Independent Assessment Team (IAT)
Summary of Initial Findings on eLoran

Briefing to ILA 38

Portland Maine

Jim Doherty, IDA

14 October 2009

IAT Charter (August 2006)

- **Conduct independent assessment of Loran**
  - ***Assemble team of experts to review & assess continuing national need for the current US Loran infrastructure***
  - ***Report findings & recommendations directly to Under Secretary of Transportation for Policy and to Deputy Under Secretary of Homeland Security for Preparedness***
- **Assess information from recent studies & working groups' reports**
  - ***Use, for example, LORAPP & LORIPP working group reports; studies by Volpe Center, FAA, USCG, HSI, others***
  - ***Supplement with information from key stakeholders and others as appropriate***

IAT Members

Dr. Bradford Parkinson – Stanford University – Chair
James Doherty – IDA, former USCG NAVCEN – Exec Director
John Darrah – IDA, former Chief Scientist AF Space Command
Arnold Donahue – NAPA, former OMB
Dr. Leon Hirsch – IDA Research Staff Member
Donald Jewell – IDA, former AF Space Command
Dr. William Klepczynski – IDA, former US Naval Observatory
Dr. Judah Levine – NIST Time Services
L. Kirk Lewis – IDA, Executive Director GPS IRT
Dr. Edwin Stear – IDA, former VP Boeing & AF Chief Scientist
Philip Ward – IDA, former Texas Instruments (GPS receivers)
Pamela Rambow – IDA Research Assistant

Who We Met with

Government Agencies

- *Department of Transportation (DOT)*
- *Federal Aviation Administration (FAA)*
- *Volpe National Transportation Systems Center (VNTSC)*
- *Department of Homeland Security (DHS)*
- *US Coast Guard (USCG)*
- *Homeland Security Institute (HSI)*
- *US Naval Observatory (USNO)*
- *National Security Space Office (NSSO)*
- *National Institute of Standards & Technology (NIST)*
- *National PNT Coordination Office (NPCO)*

User Groups & Organizations

- *International Loran Association (ILA)*
- *Aircraft Owners & Pilots Association (AOPA)*
- *National Boating Federation (NBF)*
- *American Pilots Association (APA)*

User Equipment Industry

- *Cross Rate Technology*
- *Megapulse*
- *Peterson Integrated Geopositioning*
- *Rockwell Collins*
- *Symmetricom*
- *Timing Solutions Corporation*

Studies Reviewed (Principle Investigators)

- *GPS Vulnerability (VNTSC)*
- *Timing (HSI, NIST, USNO)*
- *PNT Architecture (NSSO)*
- *eLoran Costs & Benefits (USCG, FAA, VNTSC, Megapulse, Trinity House)*
- *Loran Integrity Performance Panel research & findings (LORIPP)*
- *Loran Accuracy Performance Panel research & findings (LORAPP)*
- *eLoran Characteristics (FAA, USCG, Stanford University, Peterson Integrated Geopositioning)*
- *Aviation Backup Requirements (FAA, Aviation Mgmt Associates)*
- *Aviation Certification Issues (FAA)*
- *Aviation eLoran Performance (FAA)*
- *Maritime Backup Requirements (former TASC/Litton/Northrop Grumman)*
- *Maritime eNavigation (Trinity House & University of Wales)*
- *Interference Detection & Mitigation (IDM) Plan (DHS, USCG)*
- *eLoran Performance Data (Ohio University, Stanford University, Peterson Integrated Geopositioning)*
- *Location-Based Security (Logan Scott Associates, Stanford University)*
- *eLoran as Time & Frequency System (Timing Solutions Corporation)*

IAT Schedule

- **Mid-Aug 2006** — **IAT begins**
  - *Establish membership & select chair*
  - *Collect read-ahead materials & provide to members*
  - *Develop data collection plan (meetings & briefers)*
- **19-20 Sep 2006** — **First meeting – IDA**
  - *Focus on vulnerability study, user requirements, & other major studies*
- **10-11 Oct 2006** — **Second meeting – IDA**
  - *Meet with DOT sponsor & invited DHS co-sponsor*
  - *Focus on other studies plus international, environmental, other issues*
- **1-2 Nov 2006** — **Final meeting – Stanford**
  - *Focus on user equipment – availability, cost, market research, etc.*
  - *Review need for standards & other equipage issues*
- **6 Nov-12 Dec 2006**
  - *Detailed eLoran cost review*
- **13 Dec 2006** — **Initial report – DOT HQ**
  - *Chair & Executive Director*
  - *DOT Under Secretary for Policy, DHS Deputy Under Secretary for Preparedness, & USCG Assistant Commandant for Prevention*

Government Decision Options

- **Terminate Loran-C**
  - *Declare end date for operations*
  - *Mothball or decommission infrastructure*
- **Continue status quo***
  - *No stated Government position*
  - *Continue current uncertainty & resulting turmoil*
- **Decide that eLoran is primary GPS backup**
  - *Complete eLoran upgrade*
  - *Establish eLoran as primary backup for ~20 years*

Status quo option means "terminate"
NO DECISION IS A TERMINATE DECISION
Manufacturers and Users will not equip

IAT Conclusions & Recommendation

- **Reasonable assurance of national PNT availability is prudent & responsible policy**
  - ***For critical safety of life & economic security applications***
  - ***And for all other "quality of life" applications***
- **eLoran is cost effective backup – *to protect & extend GPS* – for identified critical *(& other GPS-based)* applications**
  - ***Interoperable & independent***
  - ***Different physical limitations & failure modes***
  - ***Seamless operations & GPS threat deterrent***
- **Given US Government support, anticipate users will equip with eLoran as the backup of choice**
  - ***International community looking for US leadership***
- ***Recommend* complete eLoran upgrade & commit to operate for 20 years**
  - ***Affordable within recent funding history***

Studies Indicate

- **GPS backup (dissimilar failure modes) needed for critical infrastructures requiring position, time, frequency services**
  - ***Vulnerability studies demonstrate impact to critical systems due to local interference or jamming of GPS***
  - ***Types of GPS uses & numbers of users increasing dramatically***
  - ***Technical studies review capabilities of eLoran to provide backup to GPS when needed – interoperable & independent***
  - ***Cost/benefit studies appear to support decision to retain eLoran as a backup service to GPS for a broad range of applications***
- **Government agencies & user groups report adequate, but individual system-by-system, backups to GPS already exist**
  - ***Most report either equipment or procedural backups in place***
  - ***User trade space is cost of equipping with backup system vs. risk***
  - ***Studies (limited scope) conducted dominantly in "stovepipes"– limited to domain or area of interest of one agency or user group***

Current & Future GPS Vulnerabilities

- **Inherent vulnerabilities in systems using RF spectrum**
  - *Increased due to unique GPS characteristics*
    - *Very low signal power*
    - *Single civil frequency – future mitigated with multiple frequencies*
    - *Simple known signal structure – future mitigated with new signals*
- **Unintentional interference – generally local & short duration**
  - *Radio frequency interference (RFI) & GPS testing activities*
  - *Ionospheric disturbances – exacerbated by solar activities*
- **Spectrum competition from non-radionavigation systems**
- **Intentional interference – could be 100 miles & last days**
  - *Jamming (hackers or terrorists)– denial of use*
  - *Spoofing & its variations – counterfeit signals*
  - *Global military & civil use of GPS encourages "disruption industry"*
    - **Jamming techniques well known & devices available or easily built**
- **Disruption of GPS constellation or ground control segment**
- **Human factors**
  - *Errors, over-reliance, lack of knowledge/training*
  - *Mitigated with planned upgrades to GPS control segment (OCX acquisition)*

Why eLoran

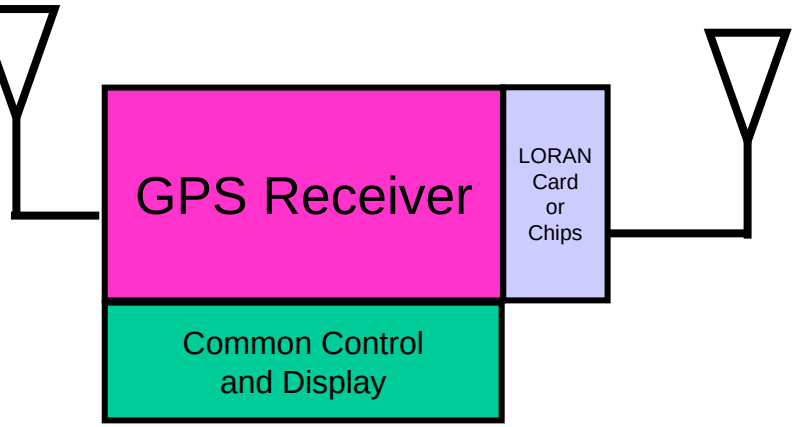
- **eLoran meets needs of all identified critical applications – and others**
  - *10-20 meter navigation accuracy for harbor entrance*
  - *0.3 mile required navigation performance (RNP 0.3) & aviation integrity*
  - *Stratum 1 for precise frequency users & 50 ns time accuracy*
- **eLoran is a *modern* system, NOT 1958 Loran-C**
  - *New infrastructure – solid state transmitters, state-of-the-art time & frequency equipment, uninterruptible power supplies* – **essentially complete**
  - *New operating concepts – time of transmission, all-in-view signals, message channel with differential corrections, integrity, etc.* – **fully tested**
  - *New user equipment – digital, process eLoran & GPS interchangeably, compact H-field antennas eliminate "p-static"* – **nascent industry ready**
- **eLoran is affordable – IAT "deep dive" into costs (*over-bounded*)***
  - *Did NOT critique costs, categories, or needs – largest set of max values*
  - *$159M invested to date – $5-25M/yr FY 1997-2006*
    - **Less than $143M to fully complete eLoran ….. *most likely considerably less***
    - **Avoid $146M costs of decommissioning existing Loran-C infrastructure**
  - *Ops & maintenance currently $37M/yr*
    - **Reduce with eLoran-enabled automation** – ***start today***

*More cost detail in backup

Finish eLoran = "no cost solution"

eLoran Is "Seamless" Backup

- **Many backups require different skills; e.g., for professional navigators:**
  - ***Switch to buoys or radar***
  - ***Switch to DME or VOR***
- **Some traditional skills have been found to atrophy in the GPS era**
  - ***Operational efficiencies provide fewer opportunities to practice***
  - ***Trends expected to continue***



- **eLoran nascent user equipment industry**
  - ***"All up" prototypes exist – limited production possible near term***
  - ***Focus is on integrated eLoran & GPS digital receivers***
- **Designed as seamless backup, with common operator interface**
  - ***GPS calibrates eLoran while GPS available***
  - ***eLoran extends GPS service into GPS-challenged situations***
  - ***Receiver seamlessly switches to eLoran when GPS is lost***

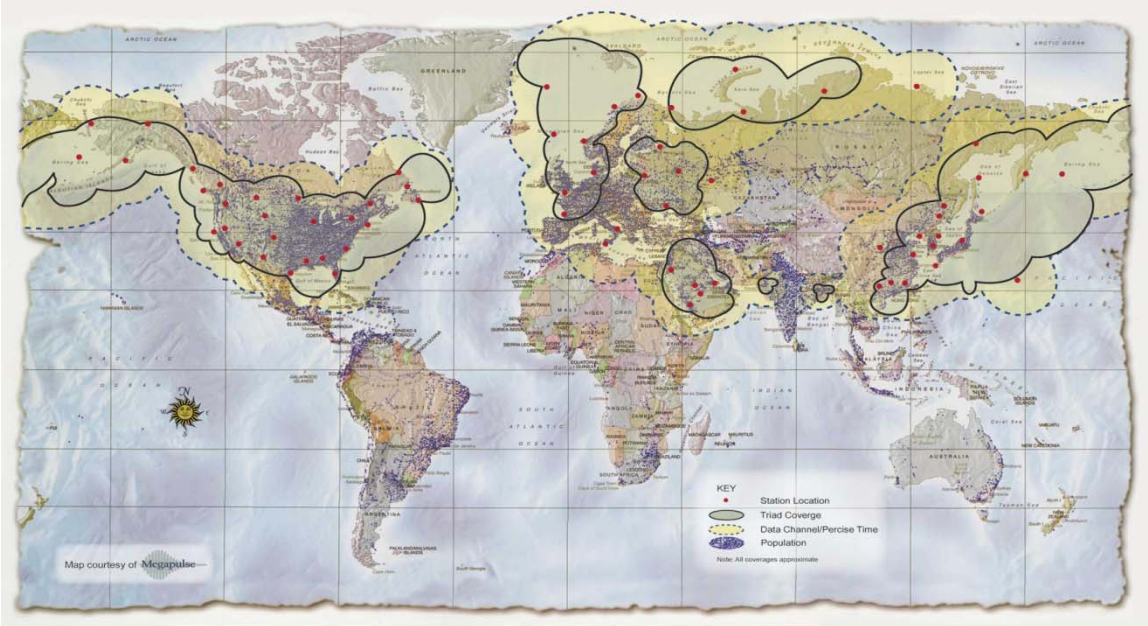
– **The implications for safety and ease of use are significant**

National Benefits of eLoran

- **Useful in aviation safety of life applications (DOT/FAA)**
  - *RNP 0.3, NPA, ADS-B*
  - *But legacy backups (eg, DME, VOR, ILS, etc.) exist*
- **Useful in maritime safety of life applications (DHS/USCG)**
  - *Harbor entrance & approach*
  - *But legacy backups (eg, buoys, harbor pilots, etc.) exist*
- **Useful in timing & frequency applications (DOC)**
  - *Digital cell phone towers & Stratum 1 network switches*
  - *Local oscillators used for backup—varying quality*
- **Useful in defense, security, & other applications (DoD, DHS, others)**
  - *Extend GPS indoors & under foliage*
  - *Augment GPS in urban & natural canyons*
- **Useful as a deterrent to disruption of GPS (DHS, DoD, others)**
  - *Enables most applications to continue uninterrupted*
  - *Hence "why bother" to disrupt (jam) GPS*
- **Much benefit overall – no one agency to claim "ownership"**
  - *Traditionally DOT (i.e., USCG (pre-DHS) & FAA) provided civil "navigation" systems, which also sufficed for other users' needs*

The Way Ahead

- **Implement IAT recommendations** (13 Dec 2006 briefing)
  - *Decide to retain eLoran for 20 years as primary backup to protect & extend critical (& other) GPS applications*
  - *Fund completion of eLoran*
  - *Reduce eLoran staffing (O&M costs) – start now*
  - *Stimulate eLoran receiver development & equipage*



Closing thoughts

- *Established capability*
- *Well proven*
- *High cost to re-establish*

vs.

- *Low cost to retain*

Post-IAT: San Diego Incident (Jan 2007)

- **Inadvertent interference**
  - *Single location, no attempted deception*
  - *Self-discovered & corrected in less than 4 hours*
- **Impacted many users, these & more:**
  - *First responder paging & dispatch routing*
  - *Harbor safety & security, including USCG AIS & DGPS*
  - *Aviation navigation & communications*
  - *Cellular telephones & other networks*
- **Best detection technology today & projected**
  - *36 hours to localize within a mile*
  - *Then door-to-door search*
- ***With eLoran would have operated through***
  - *All applications above & unidentified others*
  - *Instantly & seamlessly*

This is not the only incident, but the best studied

Post IAT: Federal Register Notice (Jan 2007)

- **Released 8 January 2007**
  - *Jointly release by DOT & DHS*
  - *USCG action office & docket # USCG 2006-24685*
- **Regarding possible actions on future of US Loran**
  - *Develop & deploy eLoran*
  - *Maintain current Loran-C*
  - *Decommission Loran infrastructure*
- **Response**
  - *Approximately 1000 responses*
  - *Overwhelmingly supportive of need for Loran continuation (& upgrade to eLoran)*

Formal IAT Report Briefings (Jan-Oct 2007)

- **US Government officials**
  - *Dep Sec DOT & DHS, Under & Asst Sec DoD, Asst Admin FAA & NGA, Asst COMDT USCG, Deputy CIO DNI, others*
  - *OMB & NSC; Natl PNT Coordination Office; Natl PNT Architecture (NSSO), Joint Program Dev Office (JPDO)*
  - *DoD PNT SWarF, DOT Extended POS/NAV Executive Committee, DHS Geospatial/PNT Executive Committee*
    - **Key to decision at March 2007 National PNT Executive Committee meeting – assigned to DOT & DHS to implement**
- **Outside US Government**
  - *Natl Security Telecommunications Advisory Committee*
  - *UK Ministry for Transport's "Cross Government" meeting*

eLoran Standards – work in progress

- **Radio Technical Commission for Maritime Services (RTCM)**
  - *eLoran signal in space & user equipment*
  - *RTCM special committee 127 (SC-127) established 2007*
- **International Association of Lighthouse Authorities (IALA)**
  - *e-Navigation standards for maritime operations*
    - **Electronic Charting & Display (ECDIS)**
    - **Electronic Nautical Charts (ENC)**
    - **Radionavigation systems (positioning inputs) – two needed: GPS/DGPS & eLoran**
  - *Consultative group established summer 2007*

Status of eLoran (October 2009)

- **Critical PNT applications remain vulnerable**
  - ***Maritime, aviation, land mobile, and time & frequency***
- **eLoran ready to be US (& global) PNT backup**
  - ***For assured, robust PNT for "big four" user groups (above)***
- **US decision: *eLoran is national backup***
  - ***Policy decision at March 2007 National PNT ExCom***
    - **Congressional support FY2008 appropriations**
  - ***Announced by DHS February 2008***
    - **Continued Congressional support FY2009 appropriations**
    - **Affirmed in Federal Radionavigation Plan, January 2009**
- ***Apparent reversal* in FY2010 budget, January 2009**
  - ***Terminate Loran-C (with no "new start" for eLoran)***

Loran-C may be obsolete (as some say) & can go, but *eLoran is essential*

Would Users Equip with eLORAN?

- **Necessary conditions**
  - ***USG commitment (at least 15 years)***
  - ***UE available at small incremental costs***
- **Motivation**
  - ***Rules and regulations***
  - ***Perceptions of threat***

IAT believes speed of equipage (after necessary conditions met)
Will be driven by future events not now predictable

The USG should assume responsibility to have an affordable backup to GPS in place

Closing Thoughts

- **GPS/GNSS is a "PNT utility"**
  - *Critical national & global infrastructure*
  - *Users not limited to professional navigators*
  - *But include everyone – some don't know they use it*
- **Future is integrated user equipment**
  - *GPS/GNSS is the "global position and time grid"*
  - *Integrate with other sensors to extend into challenged environments*
  - *Integrate to function of host system*
- **eLoran is essential element of the future**
  - *Mere $36M issue in US budget*
  - *Let's make sure we do the right thing*

Questions

James T. Doherty

703-578-2710

jdoherty@ida.org

Backup

Key Questions

- **To what degree, & in what way, is GPS vulnerable to persistent outages or local transient discontinuities?**
- **What are the impacts of such events for safety-of-life, economic disruption, or inconvenience?**
- **What techniques or alternatives are available as to ameliorate such situations?**
- **In what time frame & at what costs (& to whom) could such methods be implemented?**
- **To what degree would we expect the affected users to take advantage of these methods?**
  - ***What is the proper Government role?***
- **What course of action is most reasonable for DOT?**

Vulnerabilities and Backups

	Major Vulnerability	Best Mitigations
GPS System	**G1. Satellite Clock Failure** (e.g. SVN23 1 Jan 2004)	**Addl. Satellites, WAAS, RAIM** (30+X GPS, Galileo SBAS)
	G2. Poor Signal Quality (e.g. Evil Waveforms)	**Addl. Satellites & Signals** WAAS, RAIM (30+X GPS, Galileo SBAS)
	G3. Satellite Design Flaws (e.g. Block IIR ranging code interruptions)	**Multiple Ranging Signals** (WAAS warning + GPS, Galileo Addl. signals)
	G4. Control System Failure (Sabotage or ?)	**Use Differential Corrections** (WAAS, EGNOS, NDGPS etc.)
Signal	**S1. Intentional interference** (e.g. hackers or terrorists)	**Alt. Freq. & or Dissimilar system** (e.g. GPS L5, VOR/DME, or eLoran)
	S2. Unintentional interference (e.g. Moss Landing)	**Alt. Freq. & or Dissimilar system** (e.g. GPS L5, VOR/DME, or eLoran)
	S3. Ionospheric effects (e.g. scintillation at high lat. or equator)	**System with dissimilar Frequency** (e.g. eLoran)
Receiver or User	**R1. Receiver malfunction** (e.g. Royal Majesty, 1995)	**Redundant GPS receivers**
	R2. Signal occultation (e.g. Urban canyons)	**More SVs &/or Dissimilar system** (e.g.Galileo, SBAS, or eLoran)

Backup Alternatives to GPS

GPS needs dissimilar, complementary, multi-modal, & independent source of GPtS & PNT

Service	PNT	Multi-Modal	Independent of GPS		
			System	Signal	User
Galileo	✓	✓	✓	✗	✗
eLoran	✓ (no 3D)	✓	✓	✓	✓
DGPS	✗	✓	✗	✓	✗
SBAS	✗ ✓	✓	✗ ✓	✗	✗
Radar, VOR/DME, ILS	✗	✗	✓	✓	✓

eLoran is frequency & signal diverse as well as much more powerful (virtually unjammable)

If not eLoran – Current Backup Plans

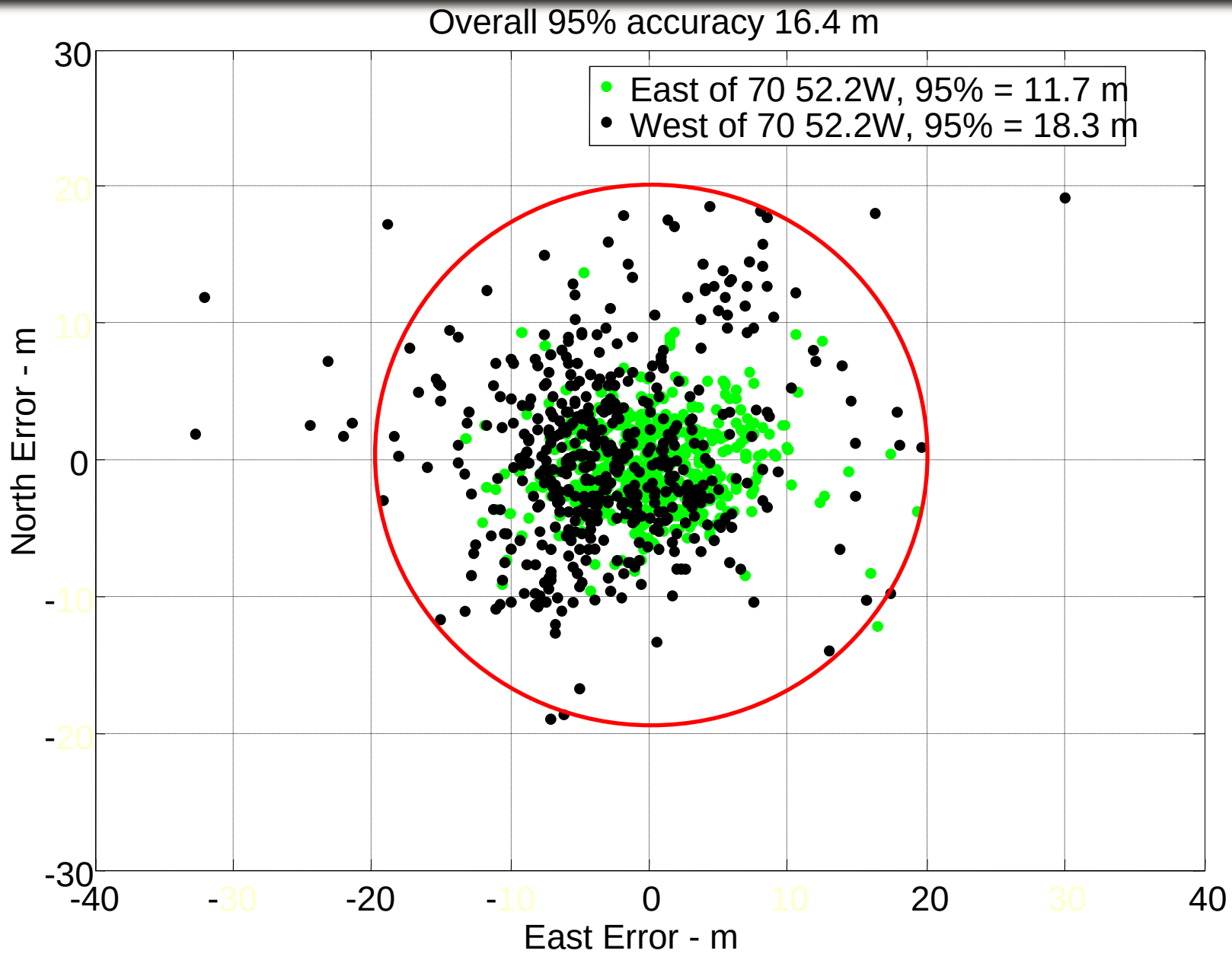
Mode	Applications	Backup
Aviation	• **Precision Approach** • **Non-Precision Approach**	**Traditional Ground-Based Navigation, Procedures**
Maritime	• **Harbor & Harbor Approach** • **Constricted Waterway**	**Conventional Navigation Methods**
Land	• **Tracking Radioactive Items** • **Collision Notification**	**Conventional Procedures, Dead-Reckoning, etc.**
Positioning	• **Survey & Geodesy**	**Optical and Inertial Systems**
Timing	• **Communications, Power Grids, etc.**	**Loran-C, WAAS, Clocks**

Source: National Space-Based PNT Coordination Office

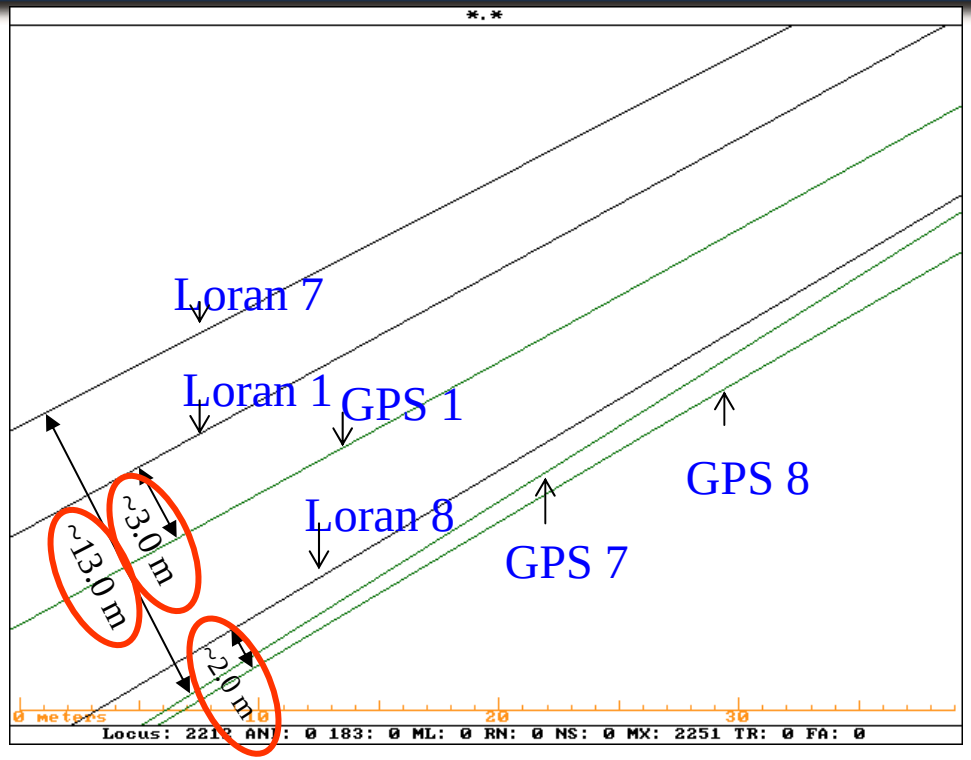
eLoran (upgrades well demonstrated)

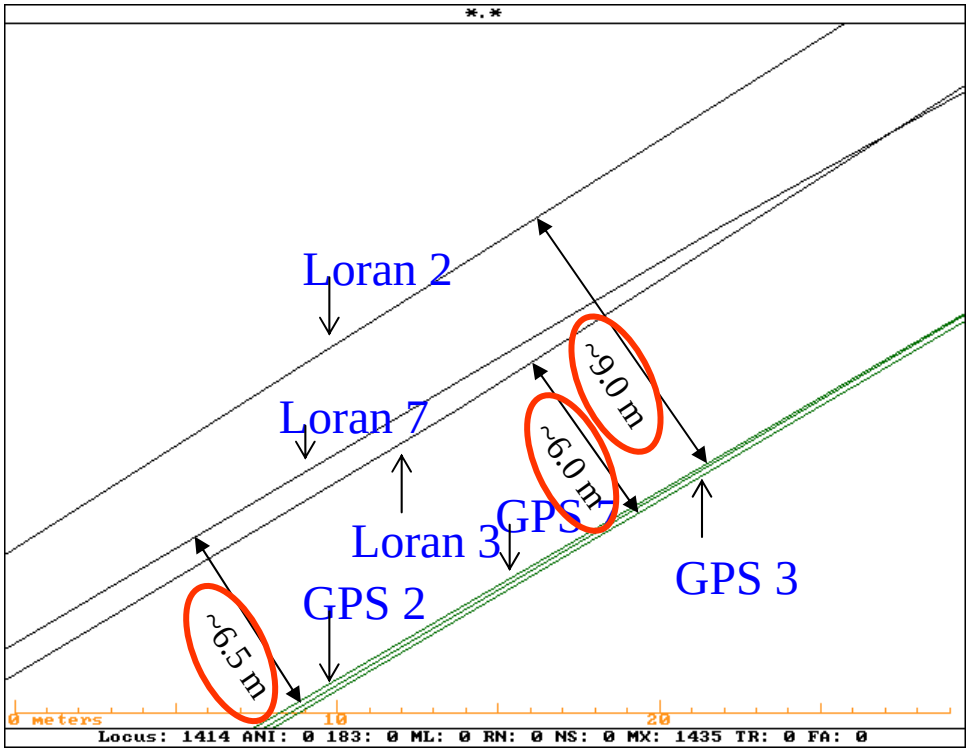
- **Upgrade of Loran infrastructure & operations concept**
  - *Signal in space updated for digital use (GPS-like, digital user equipment)*
  - *Time of arrival (TOA) or "pseudo-range" navigation (same as GPS)*
  - *New Messaging channel increases position & time accuracy using differential Loran (About 10-20m within 20 miles from monitor)*
  - *Backward compatible for legacy users*
- **"All-in-view" navigation**
  - *All masters & secondary transmitters directly synchronized (<20ns) enabling "cross chain" or "all-in-view" navigation*
  - *User stores or calculates Additional Secondary-Phase Factor (ASF) corrections for improved accuracy*
  - *All received signals useable (improves geometry/accuracy, extends coverage)*
- **eLoran transmitter stations**
  - *Solid state transmitters – "soft fail" devices*
  - *Emergency generators & full transmitter battery – no "momentaries"*
  - *Ensembled atomic clocks at each transmitter (compatible with GPS, yet independent of GPS)*

Boston Harbor – eLoran Accuracy



Non-Precision Approach (NPA) Flight Test Results

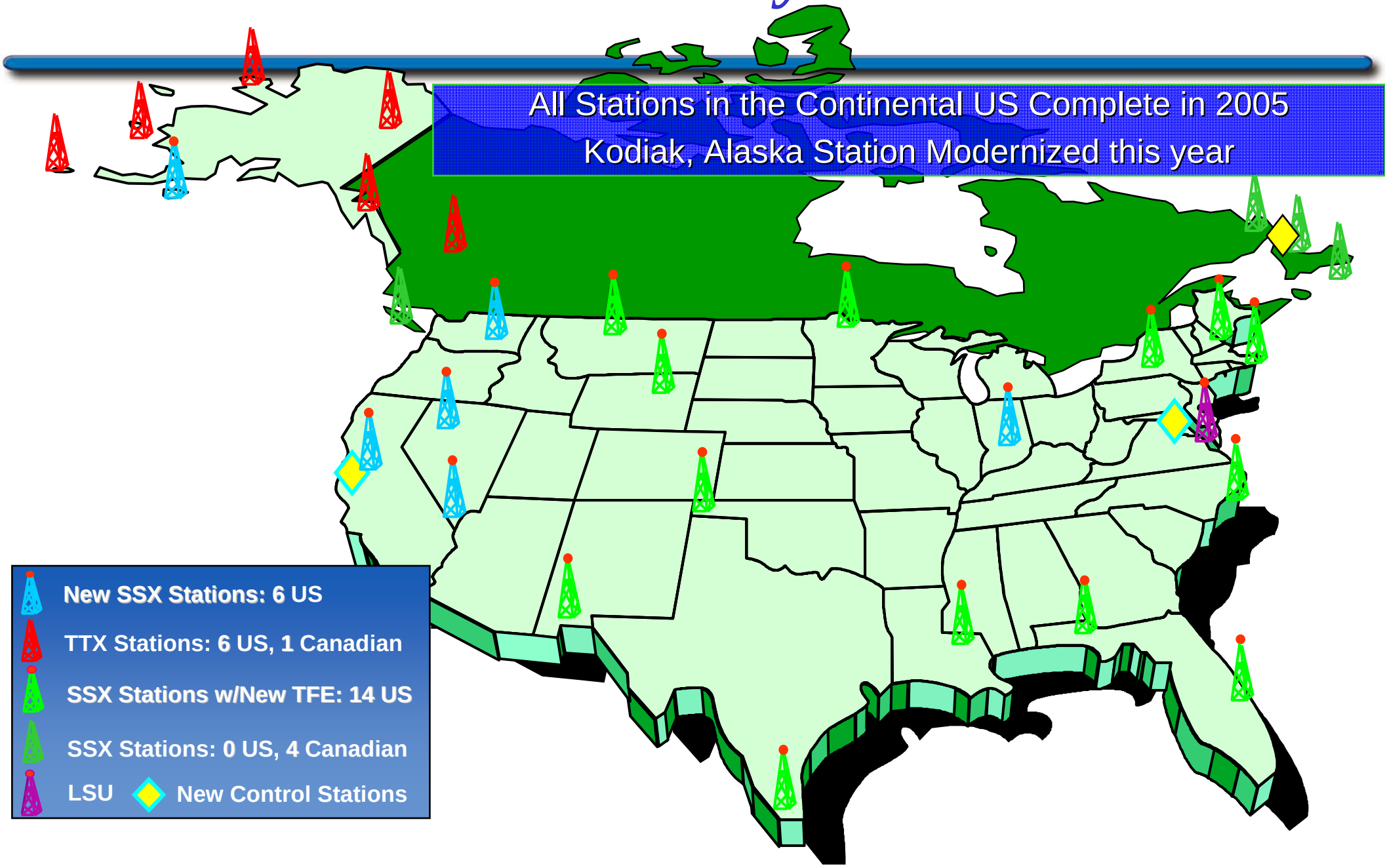




NPA Requirement: 307 m

North American Loran System

All Stations in the Continental US Complete in 2005
Kodiak, Alaska Station Modernized this year



eLoran Costs

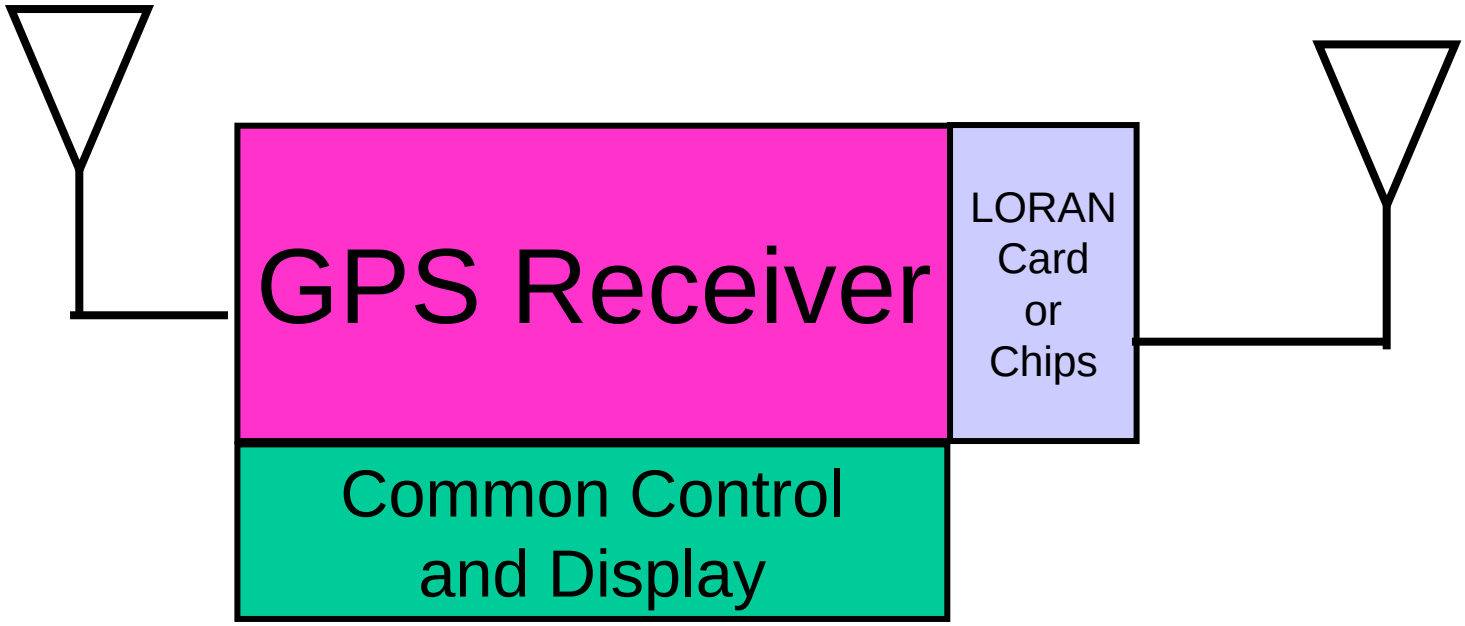
- **Nonrecurring eLoran funds to date (provided to FAA)**
  - *FY 1997-2006: $159M (FY 2001-2006: $17M - $25M per year)*
  - *Completed existing transmitters, building modifications, etc. in CONUS & began in Alaska (first of six transmitters completed)*
- **Decommissioning costs of current infrastructure**
  - *USCG estimate $146M (~$97M of this in Alaska)*
- **Operations & maintenance (recurring funds – currently in USCG base)**
  - *Currently $37M per year*
  - *eLoran estimate ~$15M per year*
- **Personnel impact of eLoran**
  - *Currently 283 USCG personnel*
  - *Reduce to less than 41 government plus 55 contractor*

IAT Assessment of Costs

- **Based primarily on USCG reported costs – overbound of costs**
- **For eLoran in CONUS**
  - *eLoran upgrades remaining* — *$ 51M (nonrecurring)*
  - *eLoran expansion (4 xmtrs @ $15M)* — *$ 60M (nonrecurring)*
  - *Major maintenance (backlog & deferred)* — *$ 44M ($2.2M/yr for 20 yrs)*
- **Alaska**
  - *eLoran upgrades remaining* — *$ 32M (nonrecurring)*
  - *Major maintenance (backlog & deferred)* — *$245M ($12.25M/yr for 20 yrs)*
- **Initial assessment**
  - *Provide additional nonrecurring funds – $143M (over 5-8 years)*
    - *$111M to complete eLoran in CONUS*
    - *$32M to complete eLoran in Alaska*
  - *Reduce current O&M ($37M/yr) thru eLoran economies*
    - *Begin with available economies available in CONUS today*
    - *Apply savings to major maintenance*
- **Full eLoran is achievable within current funding**
  - *$20-25M/yr acquisition funds (currently in FAA) for 5-8 years*
  - *$37M/yr (currently in USCG) for life of system*

Discussion of Loran User Equipment

- **Manufacturers**
  - ***Have demonstrated "all-up" prototypes***
  - ***Incremental manufacturing cost <$300 in volume***



- **Stand alone Cost <$1000 in volume**

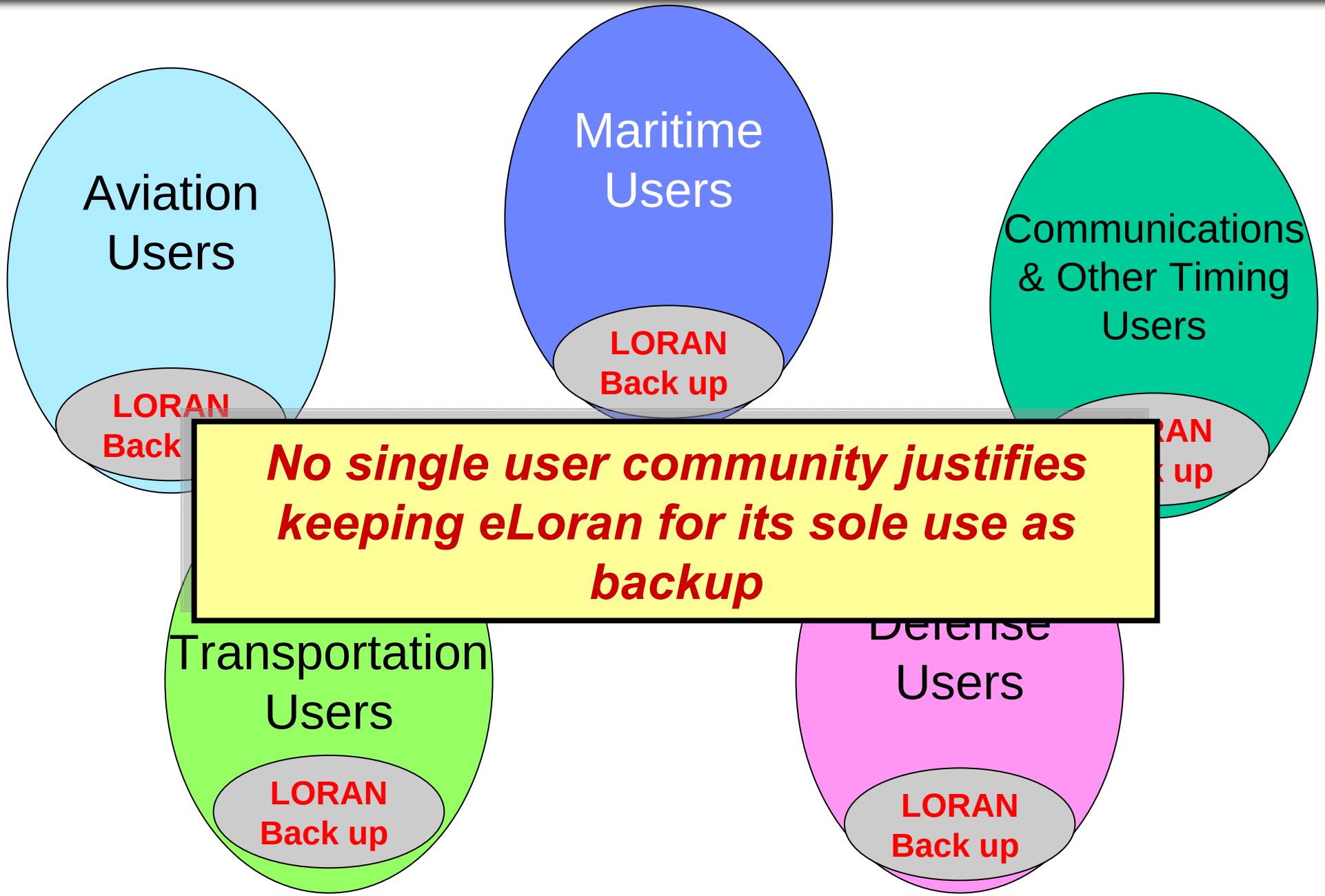
Discussion of User Equipment

- **Impact of GPS on Loran**
  - *User equipment industry shifted from Loran-C to GPS by early 1990s*
  - *Loran-C receivers are old analog designs & virtually impossible to find (even used)*
- **Small niche eLoran industry developed recently**
  - *Based on Congressional eLoran funding (beginning FY1997 & continuing)*
  - *Universities, individual researchers, & 4-6 small/medium companies interested*
- **Essential technical developments needed for eLoran user equipment**
  - *Digital receivers – virtually identical signal processing for eLoran & GPS signals*
    - **Enables integrated GPS-eLoran receiver sets**
    - **Stores & applies local databases (eg, ASF correction tables)**
    - **Processes Loran data messages**
  - *H-field antennas – eliminates former Loran-C aviation "p-static" problems*
- **Several (at least 3) integrated GPS-eLoran receiver products**
  - *Available within a few months in up to10K quantities for $700-1000 each*
  - *Plans to reduce unit price within a year to <$100 if approaching quantities 100K assured*
  - *None yet certified for aviation (RNP 0.3, NPA) –universities & researchers have tested & continue to test various models in flight situations*

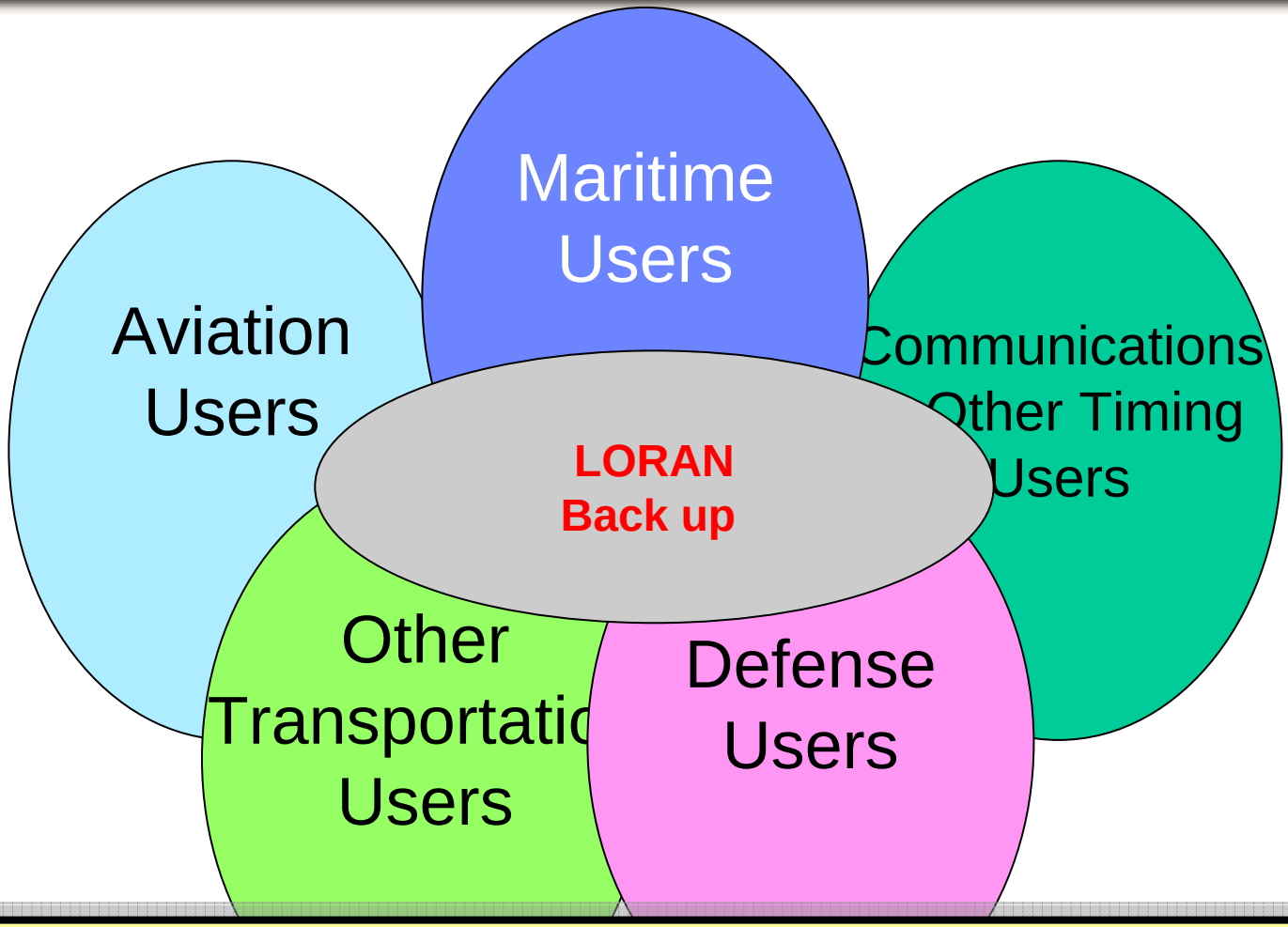
Discussion of User Equipment

- **Market research**
  - *At least two firms report robust potential markets for combined GPS-eLoran user equipment – unit cost ranging $400-$7000*
  - *Major selling point reported is reliability (to continue operation if GPS is interrupted and to deter intentional disruption of GPS)*
  - *Additionally to enhance GPS (for example, inside buildings or with additional capabilities, such as authentication messages for assured location-based services & security)*
- **User categories & market size (# potential units)**
  - *Maritime (GPS backup) – 750K*
  - *Military & first responder (GPS backup & indoors) – 32K*
  - *Fleet management (GPS backup) – 1000K*
  - *Timing (cell towers, TV, cable—GPS backup & assured location based services) – 27K*
  - *Network servers (indoors & GPS backup) – 1000s/yr.*
- **One researcher estimates market value**
  - *$1.1B today*
  - *Growing to $2B by 2010*

Current Situation – GPS is Primary



Combined Community Need – GPS Primary



But an ensemble of users needing backup could support continuing eLoran

Summary of Findings (1)

- **eLoran is Independent of, but compatible with, GPS**
  - ***Source of both position & time information***
- **eLoran is robustly engineered system**
  - ***Ensembled frequency standards at each transmitter***
  - ***Soft-fail transmitter & uninterruptible power supply***
- **Most users will not *now* voluntarily equip with a "backup" system**
  - ***Interference threats could rapidly change perception***
  - ***Regulation and/or incentive programs would speed more widespread use***

Summary of Findings (2)

- **eLoran is not yet completed**
  - ***Transmitters in CONUS completed***
  - ***Transmitters in Alaska & Canada need eLoran upgrade***
  - ***Differential Loran sites needed, ports & other locations***
    - **For harbor accuracy**
    - **For time accuracy**
  - ***Additional transmitters needed***
    - **For maritime coverage in southern Florida/Caribbean & southern California**
    - **For aviation integrity in Midwest**
- **eLoran costs must be reduced if system persists**
  - ***Reduce/eliminate transmitter staffing***
  - ***Relocate transmitters to more accessible sites in Alaska***

Summary of Findings (3)

- **There is no eLoran user equipment**
  - ***Legacy Loran (Loran-C) receivers no longer available***
  - ***Loran-C receivers will not provide eLoran benefits***
- **Prototype eLoran user equipment exists**
  - ***Several companies pursuing integrated GPS & eLoran receivers***
  - ***Cost <$1000 in 10K unit quantities; anticipate reduce to <$100 in 100K quantities***

Summary of Findings (4)

- **Principal threat to GPS is deliberate or inadvertent jamming of the GPS signals**
  - ***This would be local and could cause significant disruptions in GPS service. Particularly:***
    - **Timing**
    - **Harbor Entrance and Approach (particularly congested harbors)**
    - **Aircraft Non Precision Approach**
  - ***Government Agencies generally have some form of backup***
    - **Economic costs of such disruptions could still be substantial**
  - ***Some risk to safety of life, but it is probably low***
- **Enhanced and modernized eLoran has been well-demonstrated, could quickly be operational (less than 3 years)**
  - ***The Europeans have continued to upgrade their LORAN and are already operating "unmanned"***
  - ***Full Investment cost < $250M more than cost of total LORAN deactivation (~$143M)***
  - ***Operating costs (as demonstrated by the Europeans) ~$15M per year, requires changes in USCG operating policies***

Summary of Findings (5)

- **eLoran is capable of being a backup for most GPS-enabled critical applications**
  - ***Important Missions***
    - **Aviation – RNP 0.3 & NPA**
    - **Maritime – harbor entrance & approach**
    - **Time & frequency – 50 ns & stratum 1**
  - ***As an addition to a GPS receiver, the manufacturing cost should be less than $300***
- **As a backup to GPS**
  - ***A good backup such as eLORAN may be an effective deterrent to hackers or terrorists deliberately interfering with the signals GPS***

Conclusions

- **Reasonable assurance of national PNT availability is a prudent and responsible policy**
- **Fully upgraded eLORAN is a very cost effective backup to GPS**
  - ***Particularly useful for Timing, NPA and HEA***
  - ***Incremental net investment of ~$250M***
  - ***Also has some deterrent value***
- **With USG support for the system, users expected to gradually add the eLORAN backup**
  - ***It wll become an economically appealing insurance policy (Δ cost for mfr. ~$300)***

Unanimous Recommendations of IAT

- **Retain eLoran as primary backup for critical GPS applications**
  - ***Fund completion of eLoran***
  - ***Commit to 20 years***
- **Develop funding plan for completion of eLoran**
  - ***Add differential sites for maritime & timing needs***
  - ***Review alternatives for reducing costs in Alaska***
  - ***Add transmitters for maritime & aviation use in CONUS***
- **Convert to unmanned model (as in Europe)**
  - ***Goal $15M/year operating costs***
- **Stimulate receiver development & equipage**
  - ***Integrate eLoran as backup within GPS receivers***
  - ***Reduce costs through mass production***
  - ***Consider regulation or incentives for equipage in key applications***