The eLoran Evaluation and Modernization Program

Overview

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Federal Aviation Administration
Navigation Services

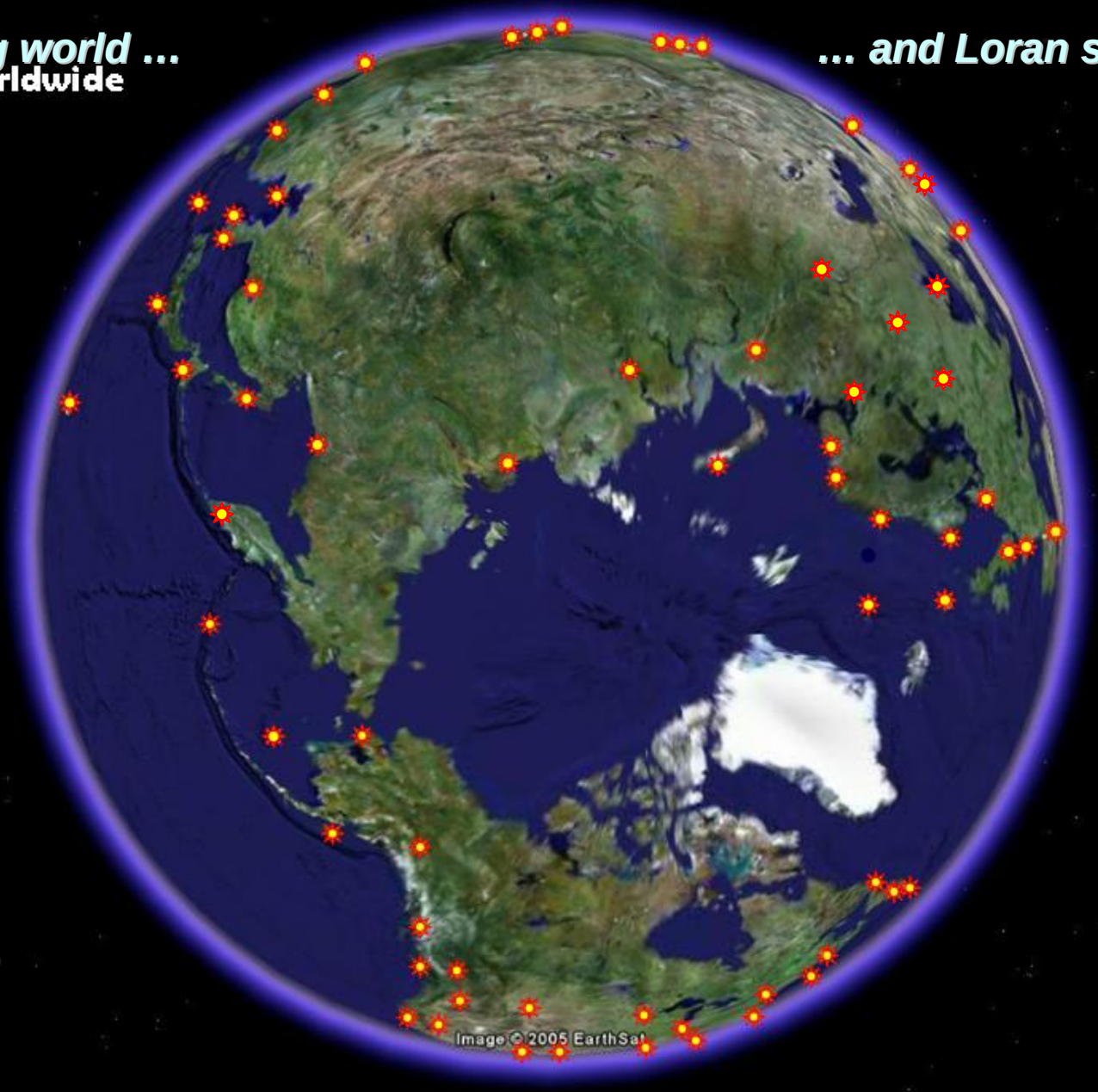
International CGSIC Meeting
Geneva, Switzerland
28 May 2007

Federal Aviation Administration

Loran Evaluation Program Logo Collection

It's a big world …
ran Worldwide

… and Loran serves ½ of it!



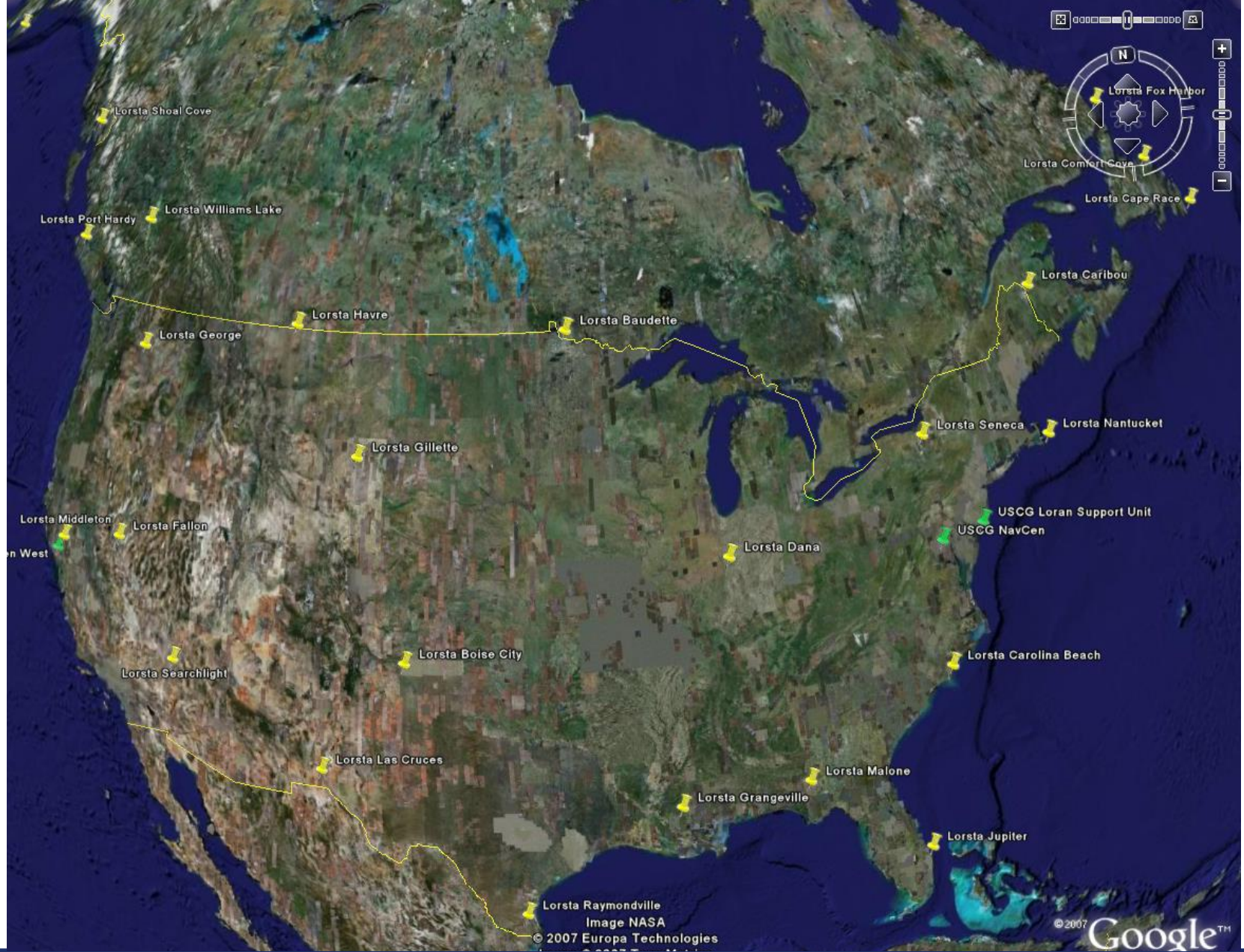

Lorsta Shoal Cove
Lorsta Fox Harbor
Lorsta Comfort Cove
Lorsta Cape Race
Lorsta Port Hardy
Lorsta Williams Lake
Lorsta Caribou
Lorsta Havre
Lorsta Baudette
Lorsta George
Lorsta Seneca
Lorsta Nantucket
Lorsta Gillette
Lorsta Middleton
Lorsta Fallon
USCG Loran Support Unit
USCG NavCen
Lorsta Dana
Lorsta Boise City
Lorsta Carolina Beach
Lorsta Searchlight
Lorsta Las Cruces
Lorsta Malone
Lorsta Grangeville
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Image NASA
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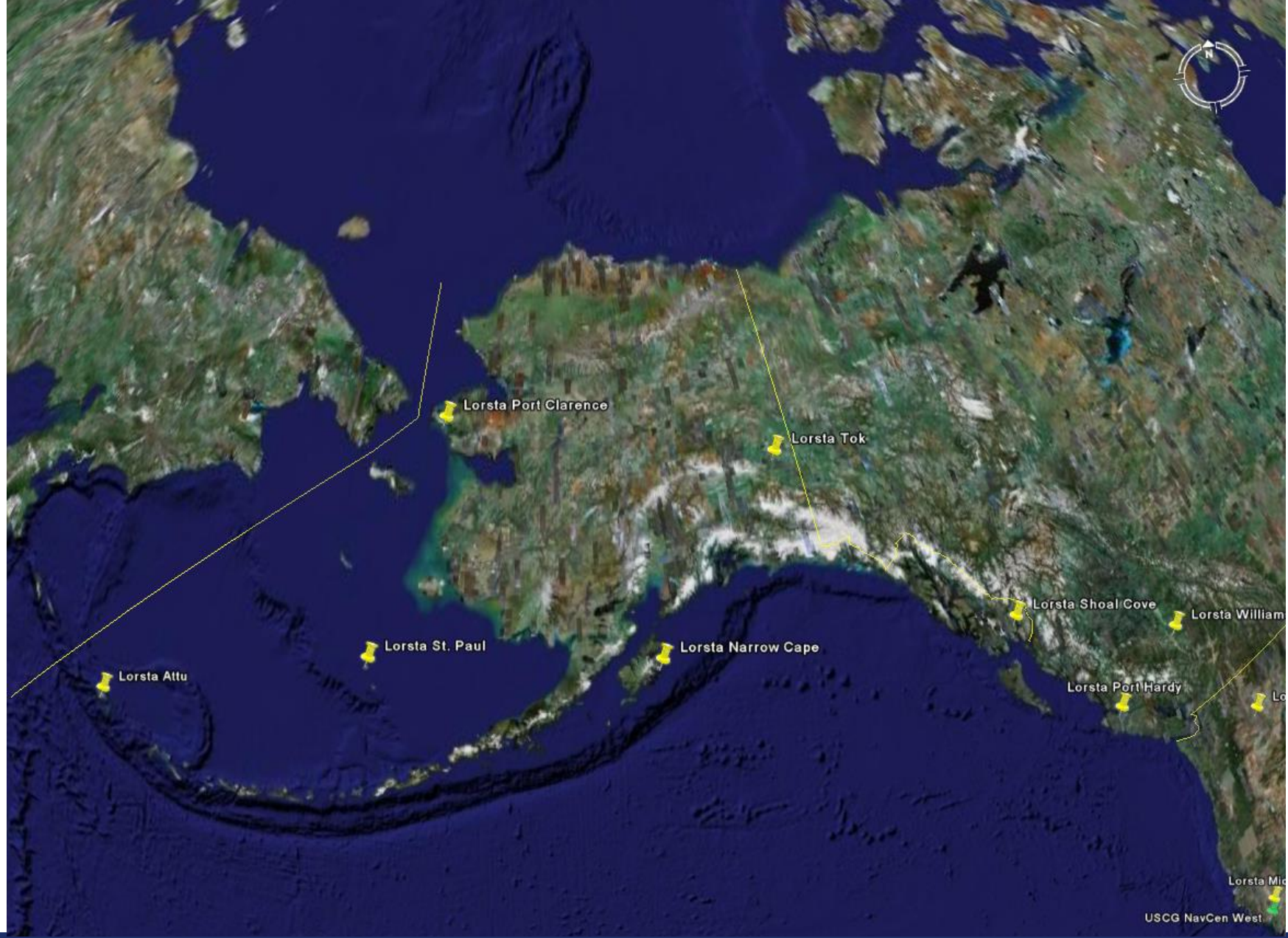
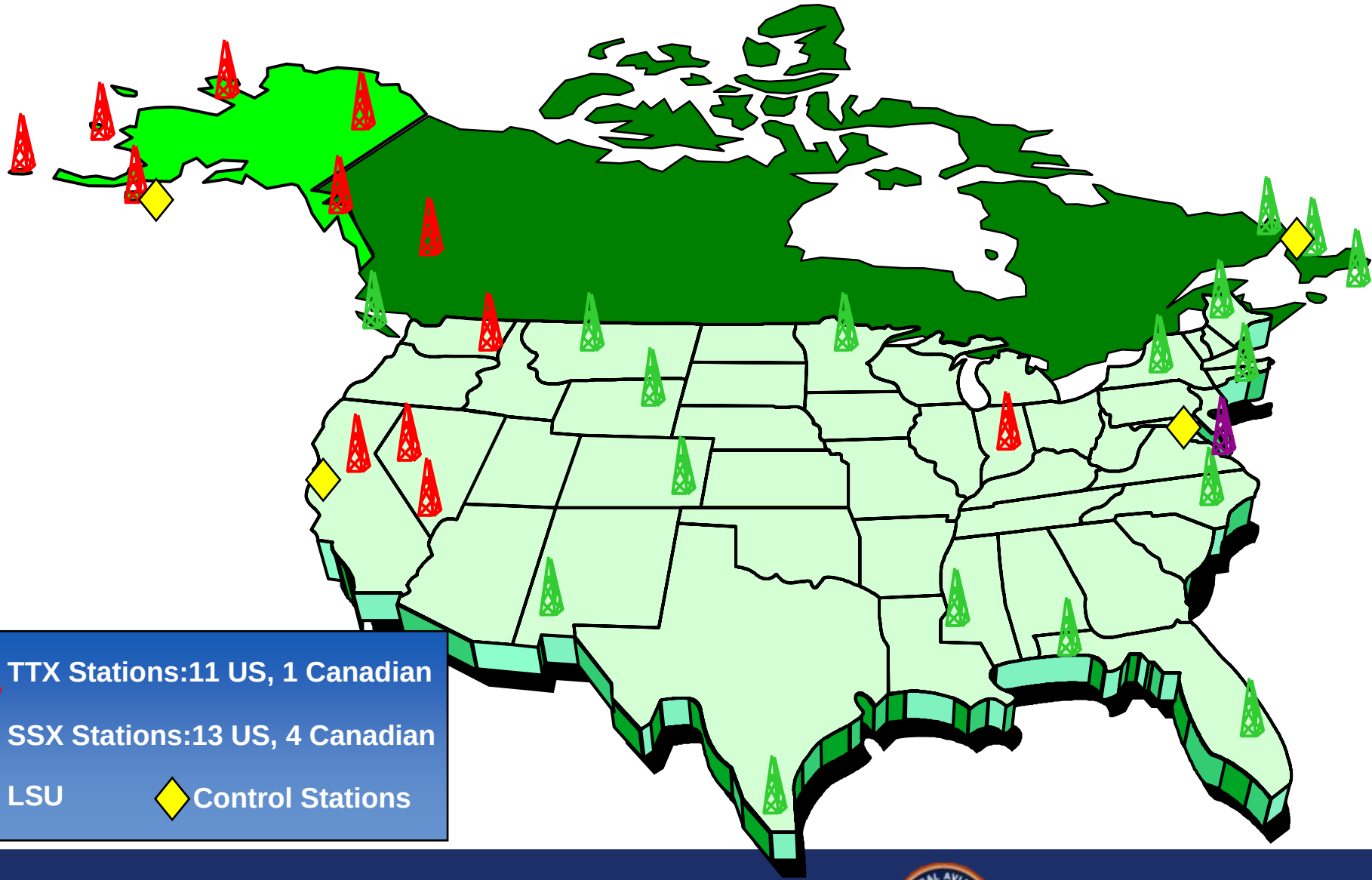

Lorsta Port Clarence
Lorsta Tok
Lorsta Shoal Cove
Lorsta William
Lorsta St. Paul
Lorsta Narrow Cape
Lorsta Attu
Lorsta Port Hardy
USCG NavCen West

Loran-C in the NAS -- 2001



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

	Accuracy	Availability	Integrity	Continuity
Loran-C Definition of Capability* (US FRP)	**0.25 nm (463 m)**	0.997	10 second alarm/ 25 m error	0.997
FAA NPA (RNP 0.3) Requirements**	**0.16 nm (307 m)**	**0.999 – 0.9999**	**0.9999999 (1 x 10-7)**	**0.999 - 0.9999 over 150 sec**
US Coast Guard HEA Requirements	**0.004 - 0.01 nm (8 – 20 m)**	**0.997 - 0.999**	10 second alarm/ 25 m error (3×10^{-5})	0.9985 – 0.9997 over 3 hours

* Includes Stratum 1 timing and frequency capability

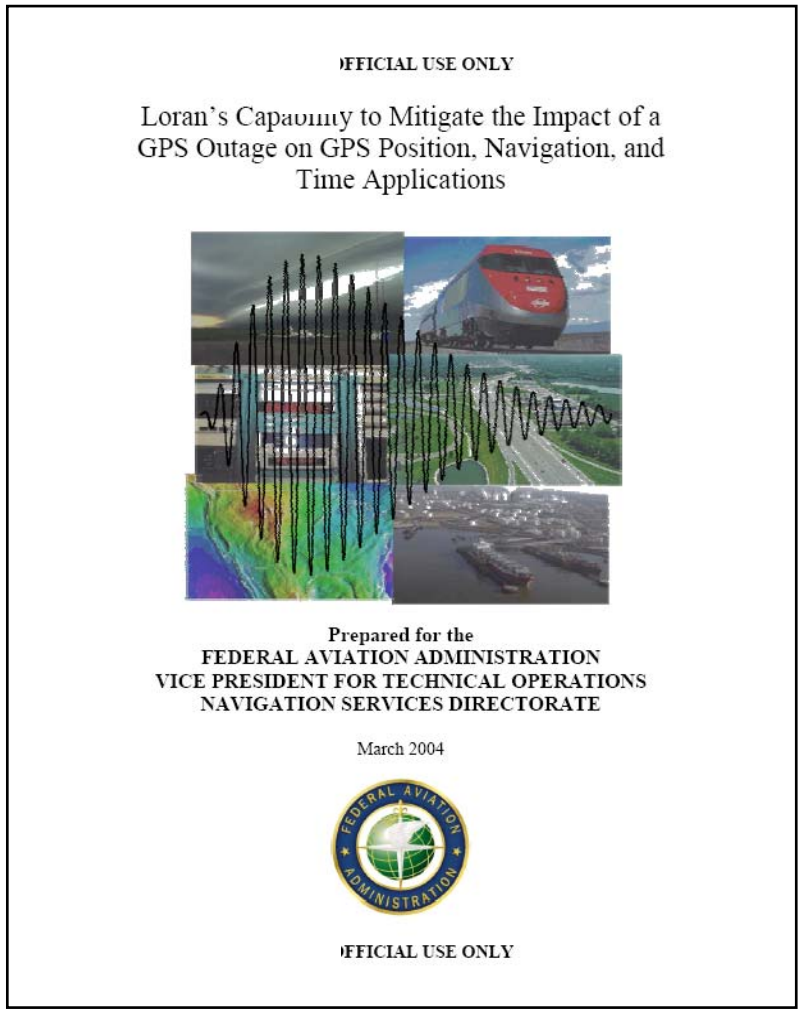
** Non-Precision Approach Required Navigation Performance

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."



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Loran's Capability to Mitigate the Impact of a GPS Outage on GPS Position, Navigation, and Time Applications

Prepared for the
FEDERAL AVIATION ADMINISTRATION
VICE PRESIDENT FOR TECHNICAL OPERATIONS
NAVIGATION SERVICES DIRECTORATE

March 2004

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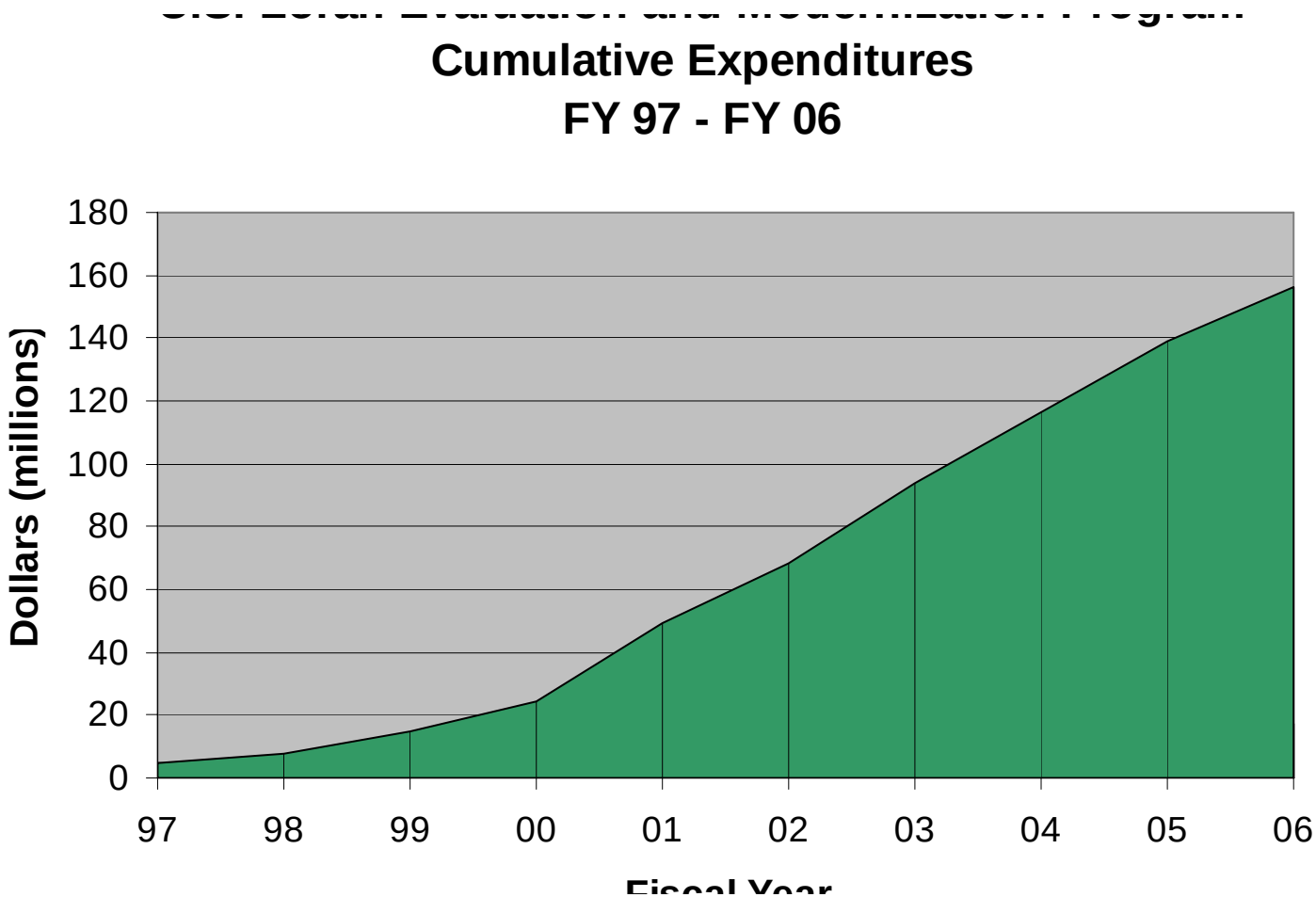
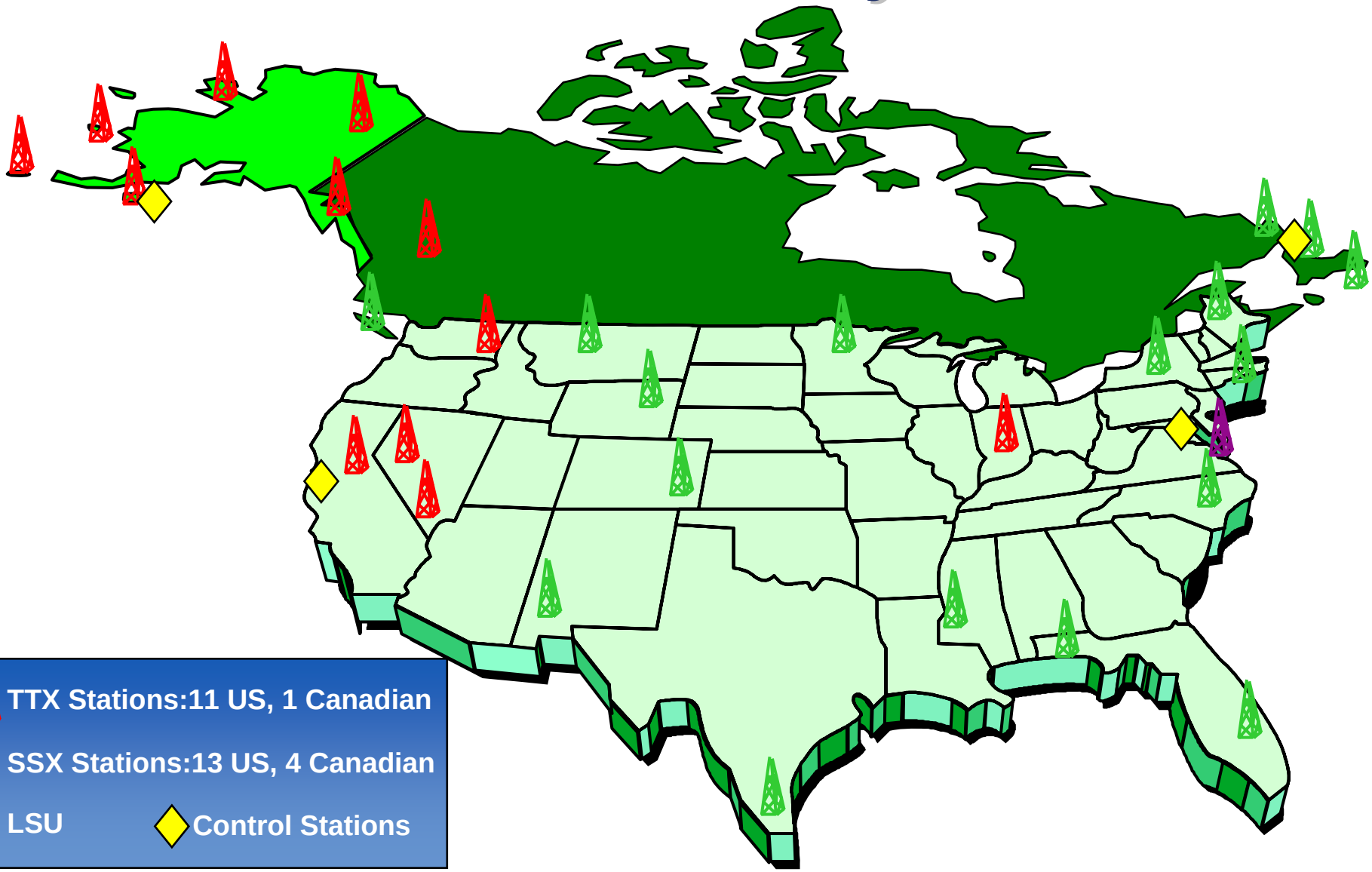
Report is available at:
https://ksn.faa.gov/km/navservices/navserviceslt/tech/Loran_Eval_Report/default.aspx

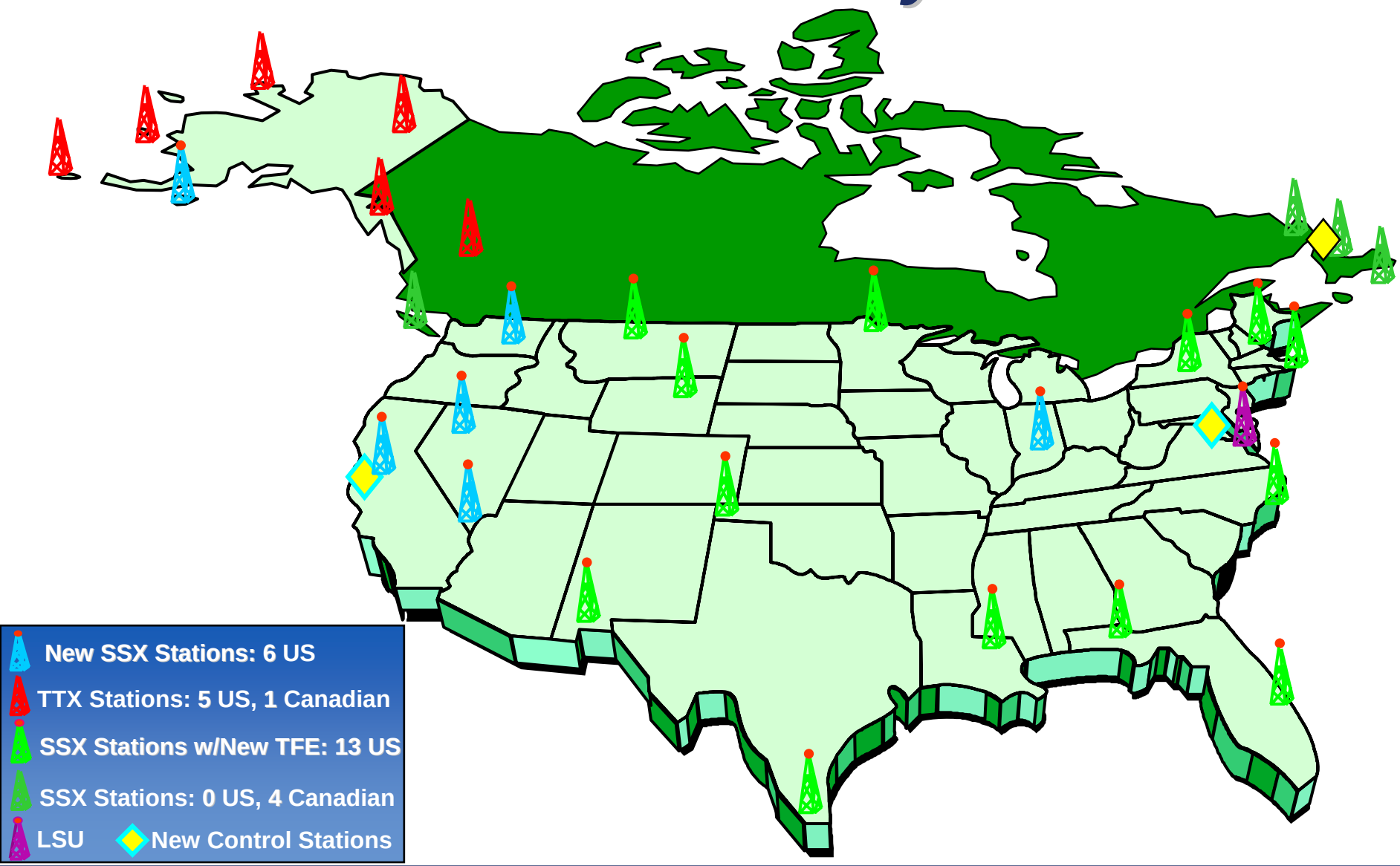
…so where are we today?



North American Loran System - 2001



North American Loran System - 2006



Status Today	Loran-C	Modernized Loran	eLoran
Aviation			
EnRoute (RNP 2.0 ->1.0)	Yes	Yes	Yes
Terminal (RNP 0.3)	No	No	Yes
NPA (RNP 0.3)	No	No	Yes
Maritime			
Ocean	Yes	Yes	Yes
Coastal Confluence Zone	Yes	Yes	Yes
HEA	No	No	Yes
Time/Freq			
Stratum 1 Frequency ($1x10^{-11}$)	Yes	Yes	Yes
Time of Day/Leap Second/ UTC Reference	No	Yes	Yes
Precise Time [<50 ns UTC(USNO)]	No	No	Yes

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**

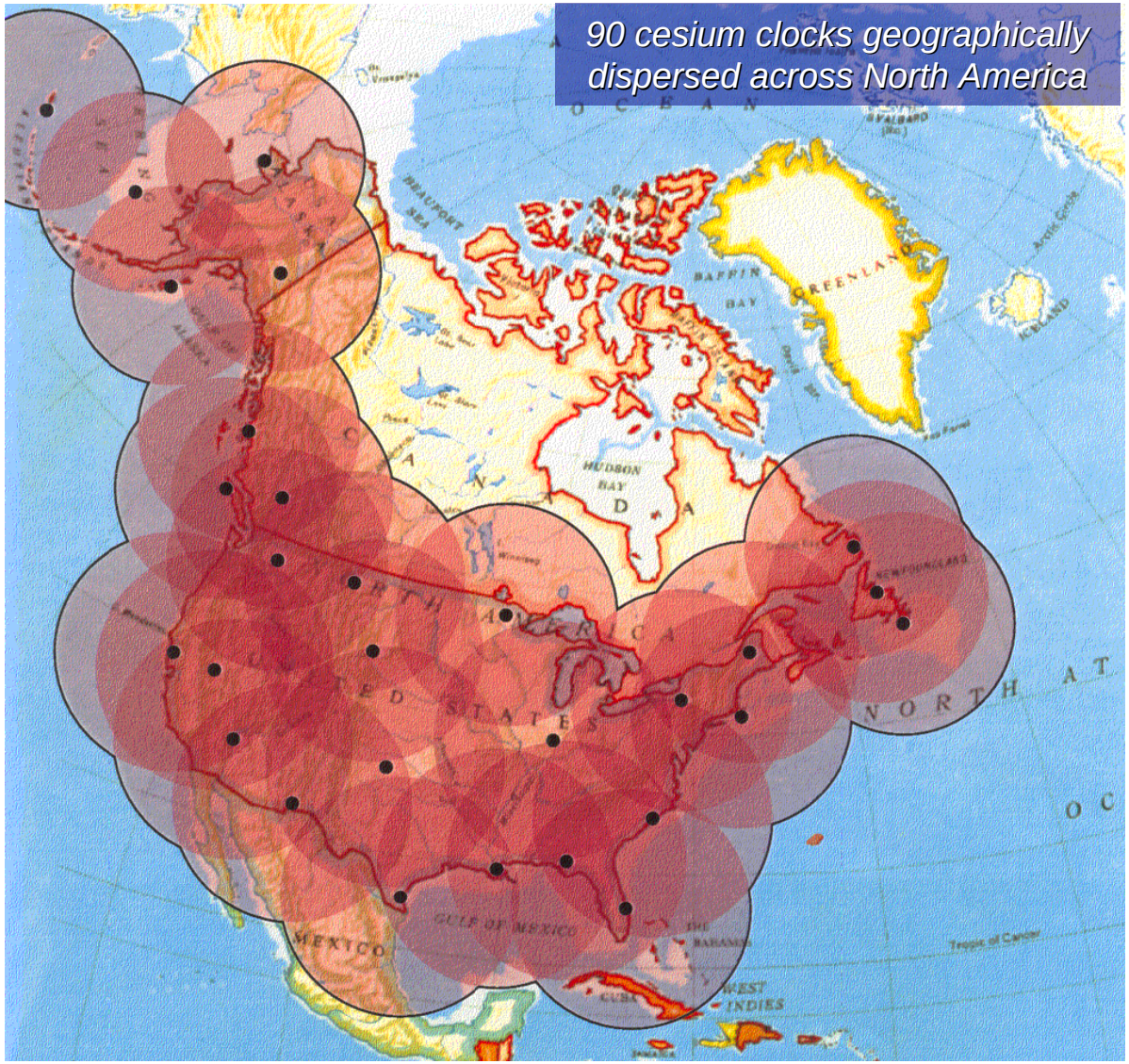
- ***"The proposal to develop an eLoran system would effectively address the need for a nationwide, distributed backup system. It is not clear that any widely reliable backup system exists now."***

  M. Lombardi, NIST, DHS briefing, July 27, 2006

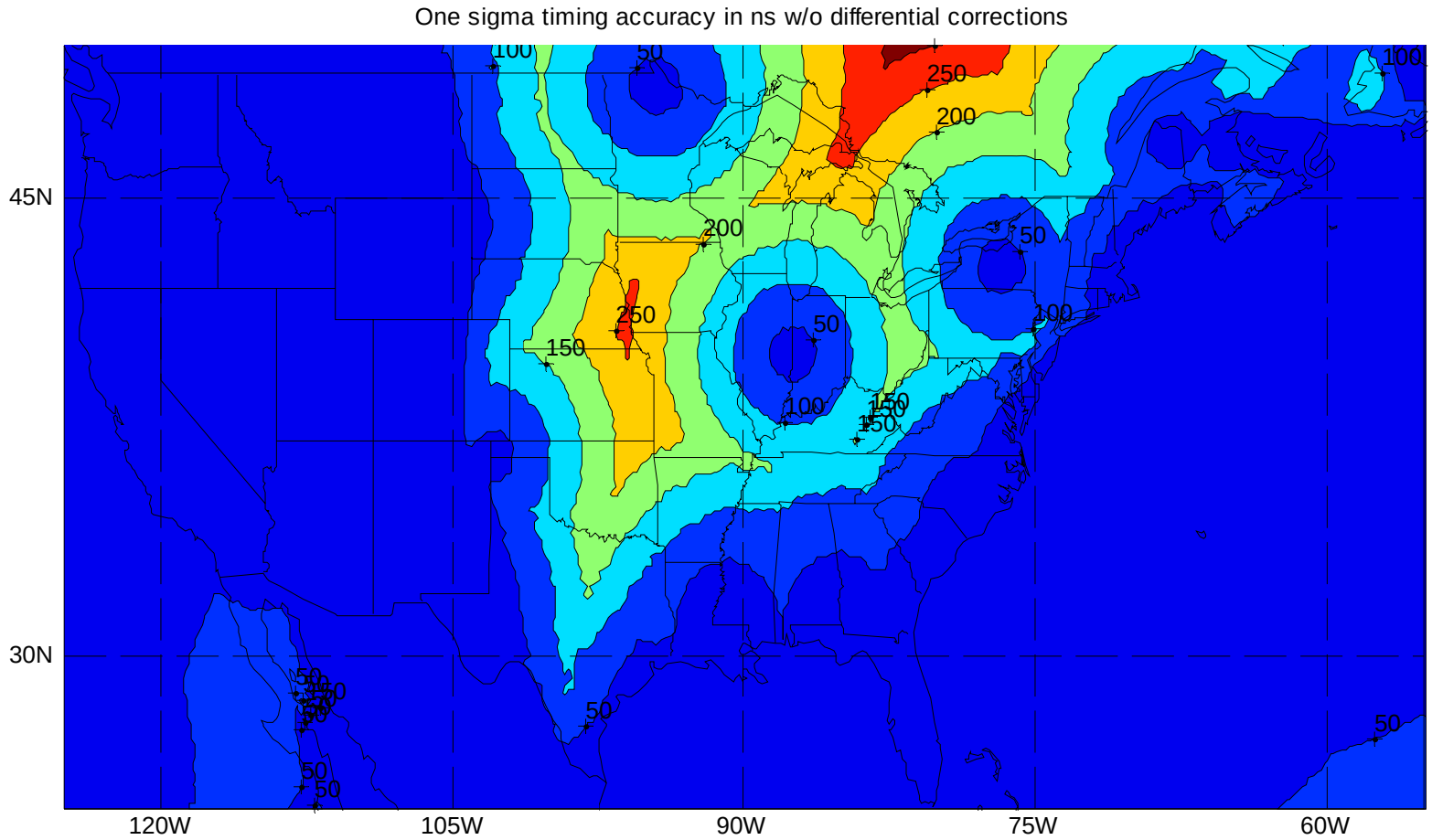
NIST Report on Time Backups for GPS

- **"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



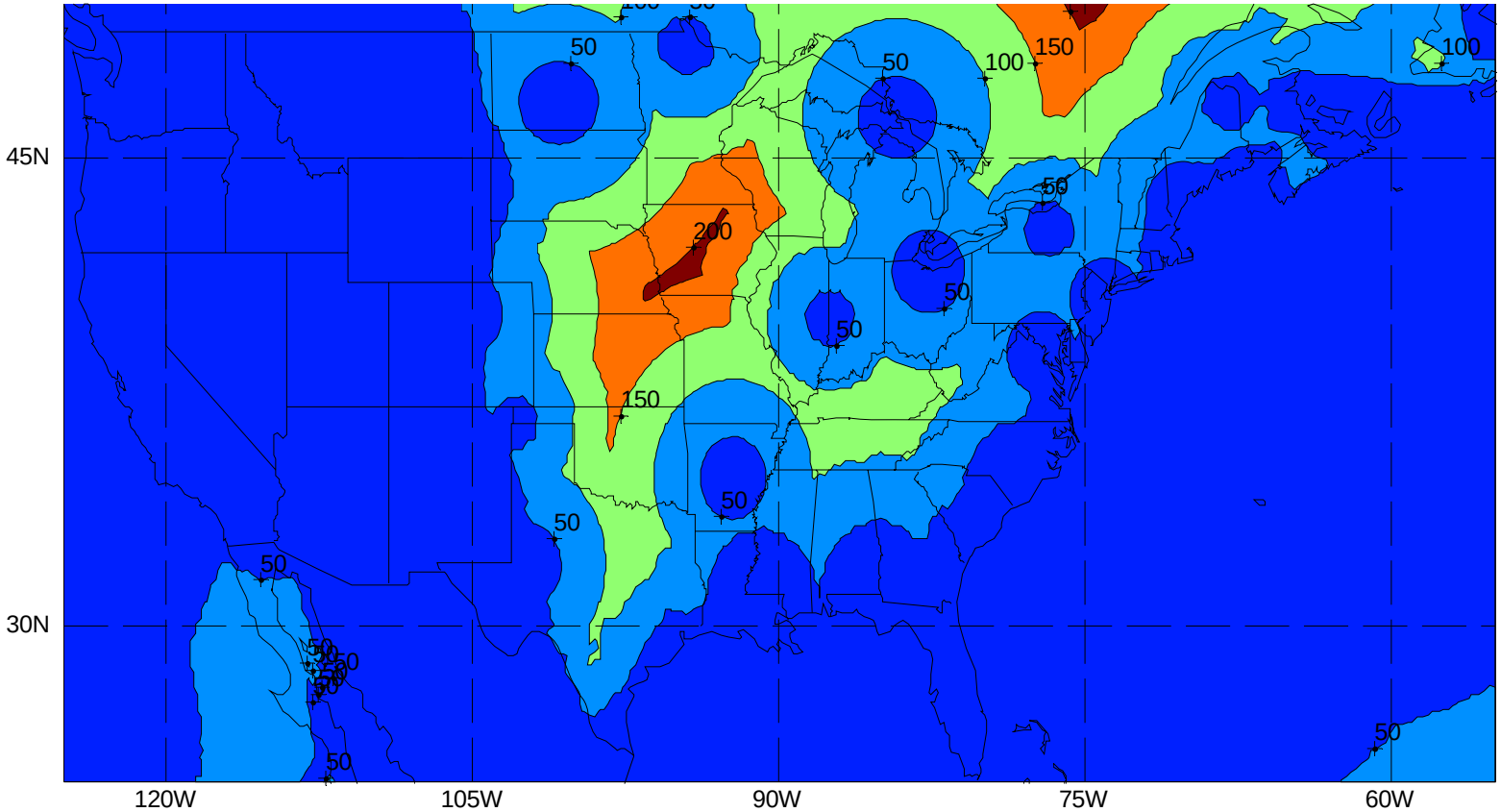
Potential* eLoran Time Capabilities



***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

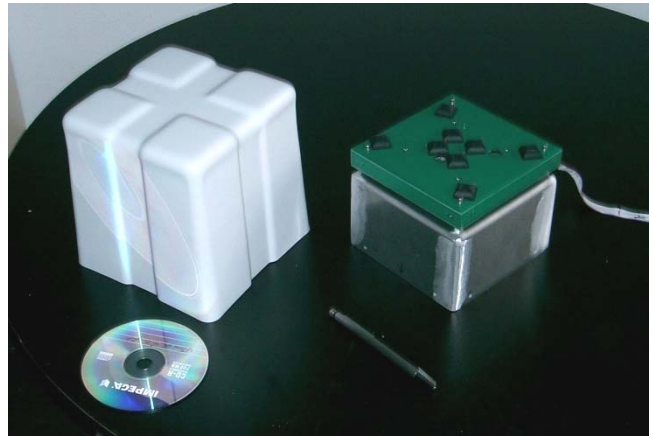
- **Draft European RNP currently under review**
  - *eLoran* a key element of ERNP for GNSS backup

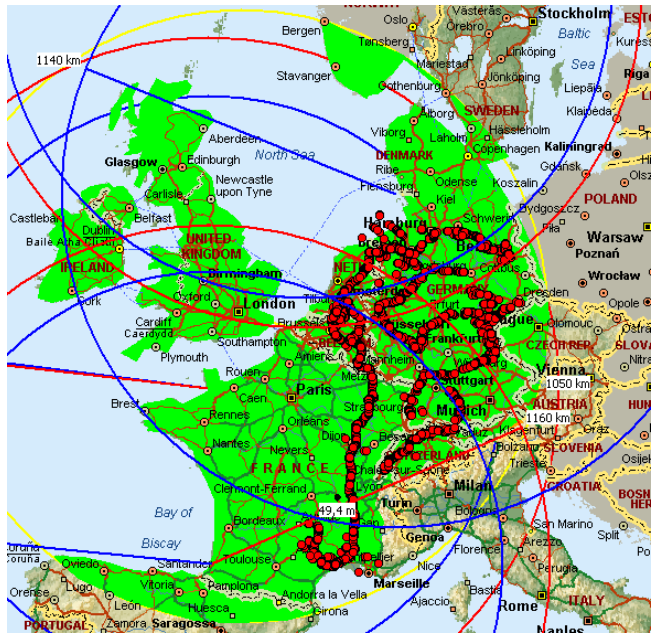
… LORAN-C/Eurofix delivers 22% of the policy benefits for only 4% of the annual total operational cost (8.5MEURO) …

… 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”

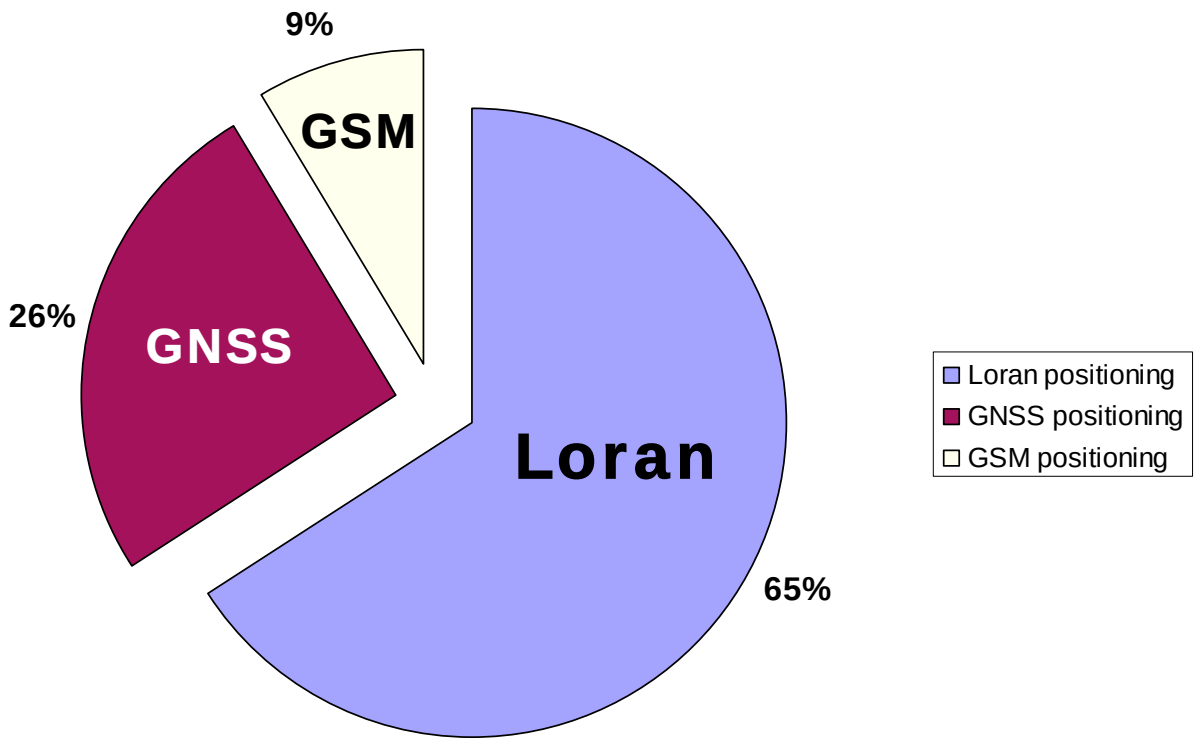
- **Dual (GNSS and Loran) Receivers**
- **Dual Antennas**
  - GNSS and Loran H-Field
- **GSM-module for telecom**
- **Battery powered (monitored)**
  - 2 year-life set at 1 position/hour
- **Dimensions:**
  - 19 x 19 x 19 cm (~7.5-inch cube)
- **Weight:**
  - ~3 Kg (~6.5 lbs)



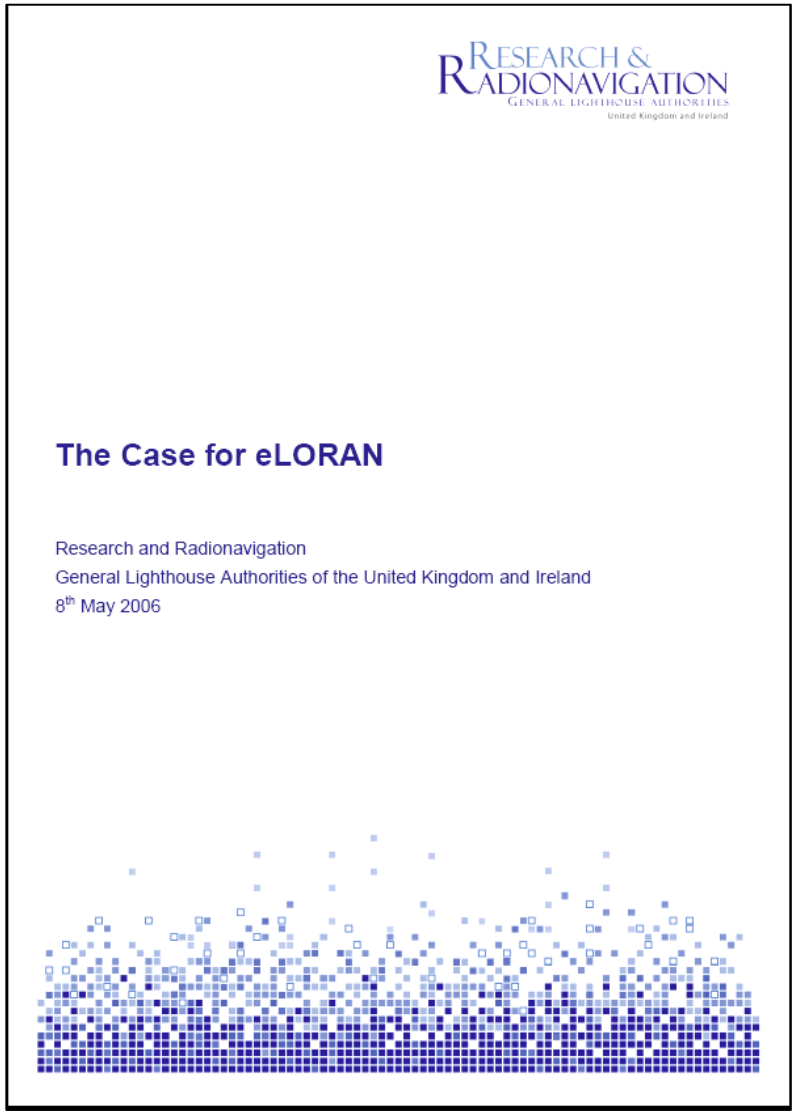


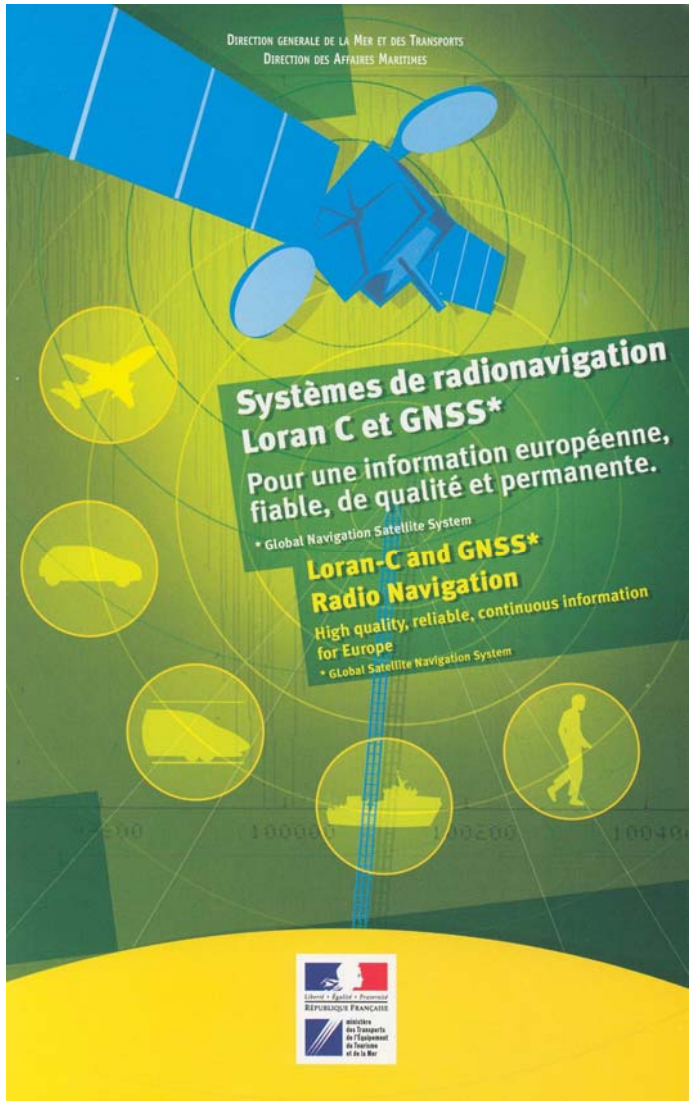
Positioning Sources During DHL Trials

Based on 4000 position calculations:

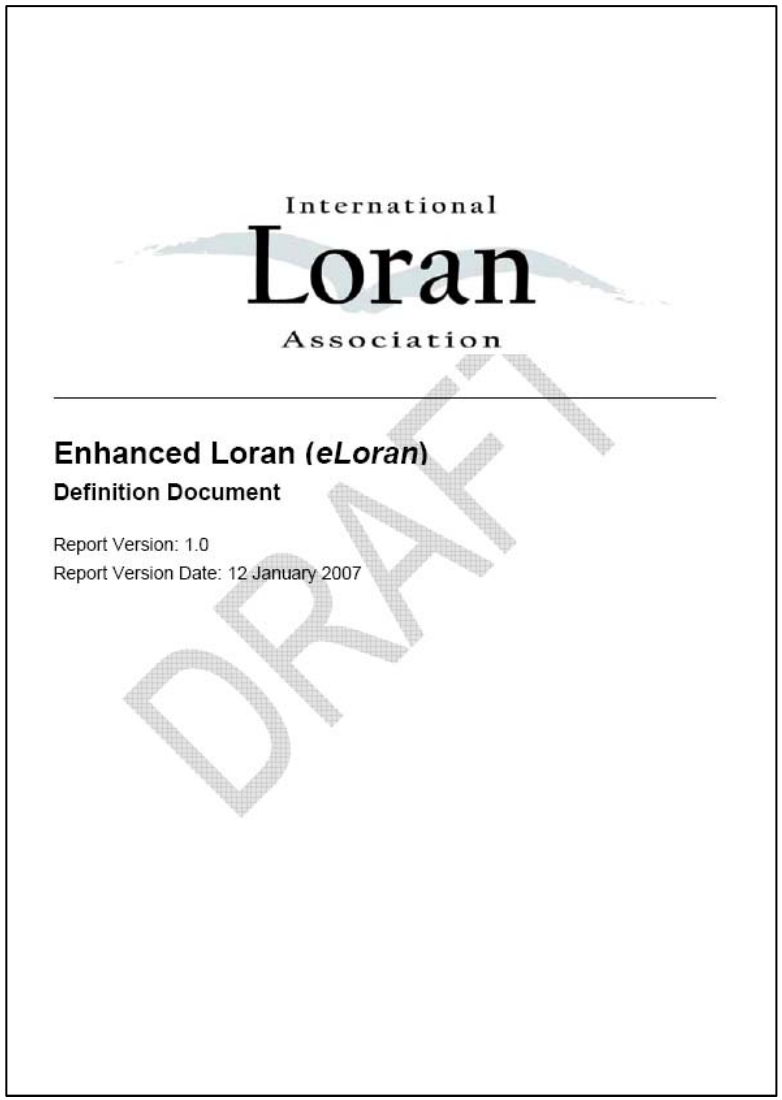


Loran from an International Perspective





Loran from an International Perspective


International
Loran
Association

Enhanced Loran (*eLoran*)
Definition Document

Report Version: 1.0
Report Version Date: 12 January 2007

DRAFT

"It's not your parent's/grandparent's Loran!"

GPS/WAAS/eLoran Receivers for Aviation

Phase I

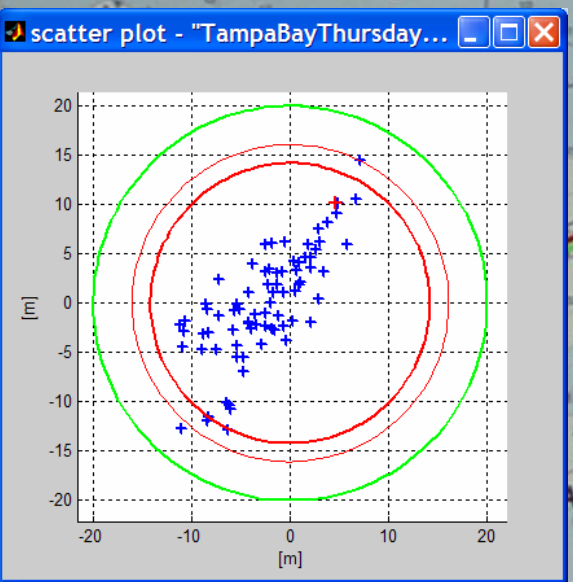
Phase II

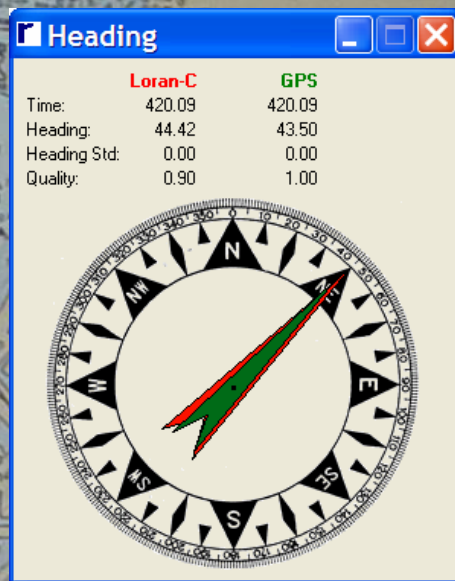
Example Aviation Tests: Rockwell/ Locus Integration of GPS-IMU-Loran

- AHC-3000A AHRS modified to add IMU outputs

GPS/WAAS/eLoran Receivers for Maritime

Tampa Bay Measurements
Megapulse/Reelektronika Receiver
April 2004





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.