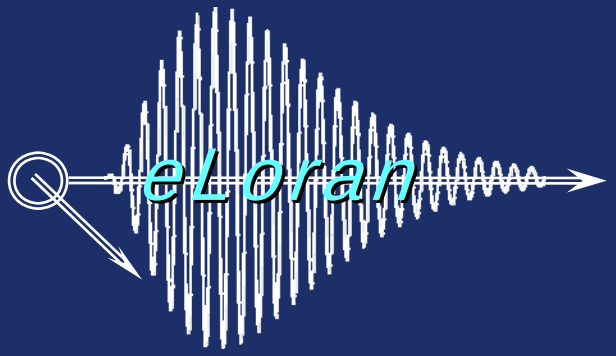
The eLoran Evaluation and Modernization Program

1997 – 2007

A Decade of Excellence



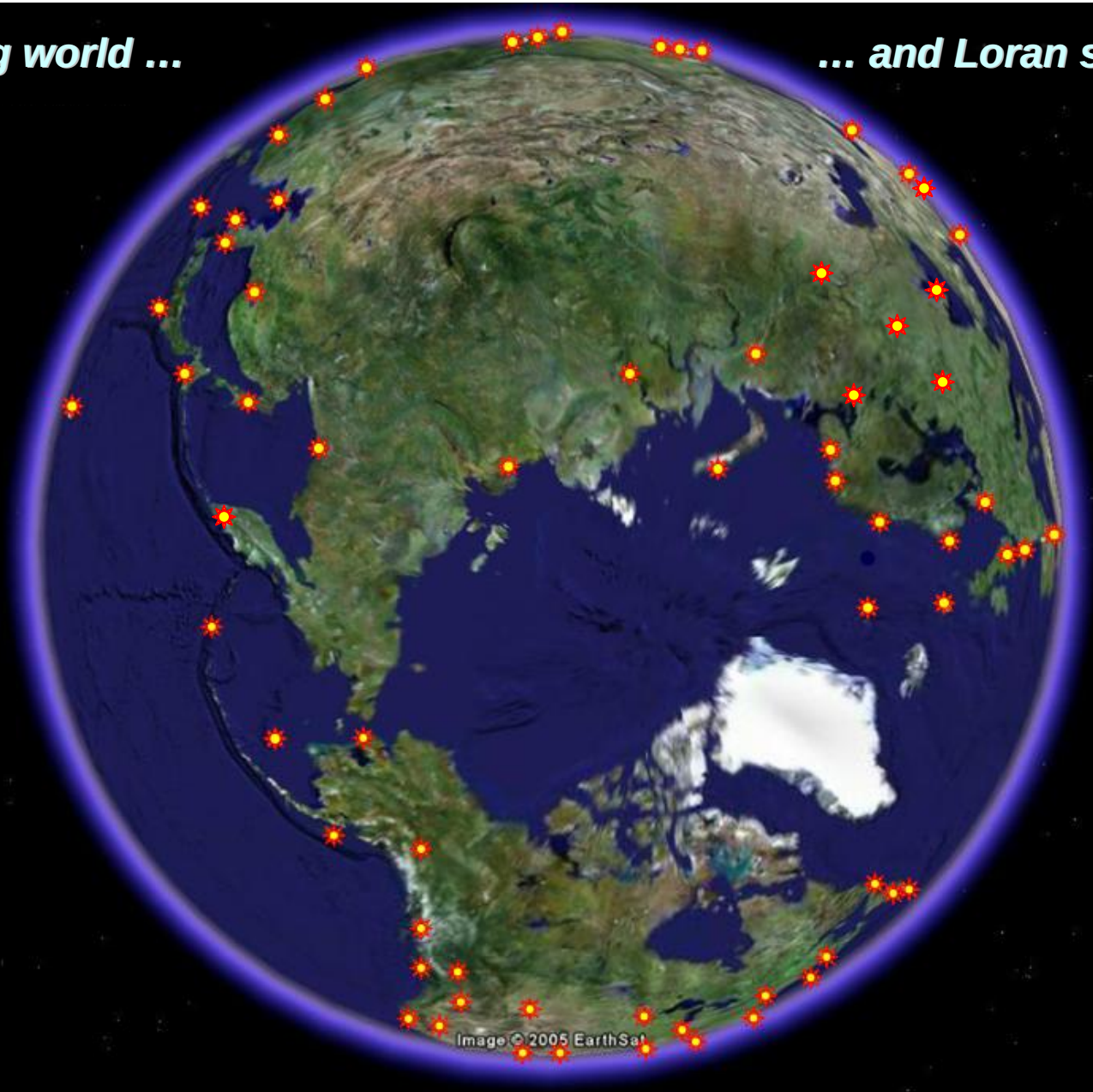
Mitchell J. Narins
Federal Aviation Administration
Navigation Services

International Loran Association
24 October 2006

Federal Aviation Administration

It's a big world …

… and Loran serves ½ of it!



A Heartfelt *Thank You*

1. ***The migration from a Loran-C radionavigation system to enhanced Loran (eLoran) has been and is key to the system's continuation.***
2. ***If it were not for the work of those in attendance here today and the work of many, many more dedicated people who could not be here, the Loran system in the United States, and perhaps the world, would have ceased to exist in the 21st Century.***
3. ***We're not there yet, there's still much to do, but every team needs to celebrate its achievements – this team has much to celebrate -- and much to be thankful for!***

1994

- **Loran-C was:**
  - A hyperbolic radionavigation system
  - A supplemental system for enroute navigation in the US National Airspace System (NAS)
  - A system for maritime navigation in the coastal confluence zone (CCZ)
  - A Stratum 1 frequency standard (i.e., 1×10^{-11}) that also provides time within 100 ns of UTC (USNO)
- **It was also going to be turned off in 2000!***

* FY 1994 US Federal Radionavigation Plan

1997 - 2000

- **Congress provides the FAA with:**
  - $ 4.6M in 1997
    - To upgrade the Loran-C navigation system and implement an automatic blink system (ABS)
  - $ 3.0M in 1998
    - To continue Loran-C upgrades initiated in fiscal 97
  - $ 7.0M in 1999
    - To further develop the Loran-C navigation system
  - $10.0M in 2000
    - To further develop the Loran-C navigation system
- **FAA establishes a Loran Evaluation Team consisting of Government, Industry, and Academia.**

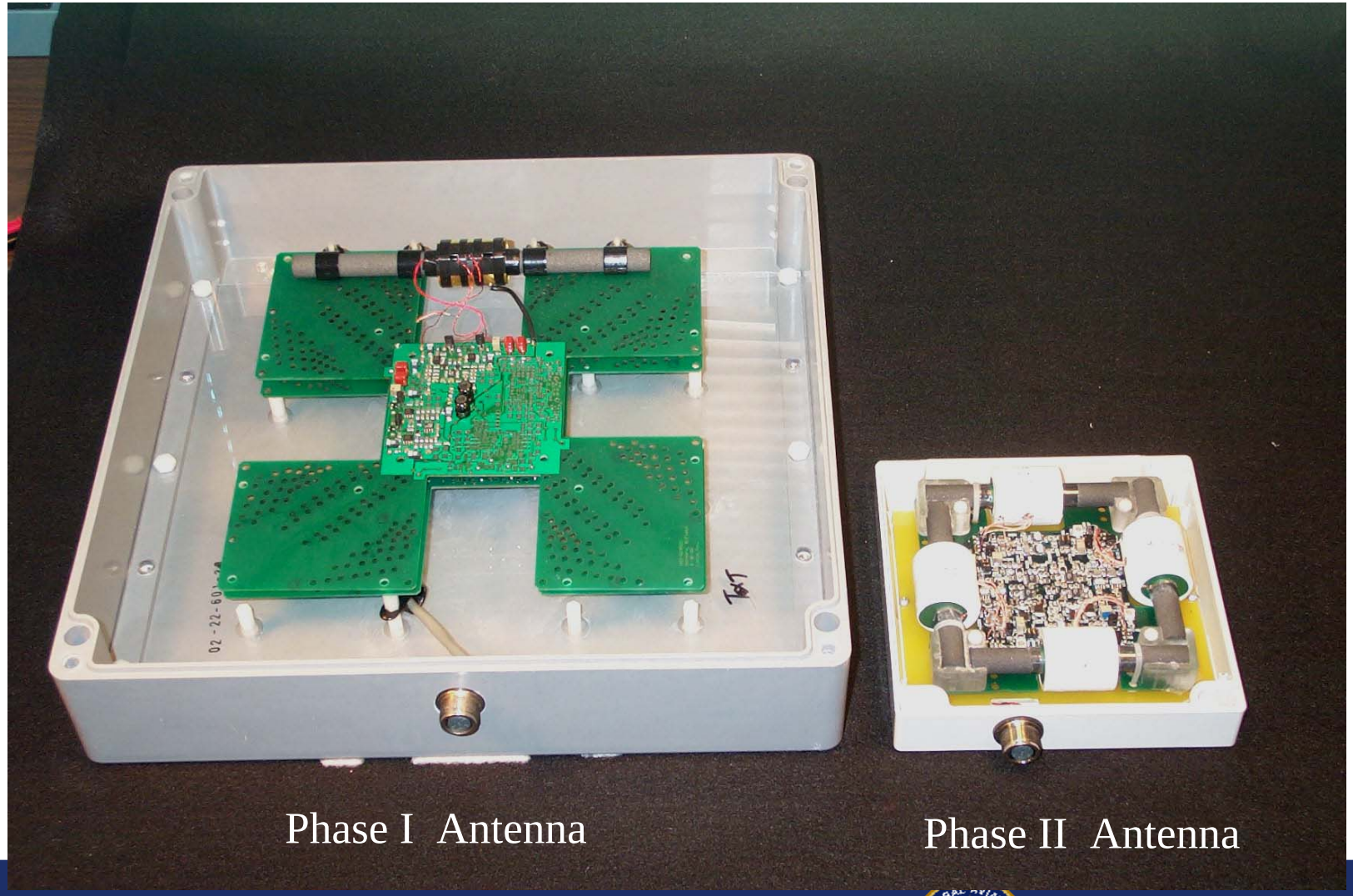
Loran Program Logo Collection

PETERSON INTEGRATED GEOPOSITIONING

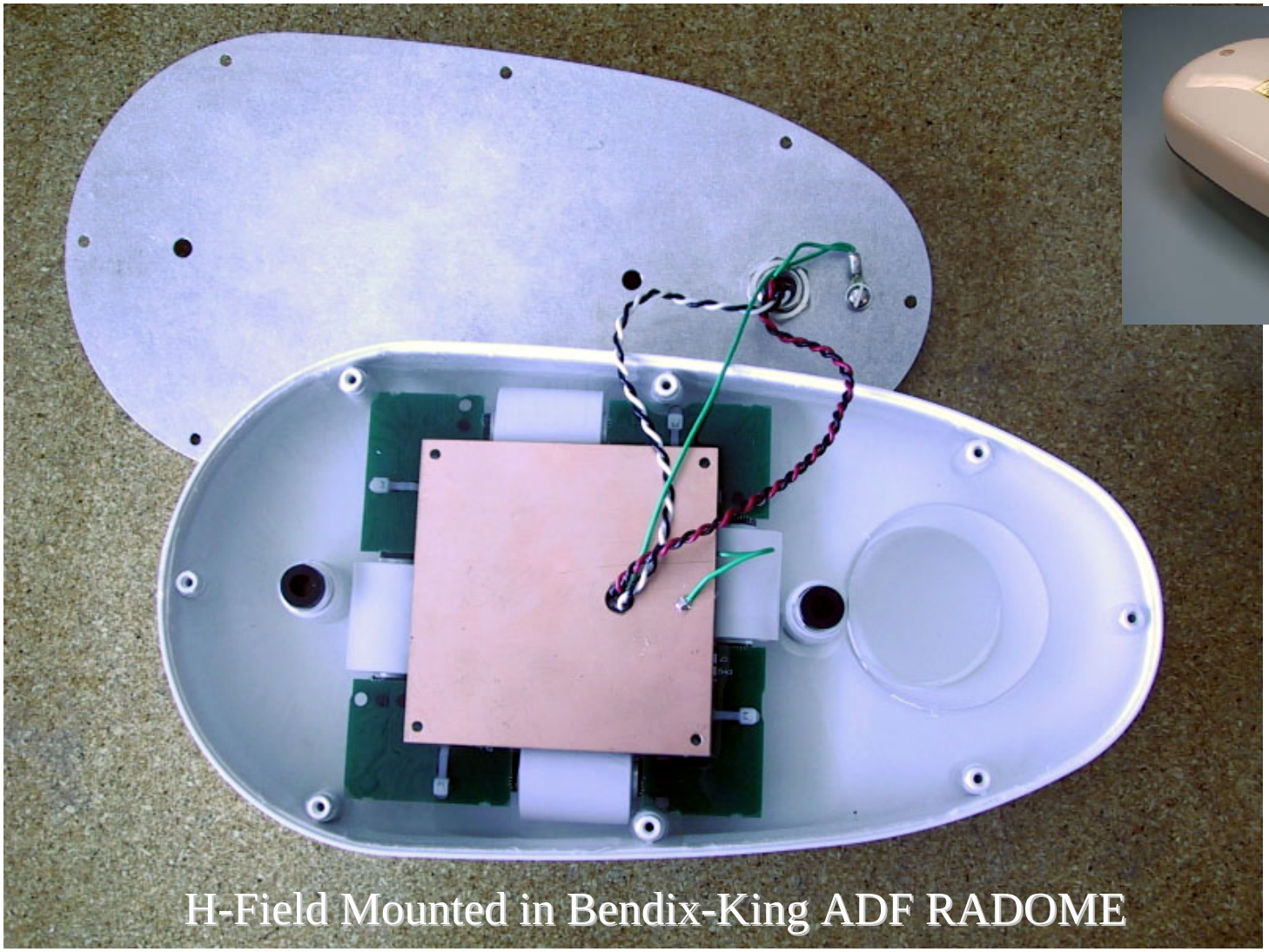
2001

- **Congress provides the FAA with:**
  - $ 25.0M in 2001
    - The Team:
      - Installs new cesium clocks at all Loran-C stations
      - Evaluates new solid state transmitter proposals and will award contract
      - Plans test and evaluation of transmitter first article prior to exercise of contract options
      - Finalizes new Loran station building design and transition planning
      - Issues RFP for new Timing and Frequency Equipment (TFE)
      - Completes tower life inspections and analysis and project costs for sustainment and/or recapitalization
- **Volpe GPS Vulnerability Study is released September 10, 2001**
- **The Loran Evaluation Team explores multi-mode DSP all-in-view receivers, H-Field antennas, and even a data channel to provide SBAS over Loran.**

H-Field Antenna Efforts - 2001

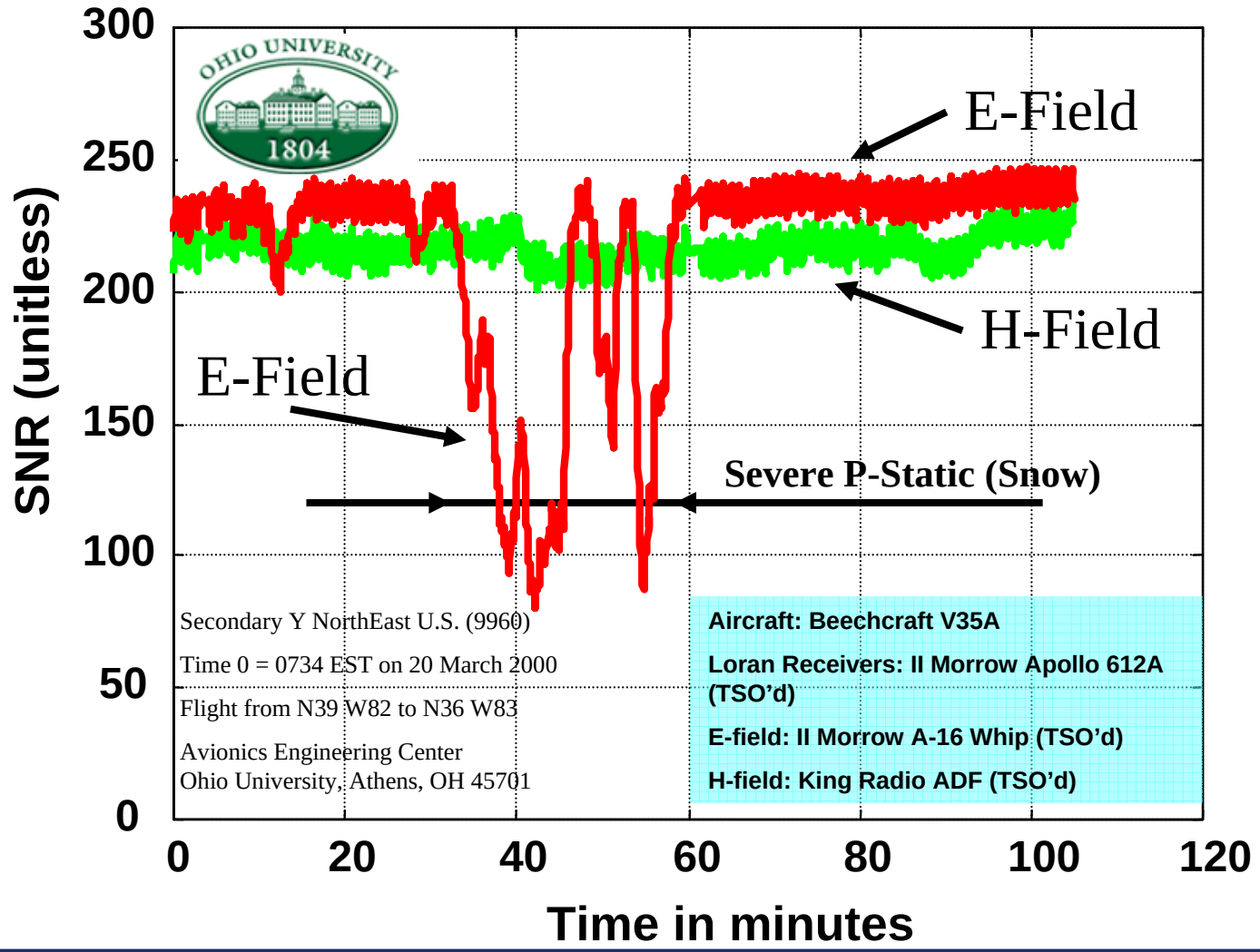


H-Field Antenna Efforts

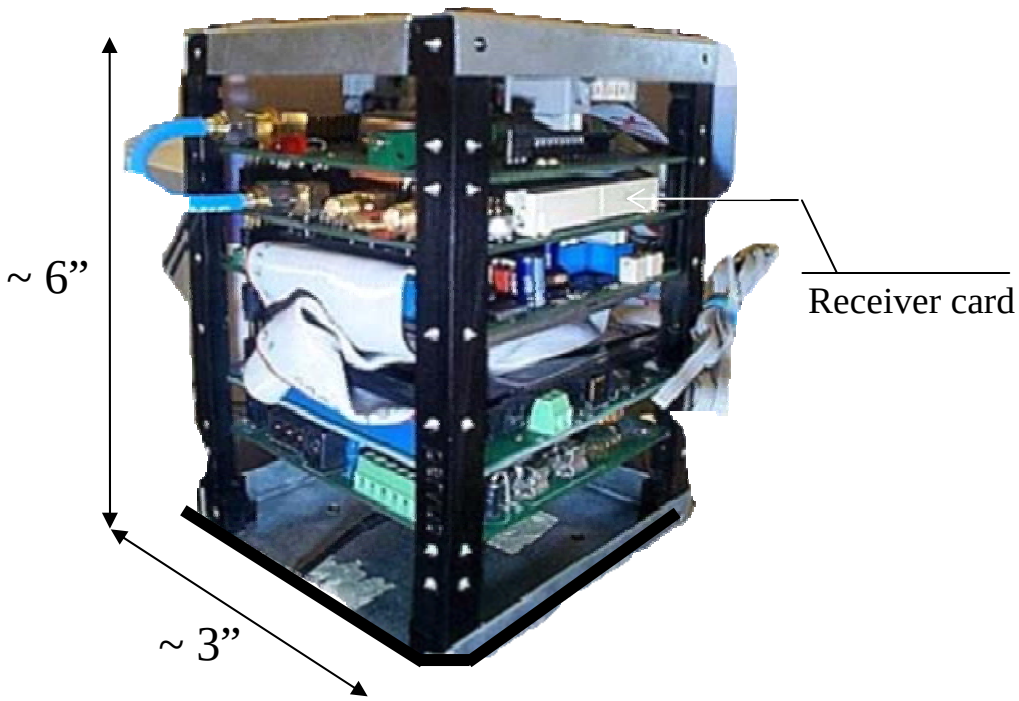


H-Field Mounted in Bendix-King ADF RADOME

E-Field - H-Field Comparison

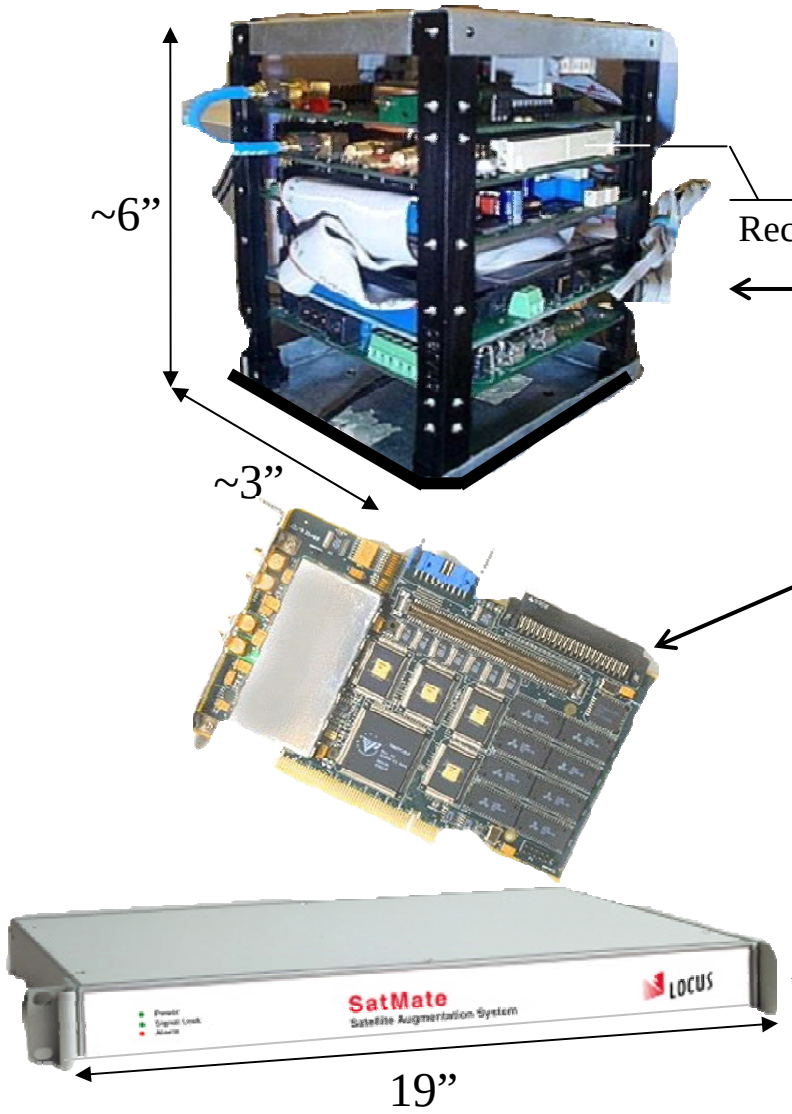


May 2001 Receiver Test



- **USCGA all-in-view DSP receiver**
  - PC-104 form factor
  - Operational at aircraft velocities
  - Used in conjunction with H-Field antenna

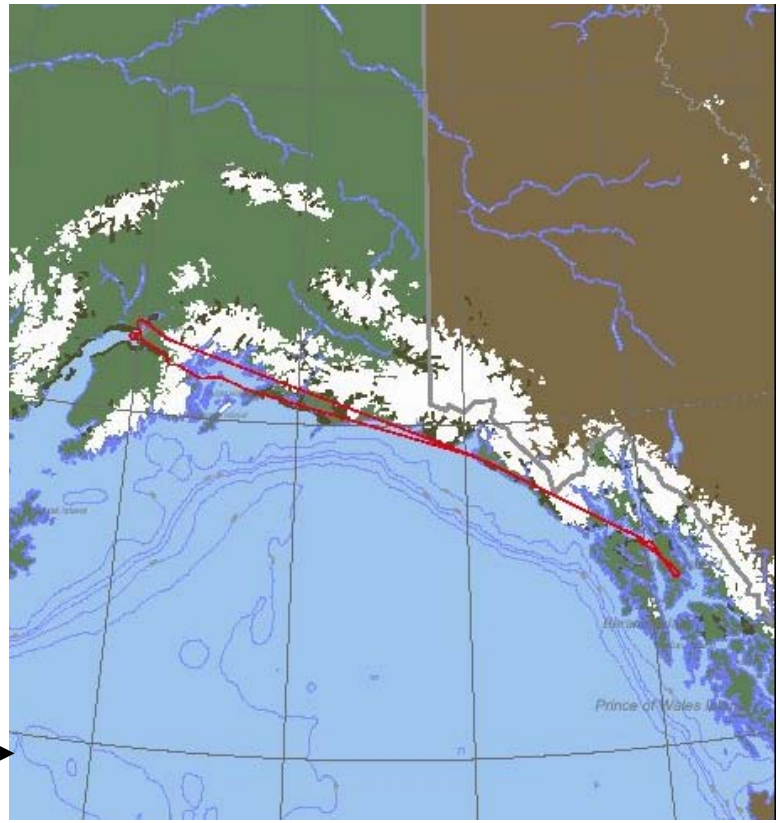
June 2001 Receiver Tests



- **Two USCGA all-in-view DSP receivers**
  - PC-104 based receiver
    - Same as used in May tests
  - ICS-650 L based receiver
    - 2-channel Digital/Analog Converter operating at 65 Hz
- **Locus, Inc. Receiver**
  - SatMate all-in-view rack mount receiver currently used as the monitor receiver at Loran stations

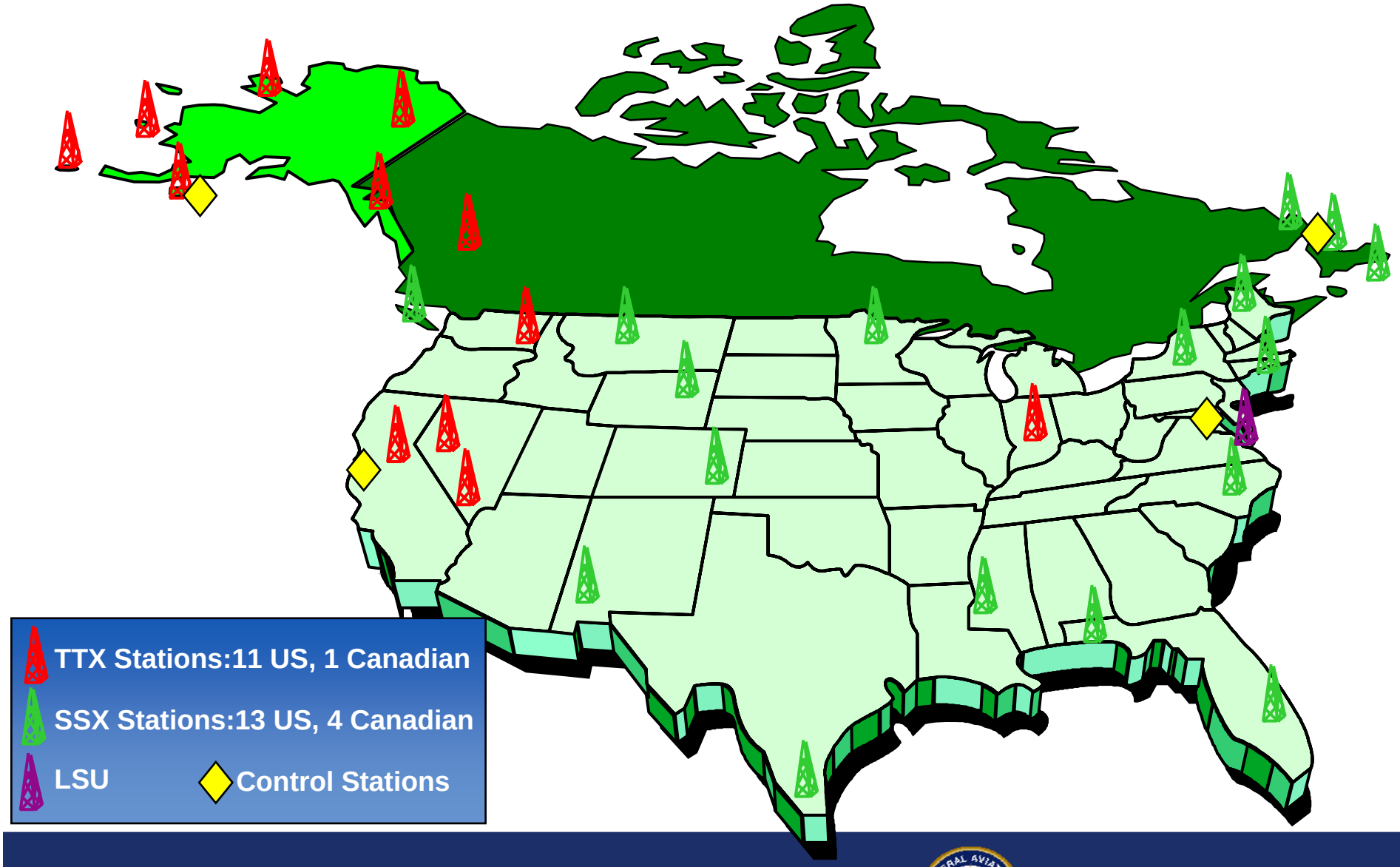
Convair Flight Paths - 2001

←23 August: Anchorage - Deadhorse



24 August: Anchorage - Juneau→

Loran-C in the NAS -- 2001



US Loran-C Policy -- 2001

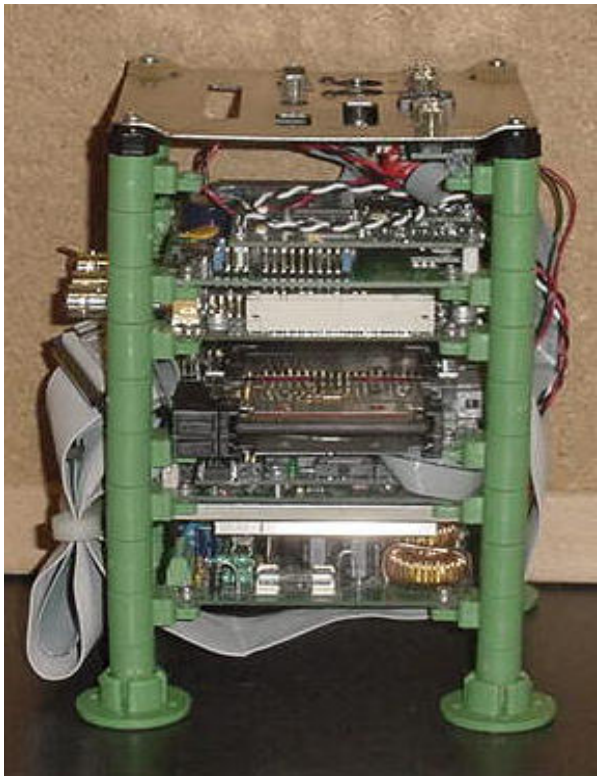
"While the Administration continues to evaluate the long-term need for continuation of the Loran-C radionavigation system, the Government will operate the Loran-C system in the short term. The U.S. Government will give users reasonable notice if it concludes that Loran-C is not needed or is not cost 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 nonprecision instrument approach operations."

– ***Para 3.2.5 B 1999 US Federal Radionavigation Plan***

2002

- **Congress provides the FAA with:**
  - $ 19.0M in 2002
- **FAA Murder Board meets to discuss Loran**
- **FAA holds Industry Day to discuss Loran with aviation users**
- **The Loran Evaluation Team continues to explore multi-mode DSP all-in-view receivers and H-Field antennas.**

Receivers - 2002



FAA Murder Board

- **An FAA "Murder Board" was convened on 19 March 2002 to determine the status of the ongoing Loran-C evaluation and to help formulate the FAA's response to DOT regarding Loran-C**
  - Specific requirements to support Non-Precision Approach, RNP 0.3, were targeted
  - ***Redundant***, ***Backup***, and ***Contingency*** systems were described in light of a GPS outage
    - **Redundant** ✈ Allows you to keep flying the way you were because you have an equivalent, GPS-independent navigation capability
    - **Backup** ✈ Allows you to keep flying, but perhaps not along the route you intended or landing at your intended destination airport
    - **Contingency** ✈ Allows you to safely land at an airport, but probably not at your intended destination

FAA Navigation Industry Day

- **A Navigation Industry Day was held on 7 May 2002 to brief aviation industry groups on the status of FAA's response to DOT and to solicit their input regarding the FAA's navigation architecture transition planning**
  - It was noted that Loran-C, as a stand-alone radio-navigation system, may be the best choice for a backup for non-FMS/INS/DME-DME equipped aircraft in the event of a GPS outage
  - ***However, for the FAA, Loran's usefulness depends on whether it has the ability to support non-precision approach, RNP 0.3***

- **Timing community states that eLoran could meet needs of the telecommunications industry.**
- **Provides means to make the system more desirable**
- **Input is used by Evaluation Team to establish requirements for time and frequency users.**

T1X1/2002-049R1

T1X1

Digital Hierarchy and Synchronization

A Technical Subcommittee of Standards Committee T1 Telecommunications

Accredited by the American National Standards Institute

Ken Biholar
Chairman

Mark Jones
Vice Chairman

A Sponsored Committee of

ATIS
Alliance for Telecommunications Industry Solutions

October 4, 2002

Dr. Marc Weiss
National Institute of Standards and Technology
325 Broadway
Boulder, CO 80305

Dear Dr. Weiss,

Re: E-LORAN

The telecommunications industry requires an alternative to existing frequency reference sources. Diverse technologies are needed to augment the existing GPS receiver and cesium based frequency sources. The availability and reliability of an accurate frequency within the telecommunication network is important to maintain the operation of critical and emergency services.

It is the expert opinion of T1X1.3 that E-LORAN could meet continuing needs of the telecommunications industry for accurate frequency if the following subjects are addressed:

1. The widespread use of the current LORAN-C system was drastically reduced by the lack of public commitment to continuing the operation of the system. In order for the industry to consider using E-LORAN, there must be a long-term commitment to operate the system for at least 15 years.

2. Frequency accuracy in the E-LORAN system is a prime concern. To be considered for telecommunications applications, a frequency accuracy of 1 part in 10^{11} (Stratum 1) or greater is required; a higher accuracy of 1 part in 10^{12} is desirable. Any modulation of the E-LORAN signal for data must not be allowed to degrade the frequency accuracy of the received signal.

Other issues with the proposed E-LORAN system would make the use of the system more desirable for use within the telecommunication industry:

1. The ability of an E-LORAN receiver to be used without an antenna external to the receiver would give the system an advantage over GPS.

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

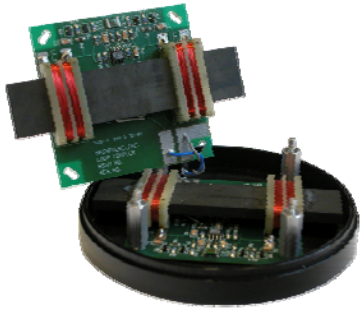
2003

- **Congress provides the FAA with:**
  - $ 25.0M in 2003
- **LORIPP and LORIPP take on challenges of the Murder Board and meeting the requirements for NPA and HEA**
- **Rockwell Collins participates in multi-mode receiver for aviation.**
- **Megapulse works on maritime receiver.**
- **University of Wales works on Balor model.**

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

- AHC-3000A AHRS modified to add IMU outputs

GPS/WAAS/eLoran Receivers for Maritime

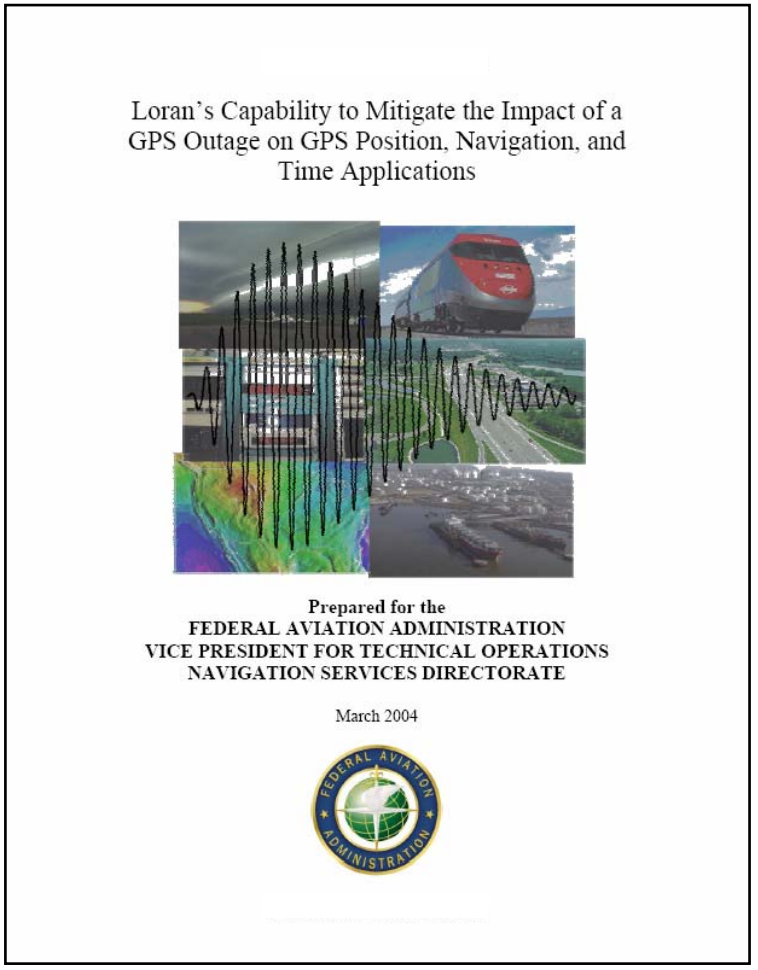


2004 – The Report is Delivered!

- **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

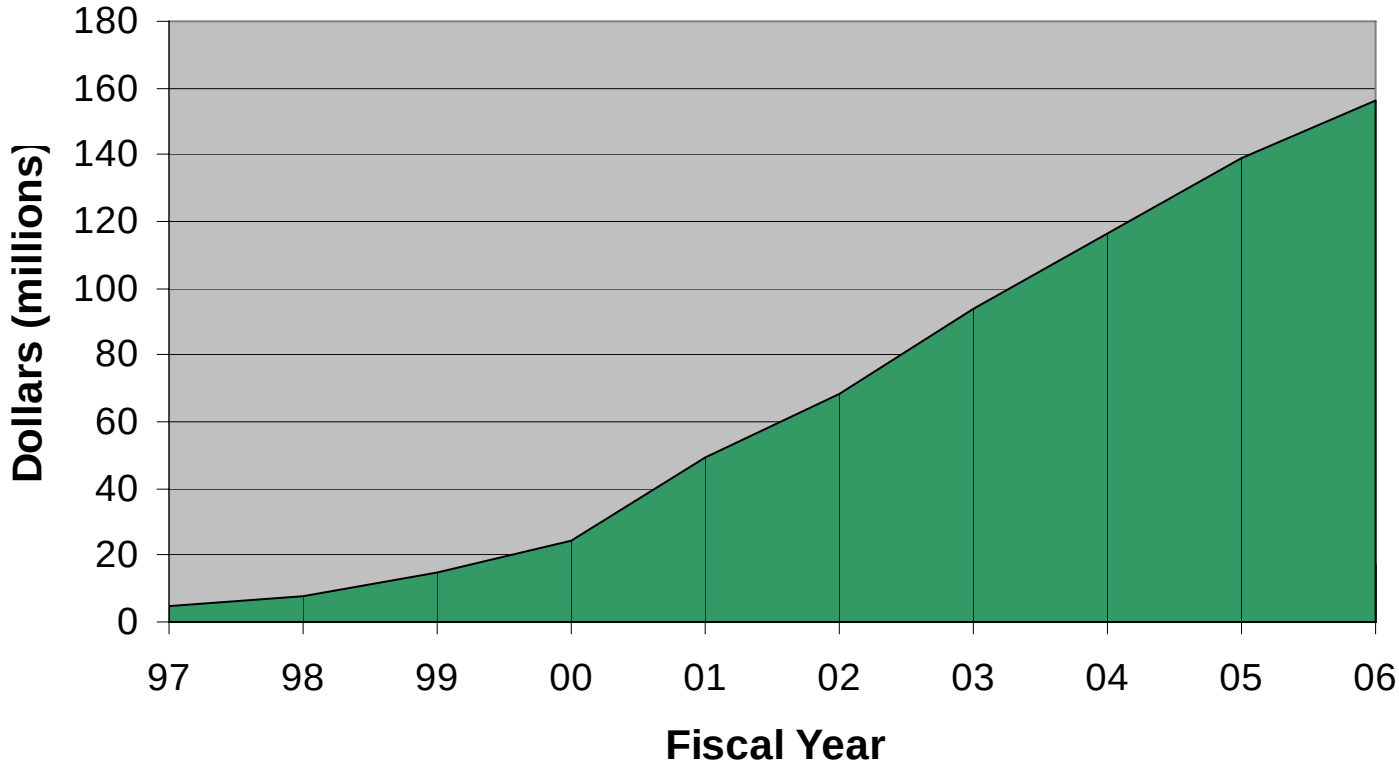
"The evaluation shows that the modernized Loran system could satisfy the current NPA, HEA, and timing/frequency requirements in the United States and could be used to mitigate the operational effects of a disruption in GPS services, thereby allowing the users to retain the benefits they derive from their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



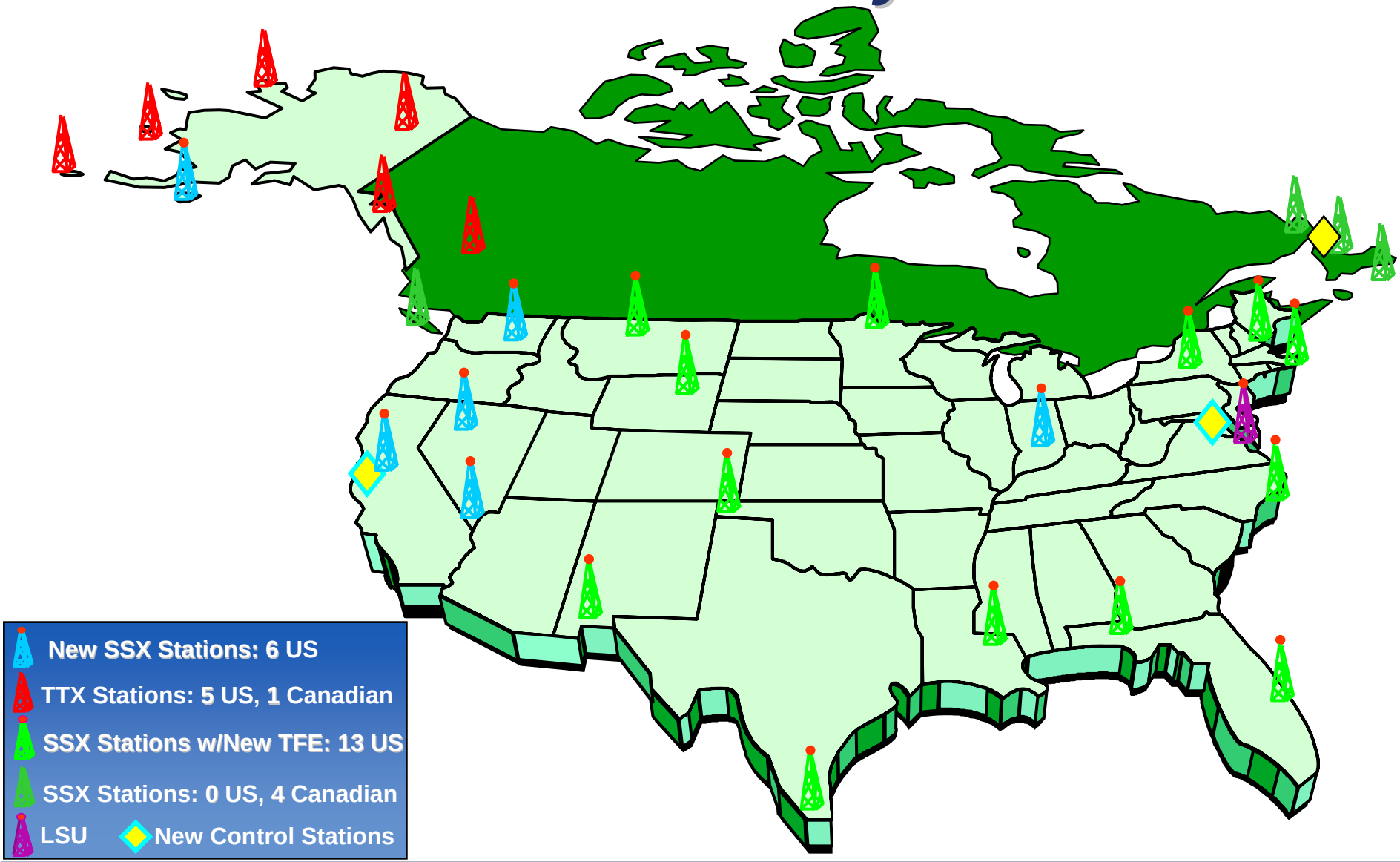
Report is available at:
https://ksn.faa.gov/km/navservices/navserviceslt/tech/Loran_Eval_Report/default.aspx

…so where are we today?

U.S. Loran Evaluation and Modernization Program
Cumulative Expenditures
FY 97 - FY 06



North American Loran System



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	Yes	Yes	Yes
Time of Day/Leap Second/ UTC Reference	No	Yes	Yes
Precise Time [<50 ns UTC(USNO)]	No	No	Yes

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

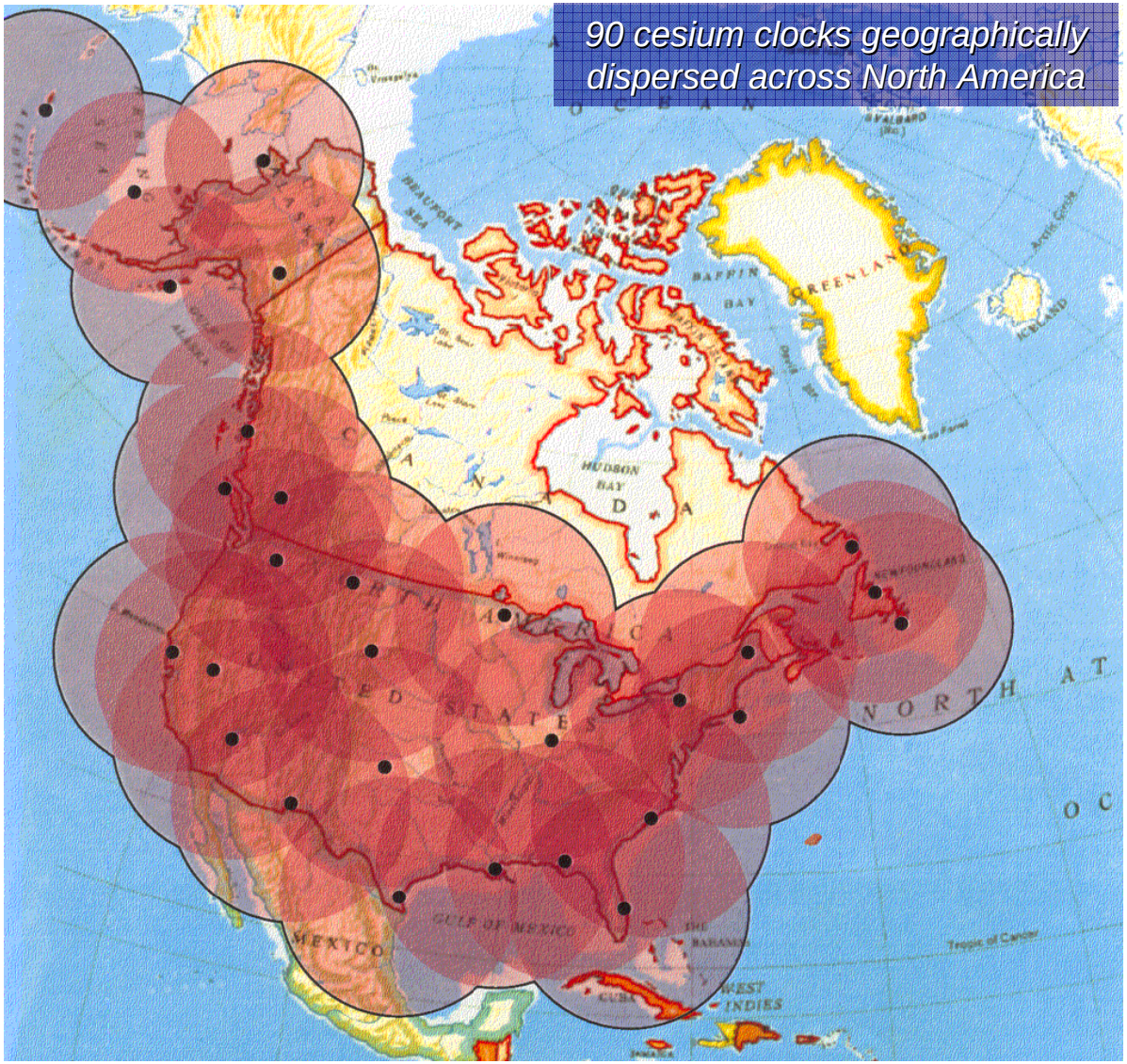
It's about time: The eLoran Clock

- **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**

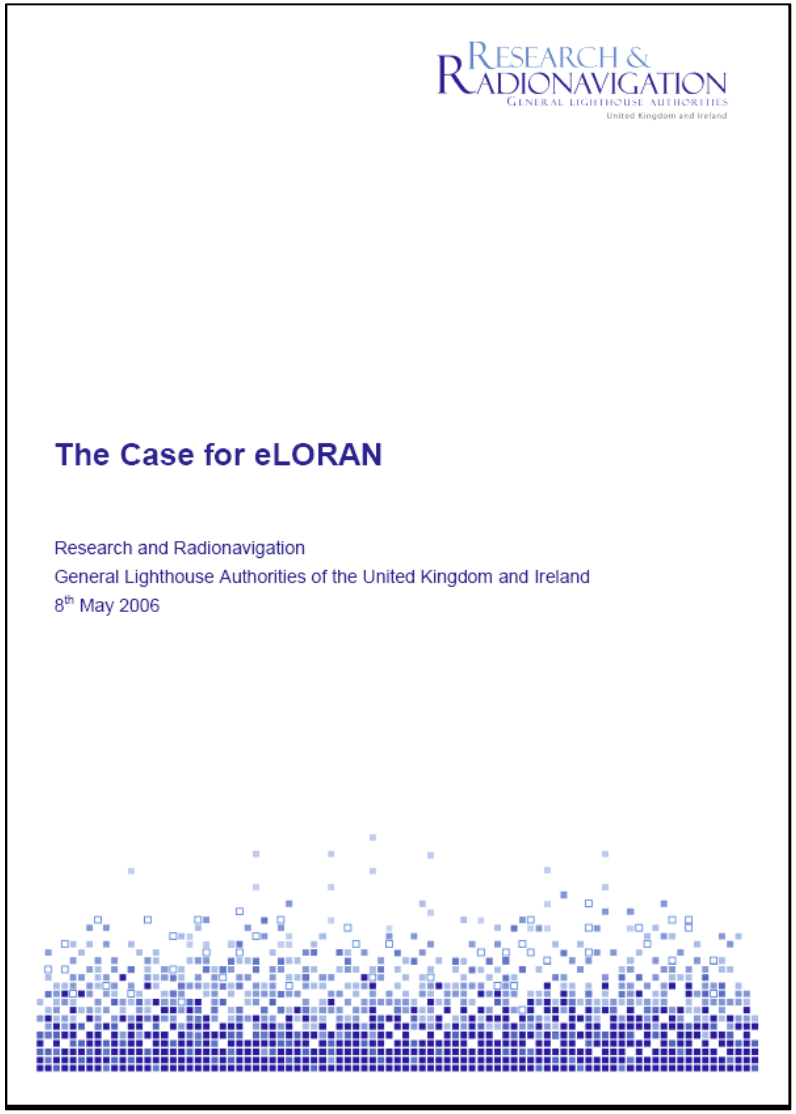
NIST Report on Time Backups for GPS

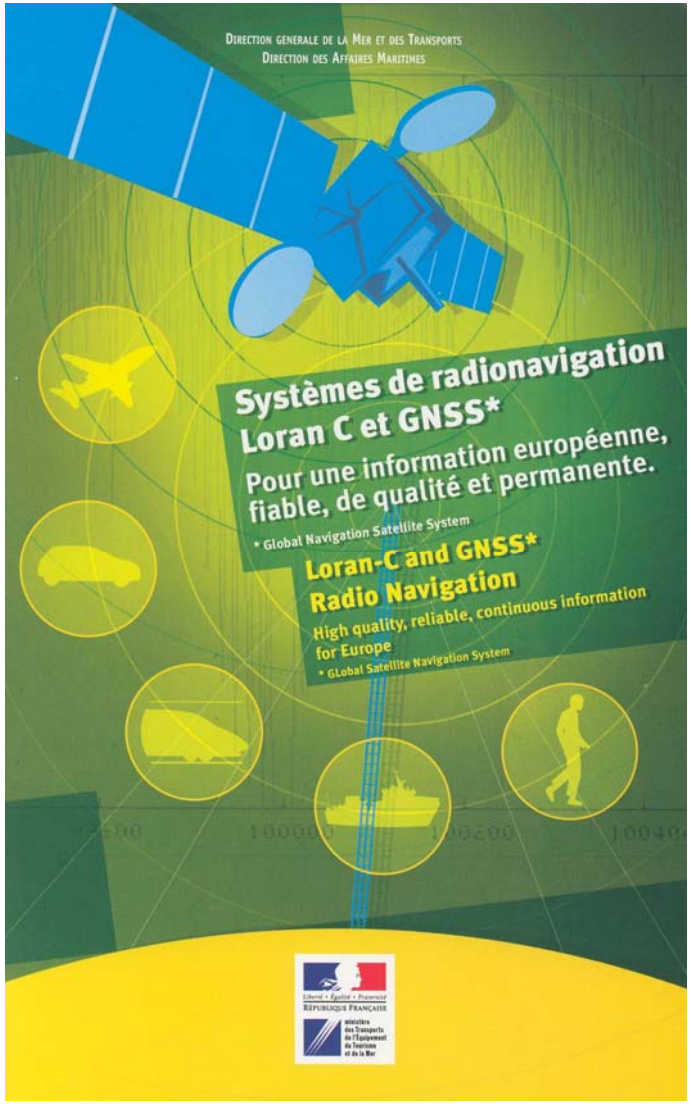
- **"We have reviewed all of the available broadcast signals that anchor the time and frequency infrastructure in the United States."**
- **"We conclude that *eLORAN* is the best available backup provider to GPS as a reference source for precise time synchronization and frequency control."**

North American Loran Time Coverage



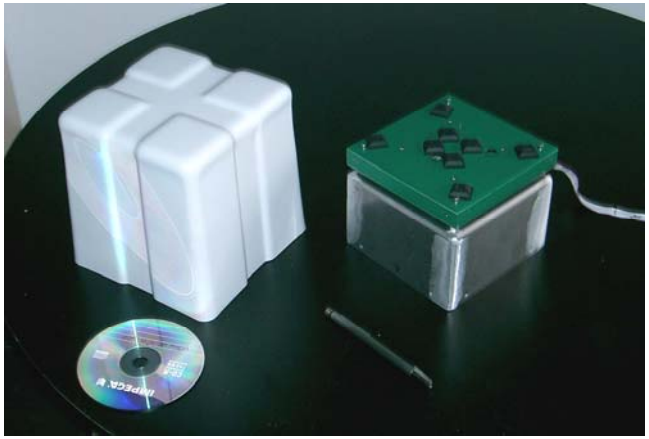
Loran from an International Perspective

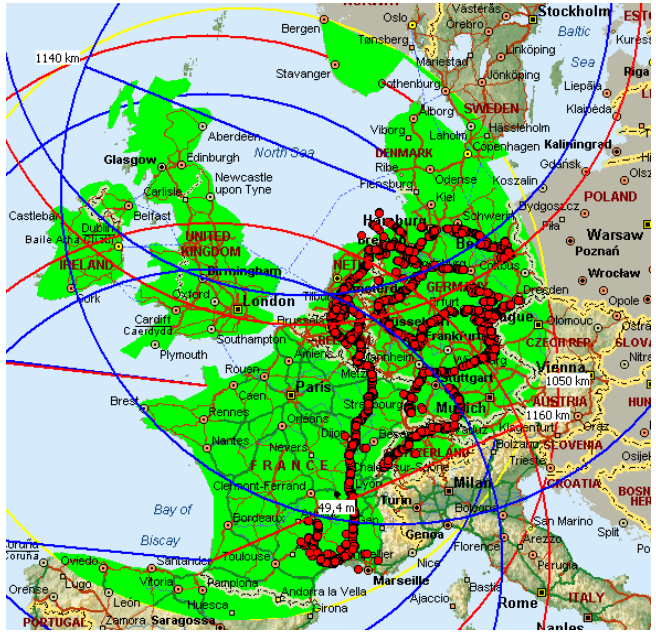




DHL European Trials – “e-Tracker”

- **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)





GPS/WAAS/eLoran Receivers for Aviation

Phase I

Phase II

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Questions