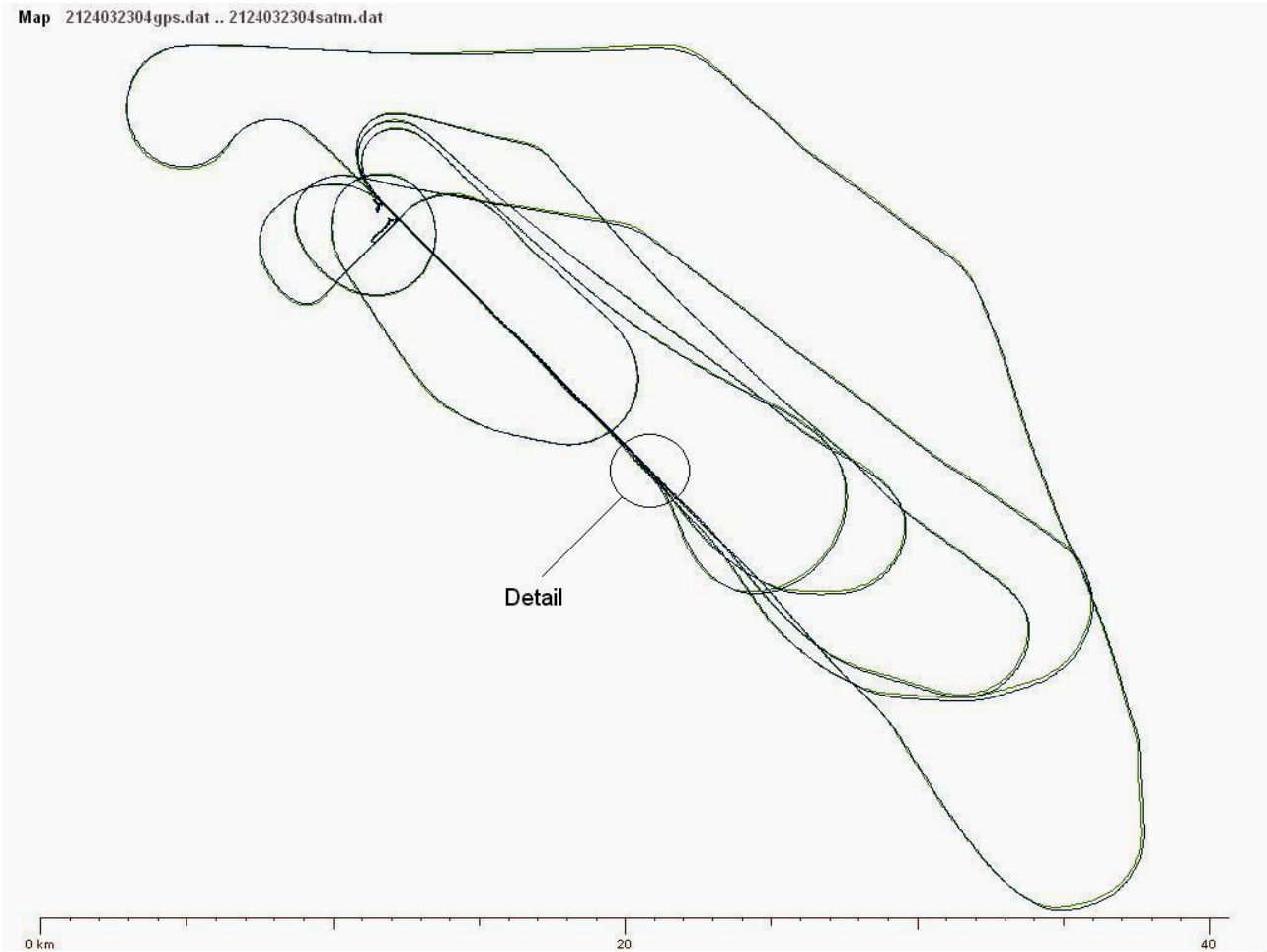


March 2004 Flights
ASFs from Same Day



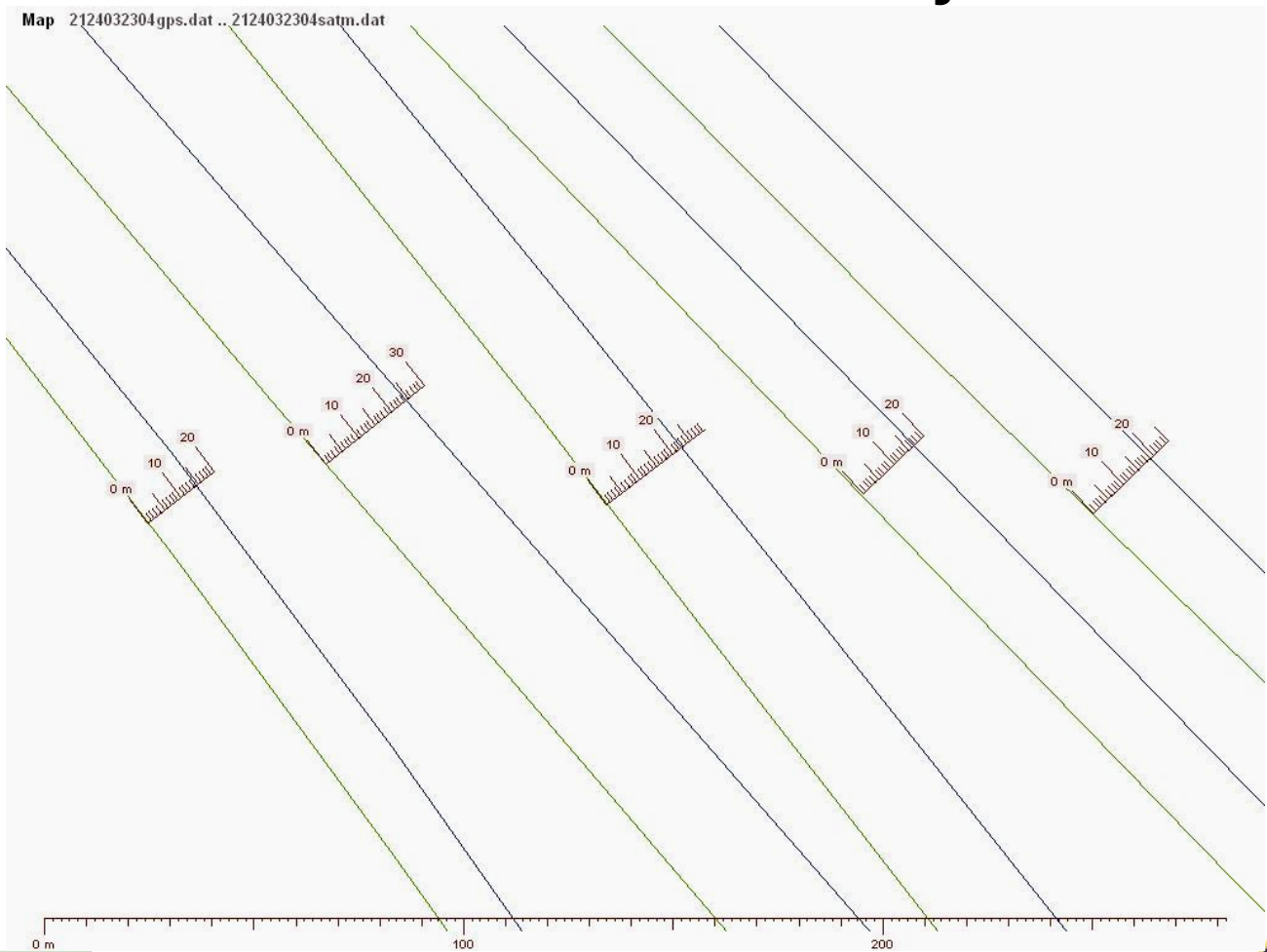
Madison, Wisconsin
Cross Track 8 - 30 m

March 2004 Flights
ASFs from Same Day



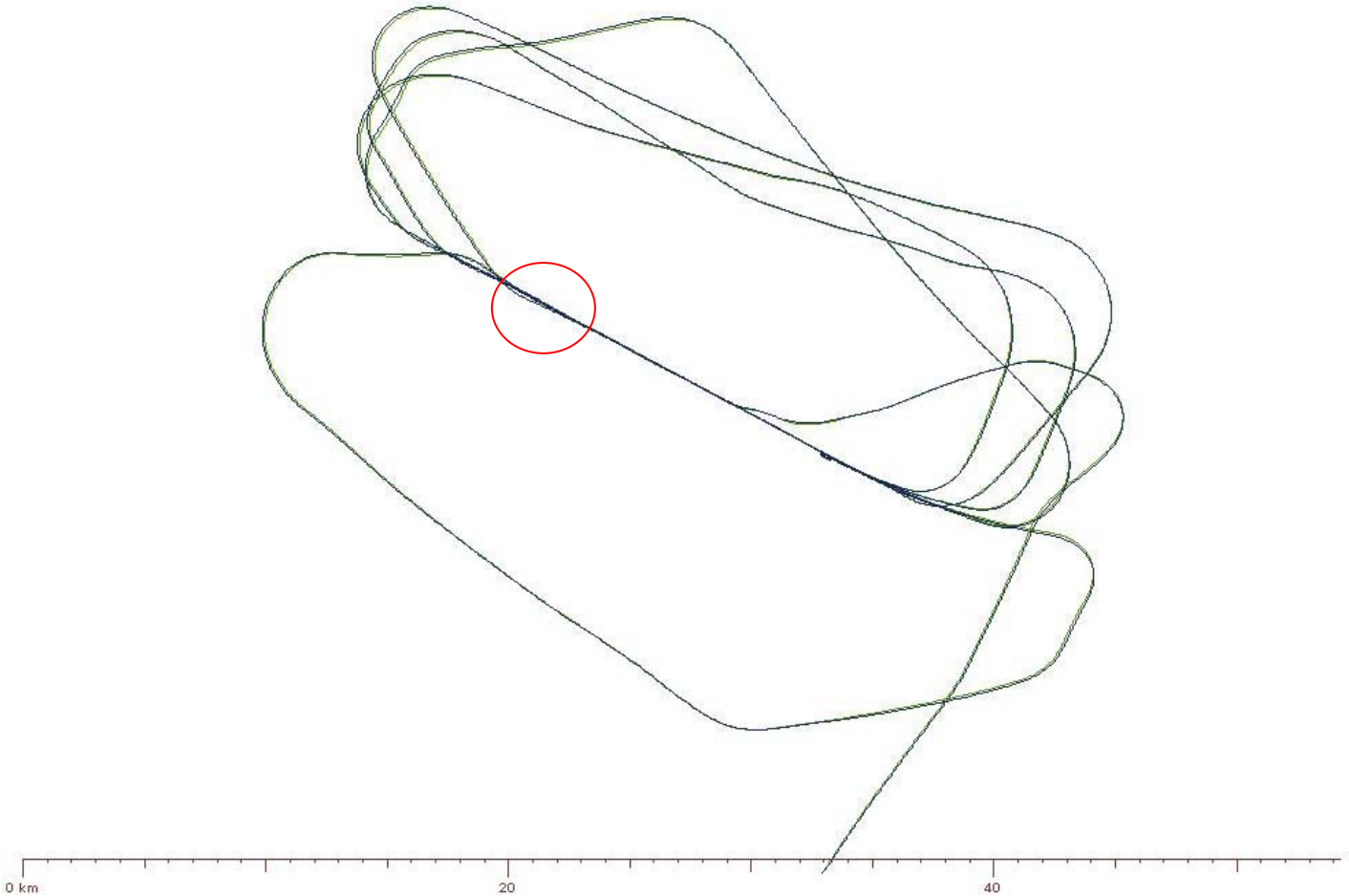
Jacksonville, Florida

March 2004 Flights
ASFs from Same Day



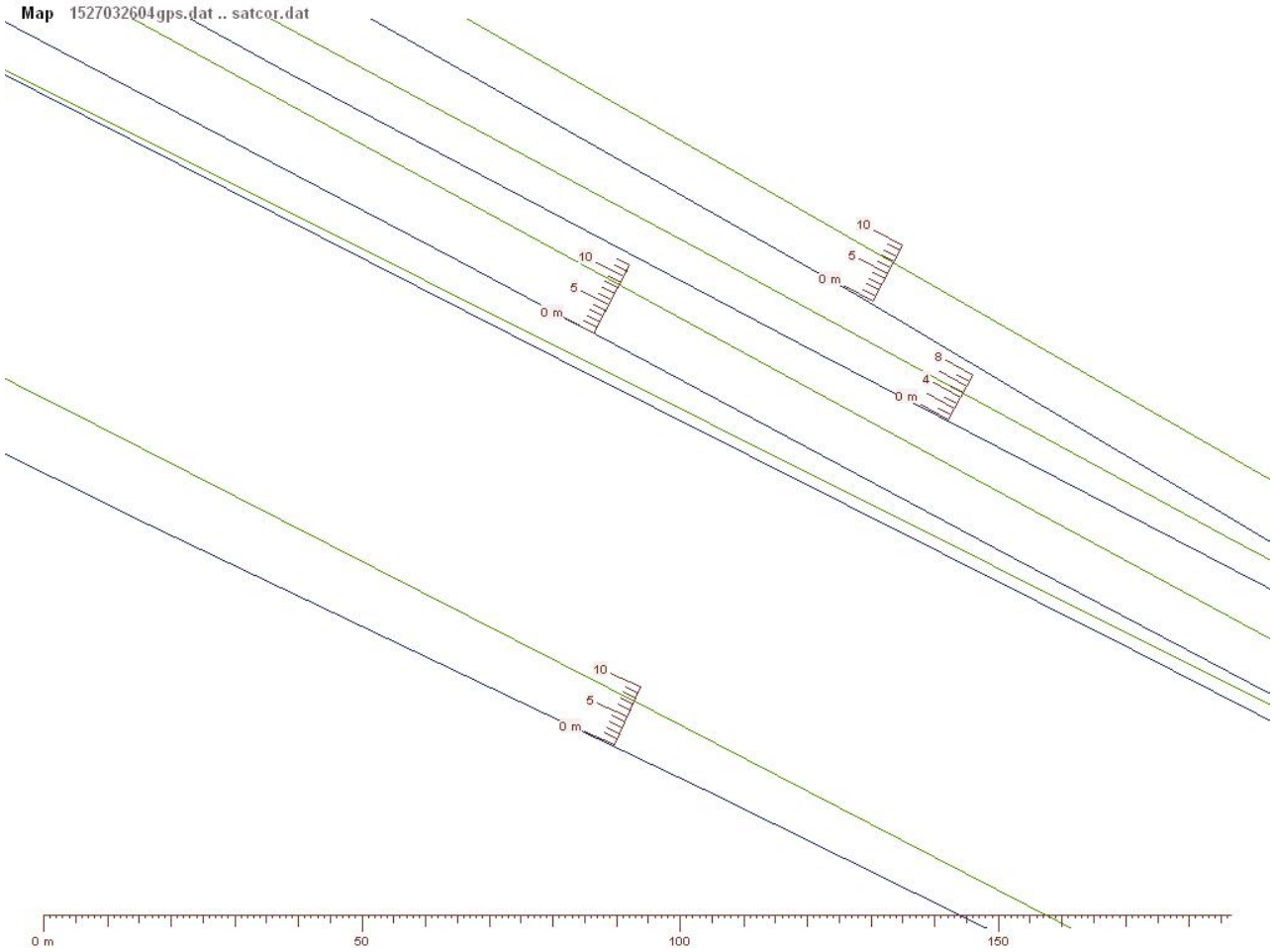
Jacksonville, Florida
Cross Track 15 -25 m

March 2004 Flights
ASFs from Same Day



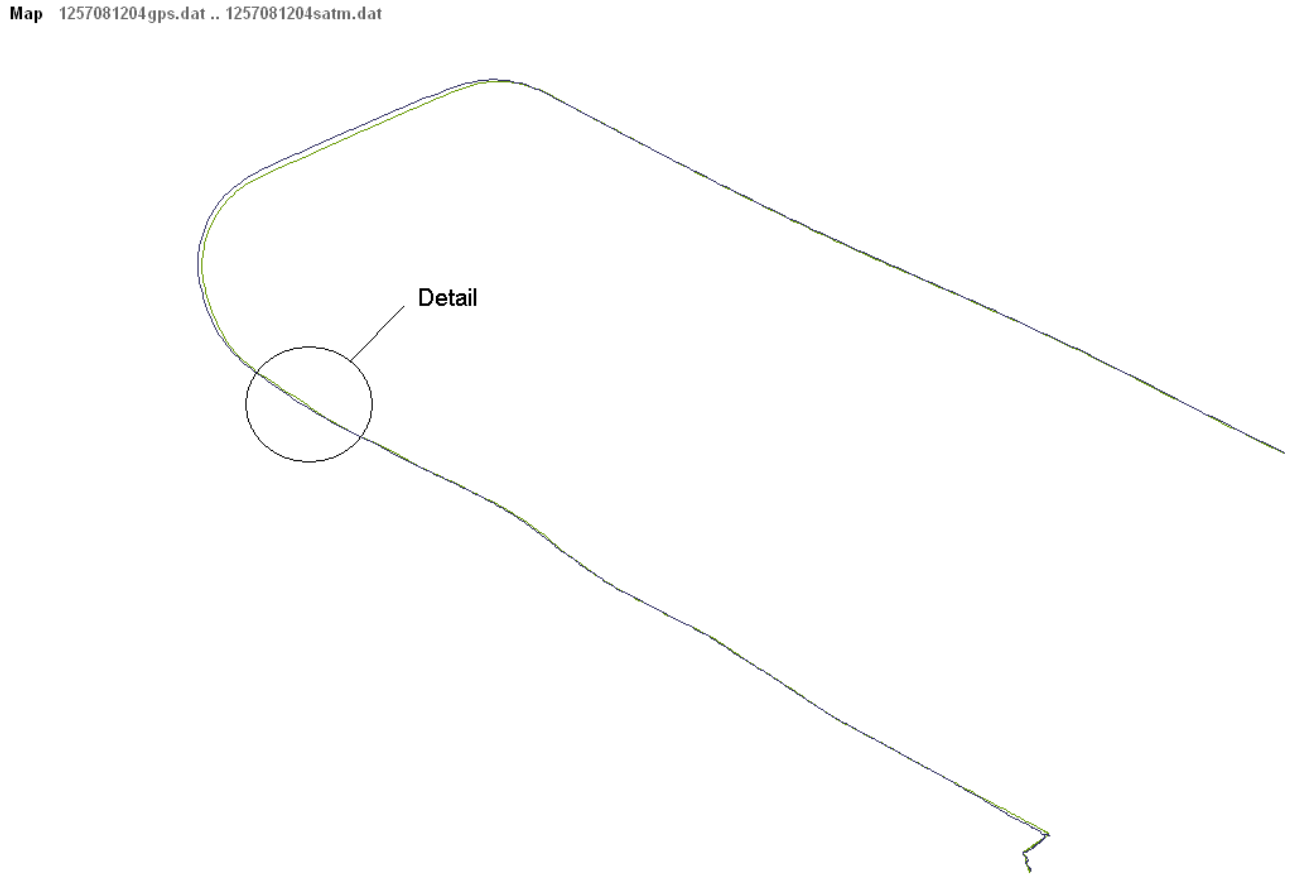
Atlantic City, New Jersey

March 2004 Flights
ASFs from Same Day

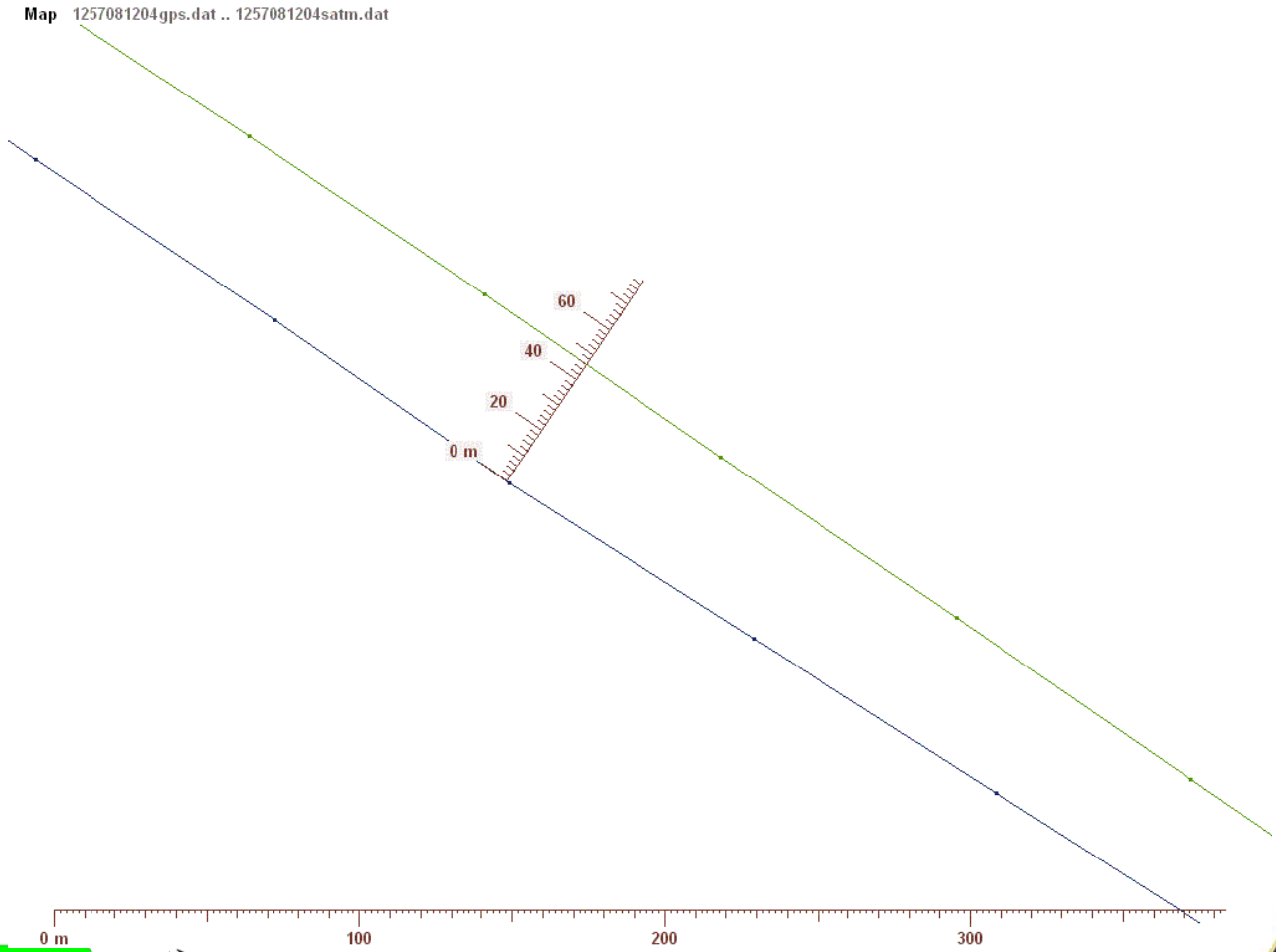


Atlantic City, New Jersey
Cross Track 1 - 9 m

August 2004 Flight
ASFs from March 26, 2004



August 2004 Flight
ASFs from March 26, 2004



Atlantic City, New Jersey
Cross Track < 50 m

Revising eLoran MOPS using existing RTCA documents

- RTCA DO-229C MOPS for GPS/WAAS used as model for eLoran MOPS
  - First draft completed in August, now undergoing review
- RTCA DO-228 MOPS for Loran antenna
  - First draft completed in April, now undergoing review
- Draft eLoran antenna and receiver MOPS revisions complete by November 30

Summary

- Locus/FreeFlight have been developing an integrated GPS/WAAS/eLoran prototype for FAA Loran evaluation program.
- The FreeFlight/Locus prototype includes tighter GPS/Loran integration and delivery is in November 2004.
- Ohio University's AEC expects to conduct flight trials on Locus/FreeFlight integrated system this year.
- Locus developed a portable ASF measurement system for FAA eLoran evaluation program that facilitates study of temporal and spatial properties of ASFs.
- Ohio University's AEC is conducting flight trials using Locus' ASF measurement system in CONUS.

Summary

- Numerous flight tests have demonstrated eLoran accuracy well within RNP 0.3 requirements over large area of CONUS:
  - with ASF corrections derived the same day
  - with ASF corrections several months old
- From these and other studies, it appears a single ASF set per airport will be sufficient to meet RNP 0.3 requirement year round for most airports.
- Program efforts represent initiation of a national ASF database that will assist development of appropriate eLoran aviation procedures.
- Draft eLoran antenna and receiver MOPS complete November 30
- US DOT has indicated it is planning to issue a long term Loran policy decision shortly.