GNSS/eLoran for Timing and Frequency

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Journée utilisateurs GNSS / Loran C
Ecole Nationale Supérieure des Techniques Avancées
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Outline

- My Main Message
- Where precise time and frequency are used – today and in the future
- The sources of precise time and frequency
- Advantages of eLoran for time/frequency applications
- Example eLoran results
- eLoran receivers and antennas
- My Main Message

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My Main Message

Today, time and synchronization (i.e. frequency) are critical to the operations of all modern societies and to the daily life of all citizens. The provision of precise time and frequency has greater economic, social and political importance than the provision of navigation capabilities.

The demand for more precise time and frequency will grow with the evolution of technology, and therefore each country's dependence on time/frequency will grow (and each nation's vulnerability to disruption will be greatly increased).

GNSS are sources of time and frequency, but they share the same vulnerabilities. Loran is another source of precise time and frequency that does not share these vulnerabilities, and can operate as an independent, infinite backup to GNSS.

The combination of Loran and GNSS provides an extremely robust precise time and frequency system that will meet future technical needs and simultaneously make national infrastructures stronger, citizens safer, and the world more stable.

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Examples Where Precise Time and Frequency Sources are Used Today – and Our Dependence on GPS

Cellular Phone Systems (e.g. GSM)

Process Automation (e.g. factories)

Computer Networks (e.g. NTP servers)

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Examples Where Precise Time and Frequency Sources are Used Today – and Our Dependence on GPS

Power Grids

Financial Transactions (e.g. stock trades, banks, billing)

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Examples Where Precise Time and Frequency Sources will be Needed Tomorrow

Voice over Internet Protocol (VoIP)

Broadband or Next Generation Networks (e.g. multimedia real-time services such as video conferencing)

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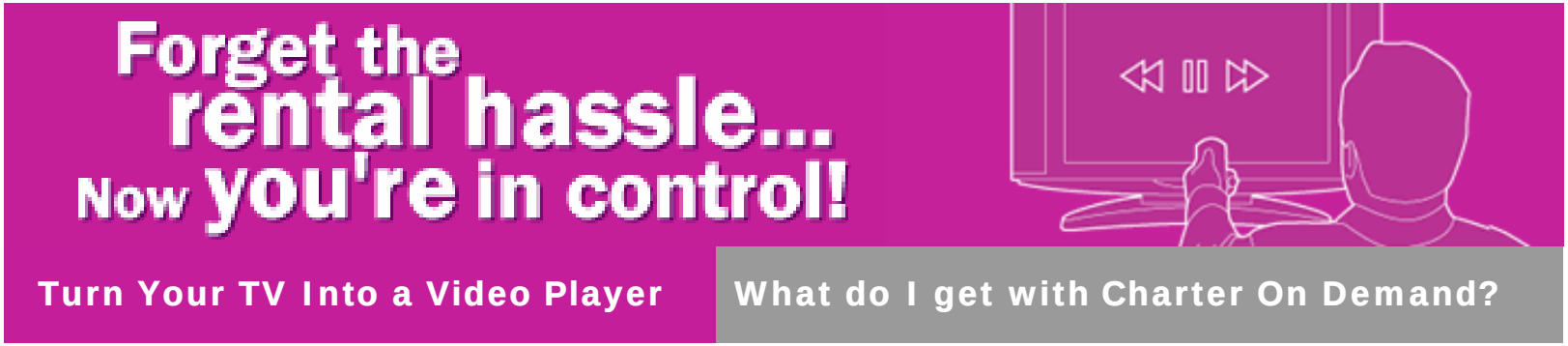
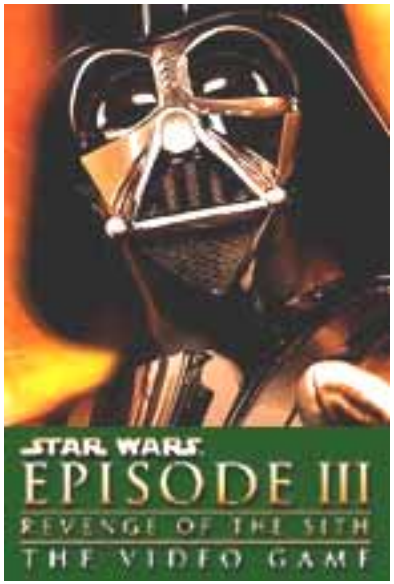
Examples Where Precise Time and Frequency Sources will be Needed Tomorrow

Your family - Video on demand (VOD):



Video gaming:



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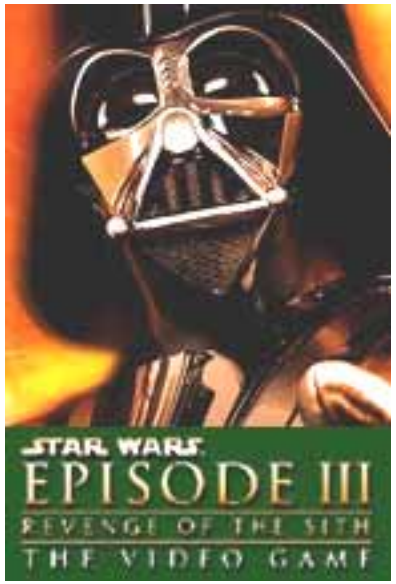
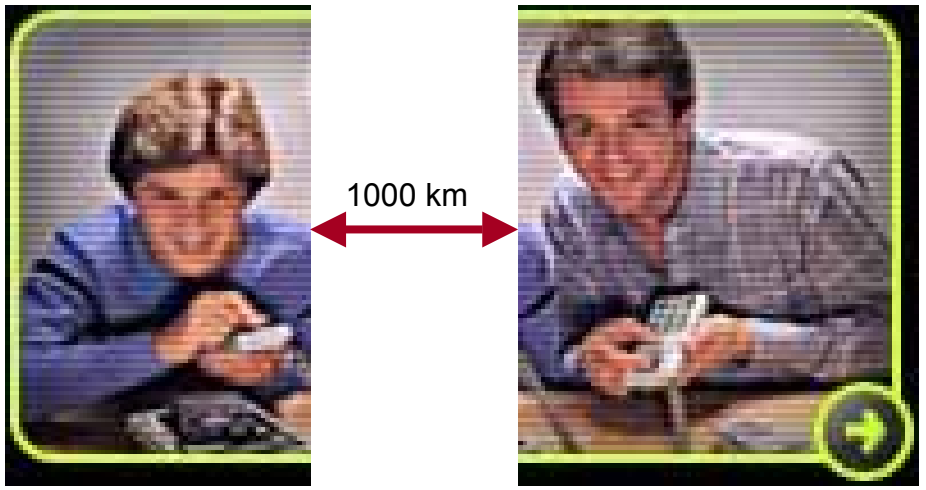
Examples Where Precise Time and Frequency Sources will be Needed Tomorrow

Video gaming:





What if users are in different residences, cities, or countries?

Future networks will require better synchronization not only at the main hubs but also toward the edges of the networks.

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Obviously, critical operations in virtually all aspects of our societies rely on time and frequency provided by GNSS, and GNSS disruption could result in enormous safety, economic, and social consequences.

Our dependence on precise time and frequency will grow in the future, and it is easy to disrupt GNSS.

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Sources of Precise Time and Frequency

Frequency – Primary Reference Sources:

1. Cs oscillators – very expensive and do not provide time
2. Hydrogen Masers – extremely expensive and do not provide time
3. GNSS
4. eLoran

Time:

1. GNSS
2. eLoran

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Because eLoran can act as in infinite backup to GNSS for both time and frequency, eLoran can virtually eliminate infrastructure vulnerabilities due to over reliance on GNSS.

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Practical Advantages of eLoran for Time and Frequency Applications

For users:

1. Provides infinite, traceable backup to GNSS (i.e. other sources can only provide backup capabilities for a limited time, and are not traceable to a source).
2. Can provide time and frequency (i.e. like GNSS)
3. Not subject to GNSS vulnerabilities (e.g. a local, unintentional jammer)
4. Only one eLoran transmitter is required to obtain time and frequency, and typically several eLoran transmitters can be tracked simultaneously (i.e. greater reliability)
5. Much less expensive than Cs or H Maser (i.e. the only other Stratum 1 sources)
6. Signal penetration can enable site location where difficult with GNSS
7. No periodic calibration required
8. H-field antennas require no ground, reduces installation costs
9. Offers opportunity for indoor reception

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Practical Advantages of eLoran for Time and Frequency Applications

For providers (i.e. governments):

- Multimodal (e.g. serves multiple navigation and time/frequency communities)
- Extremely inexpensive/cost-effective to operate
- Host nation controls system (i.e. independence)
- Strengthens national infrastructure
- Government can ensure system quality (e.g. traceability)

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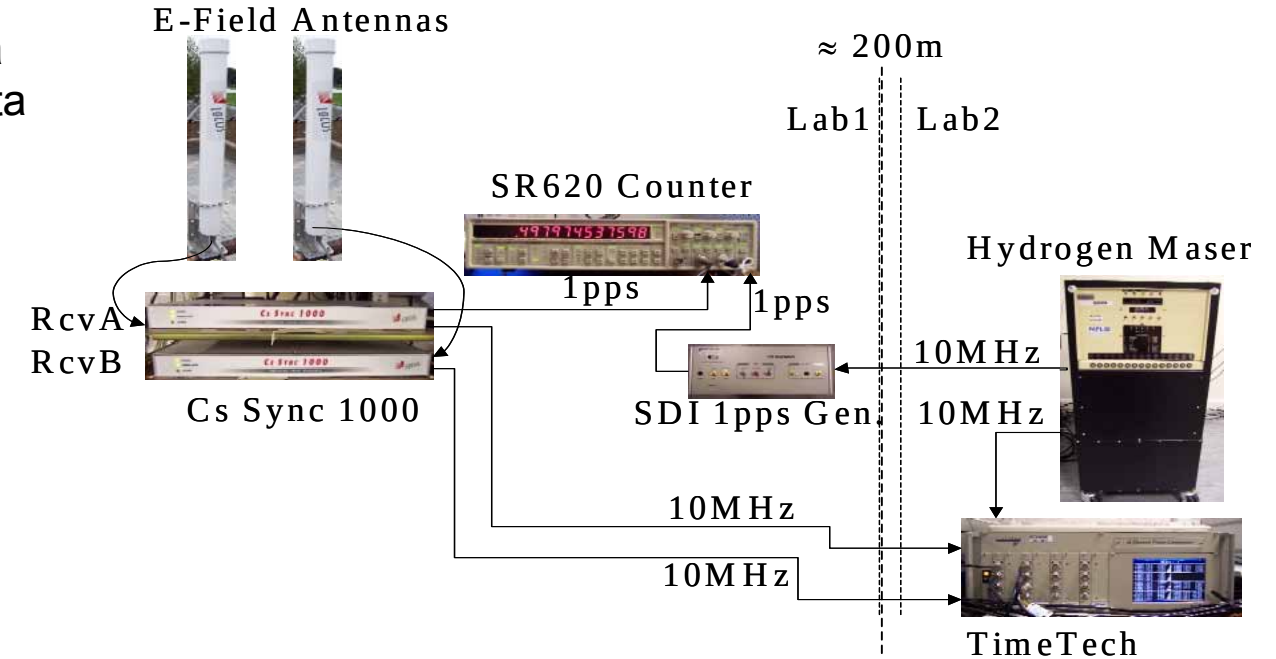
France's Loran System Currently Provides Excellent Performance – Tests using Lessay

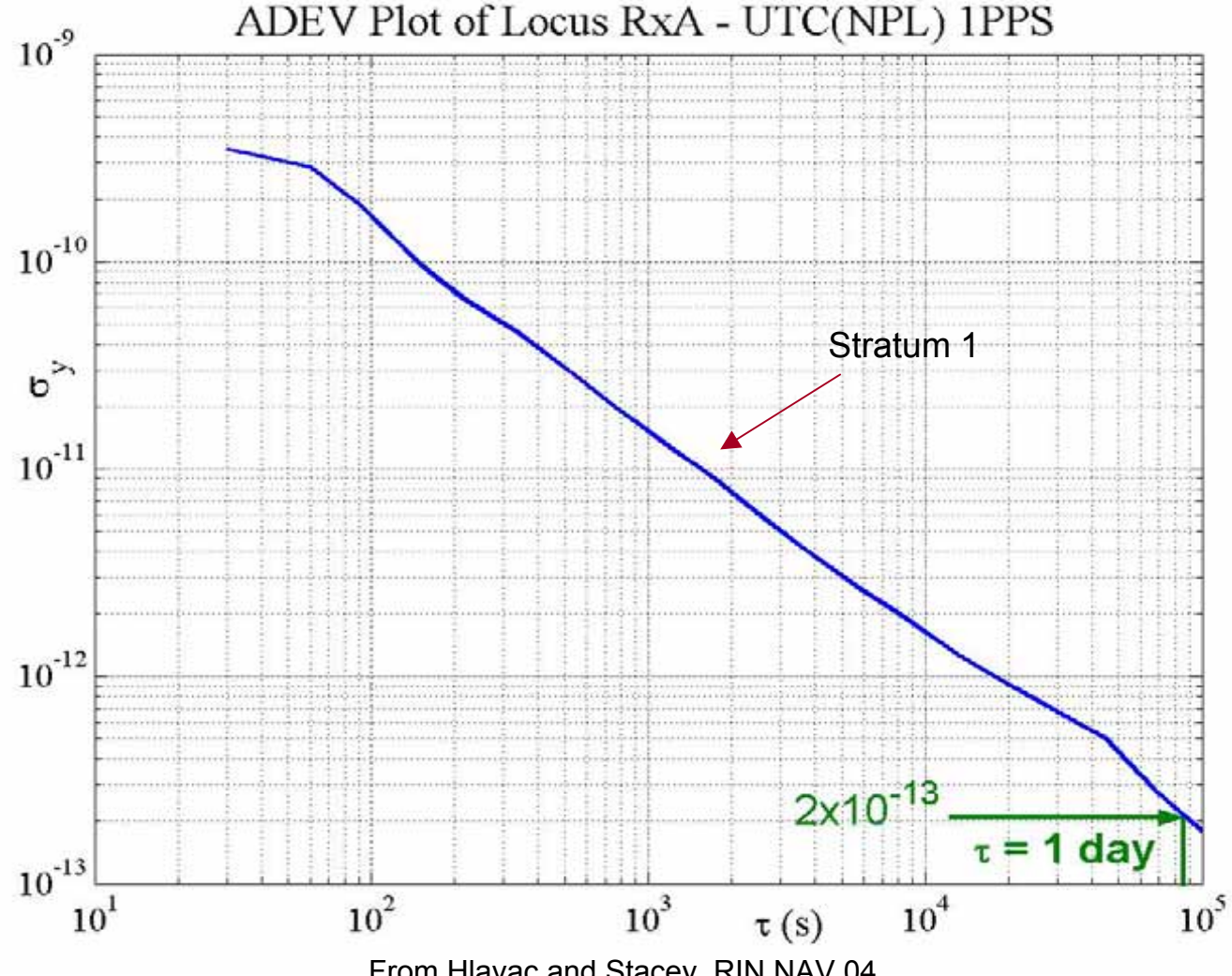
- NPL – **similar to BPM**
- NPL tests 9thJune – 6th September 2004
- **Receivers locked to Loran-C station in Lessay, France**
  - Rcvrs 10MHz output (derived from Lessay)
  - Rcvrs 1pps output not aligned to UTC
- Sampling rate
  - 30s for 1pps data
  - 10s for phase data
- Common-view studies shortly



NPL Test Setup

France's Loran System Currently Provides Excellent Performance – Tests using Lessay

- Fractional frequency
  fr= (f-f0)/f0 [-]
- Frequency stability
  (Allan deviation)
  2x10 -13 (τ= 1 day)
- **Comparable to Cs clock**
- Better than MSF
- Similar results to
  TSC/USCG/NIST tests



From Hlavac and Stacey, RIN NAV 04

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NPL

An Example of Indoor eLoran Reception

Recent indoor Loran tests

H-field antenna

CsSync eLoran receiver

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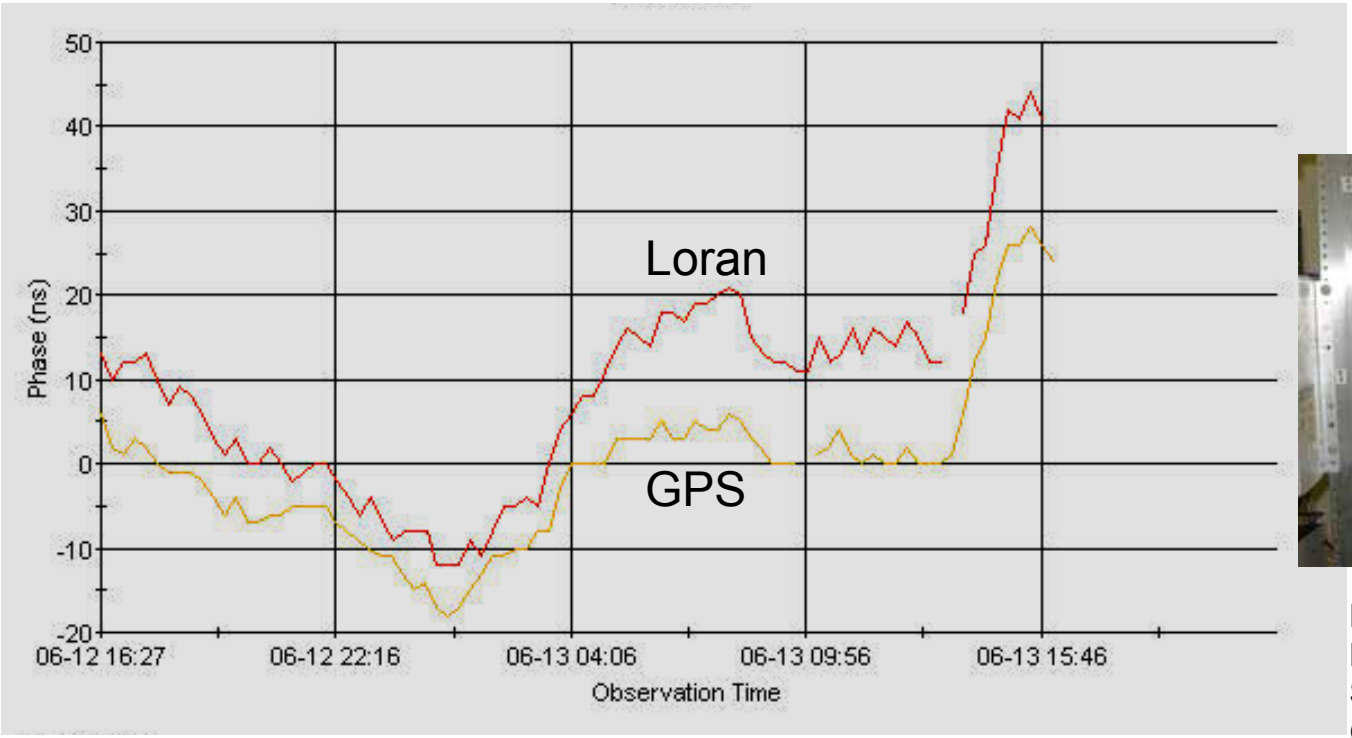
An Example of Indoor eLoran Reception



Measured by SSU – 2000 BITS Clock with internal Stratum 2E clock locked to GPS with 9000 second Tau

Phase stability of indoor Loran < +/- 30 ns over 24 hours

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eLoran Receiver Technology

- A single source for time and frequency

- Can be combined with GPS or Galileo in a single system

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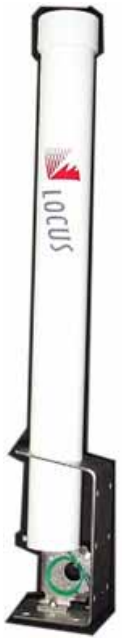
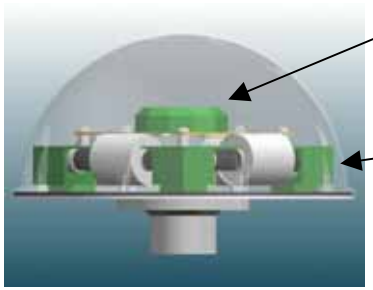
eLoran Antenna Technology



E-field - short (46 cm)

H-field - small (20x10 cm)
- no ground required

Combined GPS/H-field antennas



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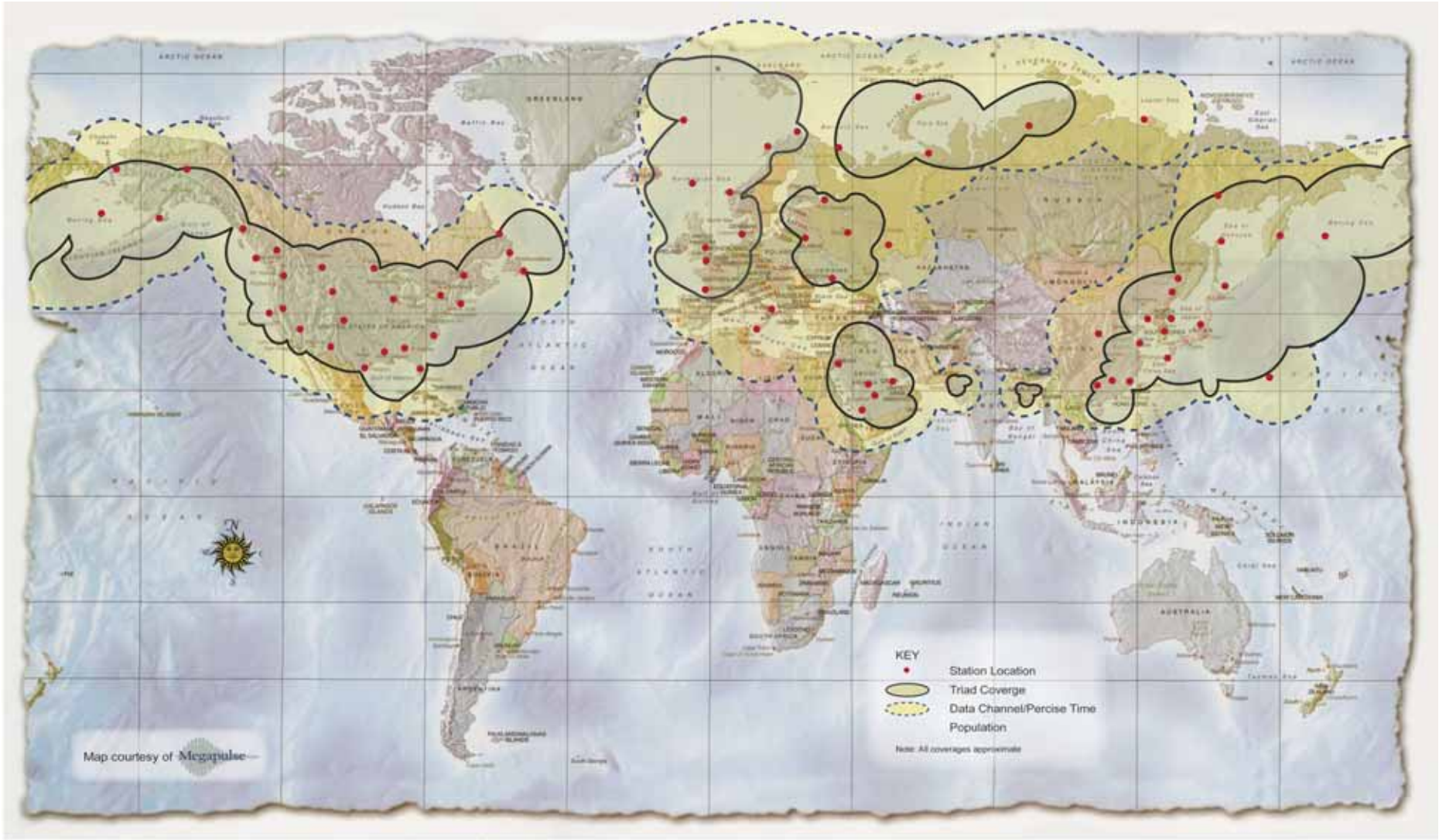
World Loran Coverage 2005



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Why Backup Systems Make Good Sense – Cellular Base Station Examples from Motorola

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GPS Alone Cannot Provide Necessary Reliability

Real Life Problems Encountered by Motorola:

- **Unintentional Jamming**
  - **Television Stations**
  - **Spurious Emissions by Paging Transmitters**
  - **Unknown Sources**
  - **Known Sources (e.g. Phoenix and Rome, NY)**
- **Intentional Jamming**
  - **US government tests**
- **Poor Satellite Reception**
  - **Urban Canyons**
  - **Ice / Snow Buildup on Antennas**
- **GPS Satellite Failures**
  - **September 1995 (SVN10)**
  - **March 18, 1997 (SVN35)**

From Walsh, ILA31, October 2002

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