The eLoran Evaluation and Modernization Program

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Overview

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Federal Aviation Administration
Navigation Services

International CGSIC Meeting
Geneva, Switzerland
28 May 2007
Loran Evaluation Program Logo Collection
It’s a big world …
and Loran serves ½ of it!

International CGSIC Meeting
28 May 2007 – Geneva, Switzerland
Loran-C in the NAS -- 2001

TTX Stations: 11 US, 1 Canadian
SSX Stations: 13 US, 4 Canadian
LSU
Control Stations

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US Loran-C Policy -- 2001

“While the Administration continues to evaluate the long-term need for continuation of the Loran-C radionavigation system, the Government will operate the Loran-C system in the short term. The U.S. Government will give users reasonable notice if it concludes that Loran-C is not needed or is not cost effective, so that users will have the opportunity to transition to alternative navigation aids. With this continued sustainment of the Loran-C service, users will be able to realize additional benefits. Improvement of GPS time synchronization of the Loran-C chains and the use of digital receivers may support improved accuracy and coverage of the service. Loran-C will continue to provide a supplemental means of navigation. Current Loran-C receivers do not support non precision instrument approach operations.”

– Para 3.2.5 B 1999 US Federal Radionavigation Plan
Background

• The Global Positioning System (GPS) is a major national and international asset with expanding and evolving uses in precision timing and in positioning-navigation services.

• “There is a growing awareness within the transportation community that the safety and economic risks associated with loss or degradation of the GPS signal have been underestimated … Public policy must ensure that safety [and economic viability] are maintained in the event of loss of GPS.”*

*“Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System,” Volpe Center, August 29, 2001 – Released September 10, 2001!
GPS Vulnerability

- GPS is vulnerable to unintentional and intentional disruptions covering small to extensive areas, for durations from minutes to days

- Illustrations:
  - 1-5 watt intermittent jammers (confound detection) capable of disrupting the GPS signal are available today to place in harbor and shore areas
  - “Jamfest” testing in White Sands, NM (2005) recorded cell phone disruption within 20-25 min of jamming onset
  - San Diego disruption (Jan 07)

- US public policy already requires that backup systems or procedures be available to mitigate GPS disruptions in critical applications (National Security Presidential Directive 39 Fact Sheet, December 15, 2004)
# Loran-C vs. eLoran Metrics

FAA 2002 “Murder Board” Requirements

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Availability</th>
<th>Integrity</th>
<th>Continuity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loran-C Definition of Capability* (US FRP)</td>
<td>0.25 nm (463 m)</td>
<td>0.997</td>
<td>10 second alarm/25 m error</td>
<td>0.997</td>
</tr>
<tr>
<td>FAA NPA (RNP 0.3)** Requirements</td>
<td>0.16 nm (307 m)</td>
<td>0.999 – 0.9999</td>
<td>0.99999999 (1 x 10^-7)</td>
<td>0.999 - 0.9999 over 150 sec</td>
</tr>
<tr>
<td>US Coast Guard HEA Requirements</td>
<td>0.004 - 0.01 nm (8 – 20 m)</td>
<td>0.997 - 0.999</td>
<td>10 second alarm/25 m error (3 x 10^-5)</td>
<td>0.9985 – 0.9997 over 3 hours</td>
</tr>
</tbody>
</table>

* Includes Stratum 1 timing and frequency capability

** Non-Precision Approach Required Navigation Performance
2004 – The Report is Delivered!

- Congress provides the FAA with:
  - $ 25.0M in 2004

- The Loran Evaluation Report is delivered to DOT on 31 March – as promised!
The Loran Evaluation Team’s Conclusion

“The evaluation shows that the modernized Loran system could satisfy the current NPA, HEA, and timing/frequency requirements in the United States and could be used to mitigate the operational effects of a disruption in GPS services, thereby allowing the users to retain the benefits they derive from their use of GPS.”

Report is available at: https://ksn.faa.gov/km/navservices/navserviceslt/tech/Loran_Eval_Report/default.aspx
...so where are we today?

Cumulative Expenditures
FY 97 - FY 06

Dollars (millions)

Fiscal Year

Federal Aviation Administration

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North American Loran System - 2001

TTX Stations: 11 US, 1 Canadian
SSX Stations: 13 US, 4 Canadian
LSU Control Stations

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North American Loran System - 2006

New SSX Stations: 6 US
TTX Stations: 5 US, 1 Canadian
SSX Stations w/New TFE: 13 US
SSX Stations: 0 US, 4 Canadian
LSU New Control Stations

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<table>
<thead>
<tr>
<th>Status Today</th>
<th>Loran-C</th>
<th>Modernized Loran</th>
<th>eLoran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EnRoute (RNP 2.0 -&gt;1.0)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Terminal (RNP 0.3)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>NPA (RNP 0.3)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Maritime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Coastal</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Confluence Zone</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>HEA</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Time/Freq</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratum 1 Frequency (1x10^-11)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time of Day/Leap Second/ UTC Reference</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Precise Time [&lt;50 ns UTC(USNO)]</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
It’s about time: The eLoran Clock

• All Loran Stations (US and Canadian) and the Loran Support Unit have three new cesium clocks – 90* very high stability clocks geographically dispersed across North America

• All 90 clocks can be steered to UTC (USNO) (independently from GPS) with great accuracy

• The establishment of a robust Loran clock akin to, but totally independent from the GPS clock is a valuable asset

*(29 Loran Stations + LSU) x 3
Findings - Precision Timing

• “GPS serves as a precision timing source for 100,000,000 cell phone customers in North America and 250,000,000 worldwide.”
  B. Greene, VP, Lucent, brief to DOC GPS Forum, Jan. 2006

• “Under no circumstances should the Government place total reliance on GPS and completely abandon its plans to continue to deploy eLoran.”
  • Sprint Nextel Corp., comments in Federal Register, Feb. 2007

• “The proposal to develop an eLoran system would effectively address the need for a nationwide, distributed backup system. It is not clear that any widely reliable backup system exists now.”
  M. Lombardi, NIST, DHS briefing, July 27, 2006
NIST Report on Time Backups for GPS

• “We have reviewed all of the available broadcast signals that anchor the time and frequency infrastructure in the United States.”

• “We conclude that eLoran is the best available backup provider to GPS as a reference source for precise time synchronization and frequency control.”
North American Loran Time Coverage

90 cesium clocks geographically dispersed across North America
Potential* eLoran Time Capabilities

One sigma timing accuracy in ns w/o differential corrections

*analysis ongoing
Potential* eLoran Time Capabilities

One sigma timing accuracy in ns for differential corrections from existing monitors plus USNO & NIST

*analysis ongoing
Federal Register Notice Responses

• Over 950 public comments
  – Only 8% suggested termination; The 92% favoring continuation of Loran were roughly equally split between “eLoran” or “Loran-C”
  – Note: Care is required in interpreting the responses

• Independent statistical analyses by OST & USCG are ongoing, but there is no doubt on where the public stands in regards to keeping the Loran signal on the air!

• The U.S. should “commit to Loran in the interest of a seamless international PNT service.”
  – RTCM, Federal Register response, February 2007
Loran from an International Perspective

• Draft European RNP currently under review
  – eLoran a key element of ERNP for GNSS backup

... LORAN-C/Eurofix delivers 22% of the policy benefits for only 4% of the annual total operational cost (8.5MEURO) ...

... LORAN-C is the only real stand-alone alternative to satellite radio-navigation services for many market sectors (including maritime, land and timing). Its dissimilar use of spectrum mitigates many of the vulnerabilities associated with satellite radio-navigation L-band interference and provides robust coverage in areas of limited GNSS availability (e.g. urban). It is also provides through Eurofix a DGNSS data delivery mechanism for Europe ...
DHL European Trials – “e-Tracker”

- Dual (GNSS and Loran) Receivers
- Dual Antennas
  - GNSS and Loran H-Field
- GSM-module for telecom
- Battery powered (monitored)
  - 2 year-life set at 1 position/hour
- Dimensions:
  - 19 x 19 x 19 cm (~7.5-inch cube)
- Weight:
  - ~3 Kg (~6.5 lbs)
Positioning Sources During DHL Trials

Based on 4000 position calculations:

- Loran: 65%
- GNSS: 26%
- GSM: 9%

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The Case for eLORAN

Research and Radionavigation
General Lighthouse Authorities of the United Kingdom and Ireland
9th May 2006
Loran from an International Perspective

“It’s not your parent’s/grandparent’s Loran!”
GPS/WAAS/eLoran Receivers for Aviation

Phase I

Phase II

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Example Aviation Tests: Rockwell/ Locus
Integration of GPS-IMU-Loran

- AHC-3000A AHRS modified to add IMU outputs
GPS/WAAS/eLoran Receivers for Maritime
Summary

• eLoran Decision “in process”
• Briefings continuing at Deputy Secretary Level
• Modernization efforts are continuing
  – St. Paul, Alaska Loran Station to be modernized this summer
  – Airport and Harbor surveys ongoing to support NPA/HEA operations
  – GPS-Independent UTC Synchronization work ongoing
  – Navigation and Time receiver development continuing
• Awaiting announcement by Sec DOT and Sec DHS this year.
Questions
Improvements Needed to Achieve eLoran Capability

• Aviation - NPA
  – Implementation of Loran Data Channel (LDC) via 9th-pulse communications to broadcast:
    • Station ID
    • Integrity Message
    • Early Skywave warning
  – Improved monitor system to detect skywave and out of tolerance condition
  – Time of Transmission (TOT) Control
  – ASF value(s) for each airport
  – Certified avionics (eLoran/multimode) to allow use of existing RNP 0.3 approach and landing procedures
Improvements Needed to Achieve eLoran Capability

- **Maritime - HEA**
  - Implementation of Loran Data Channel (LDC) via 9th-pulse communications to broadcast:
    - Station ID
    - Integrity Message
    - Differential Loran Information
  - Improved and expanded monitor system to provide real-time differential corrections to support 8m-20m accuracy requirement
  - Time of Transmission (TOT) Control
  - Harbor surveys to establish ASF grid
  - Maritime receivers (eLoran/multimode) to provide required accuracy
Improvements Needed to Achieve eLoran Capability

• Time
  – Implementation of Loran Data Channel (LDC) via 9th-pulse communications to broadcast:
    • Differential Loran Information
  – Improved and expanded monitor system to support precise time (<50ns)
  – Time of Transmission (TOT) Control
  – Time receivers to provide required accuracy
Timing accuracy model – Description & Comments

• **Non-differential (slide 2)**
  – Accuracy is rss sum of:
    • 30 ns for combination of receiver bias & transmitter accuracy
    • A noise term with noise at the 95% level, 10dB credit for clipping and 20 second averaging
    • A term based on map of seasonal variations in propagation
      – Because seasonal variations dominate in the rss sum, and western US has smaller seasonal variations, model shows better accuracy in west

• **Differential**
  – Differential Accuracy is rss sum of:
    • 30 ns for combination of receiver bias & base station error
    • Same noise term as above
    • A term proportional to distance from closest base station (currently 0.5 ns/nm)

• **Overall accuracy (in slide 3) is the minimum of the two accuracies above**
  – Slide 4 shows which is minimum, except for NE US, differential corrections do not help **timing** users, because **navigation** (HEA) users need to use much more distant stations, they still need differential corrections in the west

• **Current model suggest need for either station or monitor in Iowa/Nebraska**
  – Previous studies had suggested transmitter in this area would considerably enhance RNP availability.