

#### Loran Coverage Availability Simulation Tool



PETERSON INTEGRATED GEOPOSITIONING

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Royal Institute of Navigation NAV 08 International Loran Association 37<sup>th</sup> Technical Symposium October 27-30, 2008 Westminster, London, UK



Loran Coverage Availability Simulation Tool (LCAST)

- Purpose: Rapid analysis of Loran availability/coverage for the primary eLoran functions
- Incorporate primary models
  - Aviation & Maritime
  - Availability/Continuity of desired integrity or accuracy
- Model different assumptions



### Requirements

Performance Requirement	Aviation (NPA)	<b>Maritime (HEA)</b>
Accuracy (target)	307 meters	20 meters, 2 drms
Monitor Limit (HPL) (target)	556 meters	50 meters, 2 drms
Integrity	10 <sup>-7</sup> /hour	3 x 10 <sup>-5</sup> /hour
Time-to-Alert	10 seconds	10 seconds
Availability	99.9 to 99.99%	99.7%
Continuity	99.9 to 99.99%	99.85% over 3 hours

- LCAST determines the availability/continuity of a system that meets a fixed integrity protection level (PL) or accuracy requirement (i.e NPA, HEA)
  - Availability of the target PL/accuracy = availability of operation
- It can also determine the minimum integrity protection level or accuracy at a given availability



# Integrity & Protection Limit

- Integrity for the user means horizontal protection level (HPL) > horizontal position error (HPE)
  - HPL is a bound on the HPE
  - HPL > HAL for an operation to be available
- Hazard cause variations that contribute to HPE
- Models developed to bound the effects of hazard
  - Cycle confidence & Integrity equation





#### Calculating Horizontal Protection Limit (HPL)

Category	Hazard	Mitigation for Integrity	
Transmitter	Timing and Frequency Equipment Transmitter	Error Bound (HPL, random error) 1 Error Bound (HPL , random error) 1	
Propagation	Spatial variation of ASF along approach Temporal variation of ASF ECD SNR	Error Bound (HPL, Position Domain) Error Bound Model (HPL, Corr 2& Uncorr) Error Bound (Cycle) Measured & Error Model (HPL, Cycle)	
Receiver	Skywaves Cross-Rate Interference Receiver Calibration	Integrity Monitor & 9 <sup>th</sup> Pulse Receiver Processing Error Bound	

$$HPL = \kappa_{RNP} \sqrt{\sum_{i} K_{i} \alpha_{i}^{2}} + \left| \sum_{i} K_{i} \beta_{i} \right| + \sum_{i} |K_{i} \gamma_{i}| + PB$$

#### Accuracy: Pseudorange accuracy model

$$\sigma_i^2 = c_1 + \frac{337^2}{N_{pulses} \cdot SNR} + c_2 \cdot r_{bs}^2 + c_3 \cdot dr_{tr}^2$$

- $c_1 = \Sigma$  constants independent of position (transmitter jitter, base station noise, grid accuracy, etc.) Assumed uncorrelated from transmitter to transmitter.
- r<sub>bs</sub> = Range from user to base station, Error assumed uncorrelated from transmitter to transmitter.
- dr<sub>tr</sub> = Difference in range between transmitter & user and transmitter and base station. Error assumed correlated from transmitter to ` transmitter. Seasonal ASF term that will vary by region
- LCAST calculates limit on achievable accuracy assuming base station & user colocated
  - Last two terms are zero





# Availability and Noise



- Availability is determined by noise
- Usable stations determined by SNR
- Signal strength reasonably constant at a given location M
- Noise at different percentile given by ITU Model
  - six 4-hour time blocks, for each season

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# Models & Algorithms: Variations

- Basic Set up
  - Station configuration, range limits
  - Assumptions on noise processing, noise level
  - Assumptions on requirements
- Cycle Confidence
  - Algorithm
  - Stations used
- Integrity Equation/Accuracy
  - Worst case combinations
  - Integrity allocations

# ALMAN P

#### Calculating Availability: Basic Flow





# **Basic Calculation of Continuity**

- Continuity is probability an operation can be completed once started
  - Prob. of availability throughout operation given initially available
- Basic calculation
  - Availability in all possible user states
  - Expected continuity is availability of states weighted by probability of states
- eLoran operations max 1 station unavailable in region





# **Scenarios**

- 2004 Report
  - NPA Availability of Integrity
  - NPA Continuity
  - HEA Accuracy
- HEA Accuracy with additional stations
- Enroute Availability
- NPA Performance with model changes/ improvements
  - Noise processing, ASF



#### Average NPA Availability





#### Worst Case NPA Availability





### NPA Continuity











# HEA Accuracy at 95% Availability with 5 kW Tx at Miami, San Diego

Accuracy (Year Ave) at 95th per, SNR thres -12 dB, clip cred 12





#### **Enroute Performance**

Cycle Avail w HPL (worst time) scalar ASF 1000 m, ECDbias 1 µsec, SNR thres -24 dB, clip cred 12 dB, Praim 7e-008, Pfa 0.





#### New Noise Clipping, Weather ASF Model





# Thoughts

- LCAST enabled the analysis of FAA Loran Technical Evaluation in 2004
  - Assessed HEA and NPA performance
- Assess various configurations and assumptions in the Loran system
  - Suggest/Validate algorithm improvements
  - Suggest operational or system changes
  - Sensitivity
- LCAST is an integral part of tool set for eLoran evaluation



## Acknowledgements

- Federal Aviation Administration

   Mitch Narins Program Manager
- The views expressed herein are those of the presenter and are not to be construed as official or reflecting the views of the U.S. Coast Guard, Federal Aviation Administration, or Department of Transportation.