Loran's Role in Future PAT

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A Few Comments and Observations

- Critical Infrastructure refers to both safety, security, and economic vulnerabilities.
- Safety-responsible administrations by nature are public and slow moving.
- Loran certainly, and GPS often, are thought of as Navigation Systems especially by service providers.
- Industry sees things differently, e.g. “Trimble is a leading provider of advanced positioning solutions that maximize productivity and enhance profitability.” Nearly two thirds of Trimble revenue is from Agriculture and Machine Control Systems (not navigation). Loran would be gone if GPS had merely supplanted the Loran user base with higher performance and lower cost.
- The eLoran initiative early on recognized that Loran-C needed to be modernized to meet higher performance requirements if it were to serve a role in future PNT infrastructure.
- Bad Policy or No Policy? Current policy is artificial impediment to market development. It results in inefficiencies in how Government invests in system development and prevents industry from realizing its potential.
- The correct question is not “How does Loran compare to GPS?” but rather “What information types does Loran offer and what applications are enabled?”

The information types of PAT

- Position:
  - Location, place where something is in relation to other things
  - This recognizes TDs, MGRS, WGS84
- Azimuth:
  - Orientation, direction in which something lies or faces
  - Most useful with position info if it is True North
- Time:
  - Moment at which something takes place,
  - Relative is frequency, absolute is time

The Megapulse To-Market-Strategy:

- Leverage information types into “friendly” segments.
- Develop hybrid products where Loran brings added value.

Quantifying Loran "Friendly" Market Potential

- Neither regulation nor incentives are needed, just policy affirmation that Loran will continue well into the future.
- The total market for GPS products worldwide today is estimated at $16 Billion with growth rate of about 20%, varying by application from near zero in aviation to high rates in personal communication devices.
- Conservatively assuming addressable percentages of:
  - 40% for timing (telecomm and cell systems)
  - 12.5% for aviation (predominately general aviation)
  - 10% for marine (excludes largest group of price sensitive recreational boaters)
  - 5% for fleet tracking (high value or security)
- Total Addressable Market for the 4 Segments using percentages above would be ~$500M (just over 3% of the total market).
- The expected adoption of the integrated technology into these growing markets results in an annual industry volume of >$400M in just 4 to 5 years.

Commercial eLoran Smart Antenna

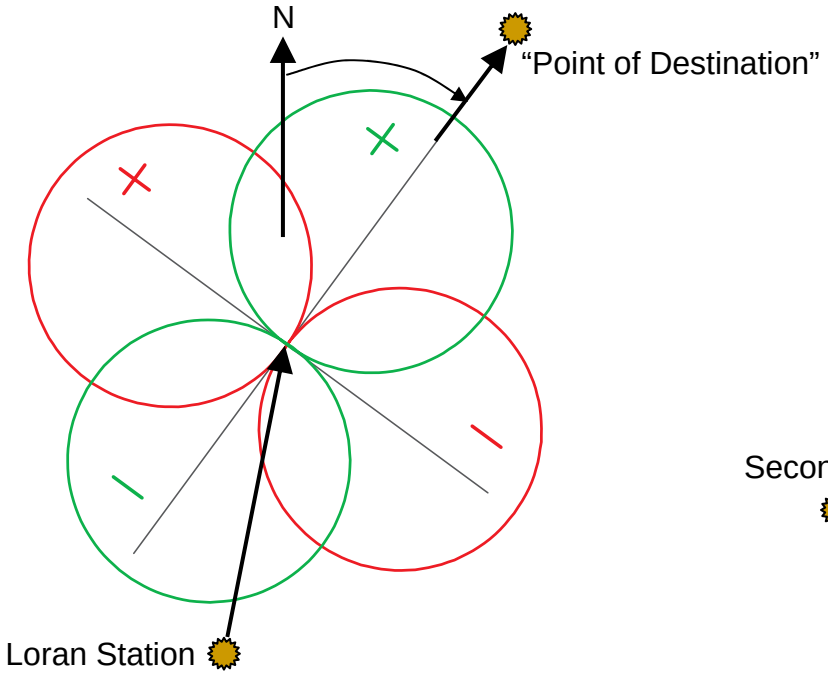
- **Product**
  - Integrated GPS/WAAS/Loran
  - Power in and data out
  - Accurate True North compass from crossed loop antenna useful for driving heads up displays
  - True legacy Loran TDs
  - Loran calibrated by GPS fixes
  - Interfaces to CMAP systems
- **Pricing**
  - ~$700 retail – GPS/WAAS only system retails for $300, incremental cost for eLoran is $400 and will be less in future

Developing Products Where Loran Can Add Value

- An Example: Digital all in view eLoran receivers with H-field antennas permit high accuracy true north azimuth determination.
- Getting the product right
  - What level of accuracies are obtainable?
  - What is the potential to reduce:
    - price,
    - form,
    - power consumption?

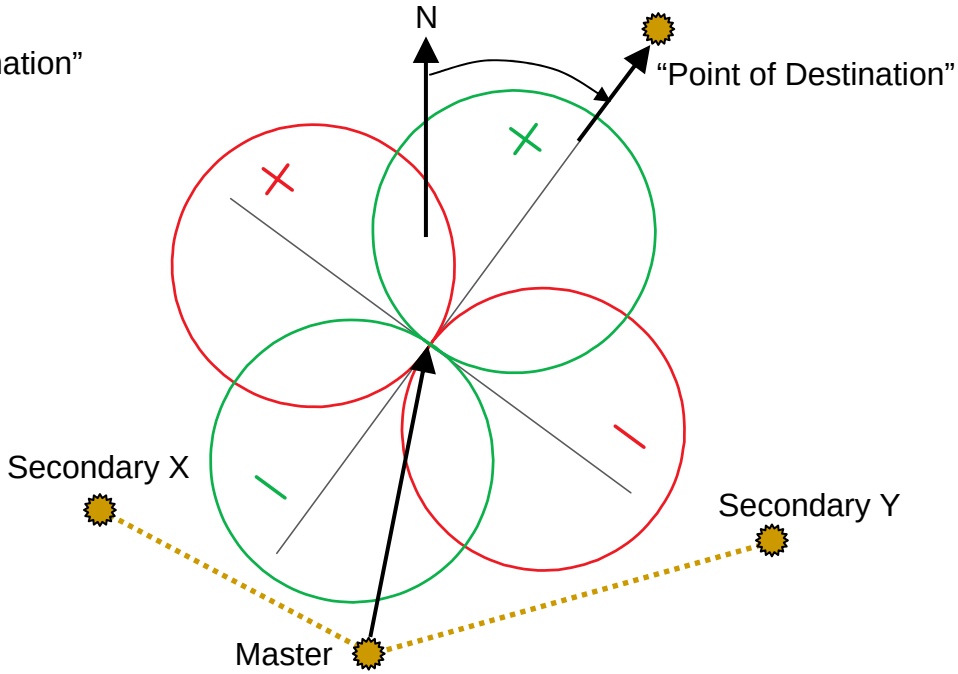
Azimuth Calculation

GPS +1 Loran Station



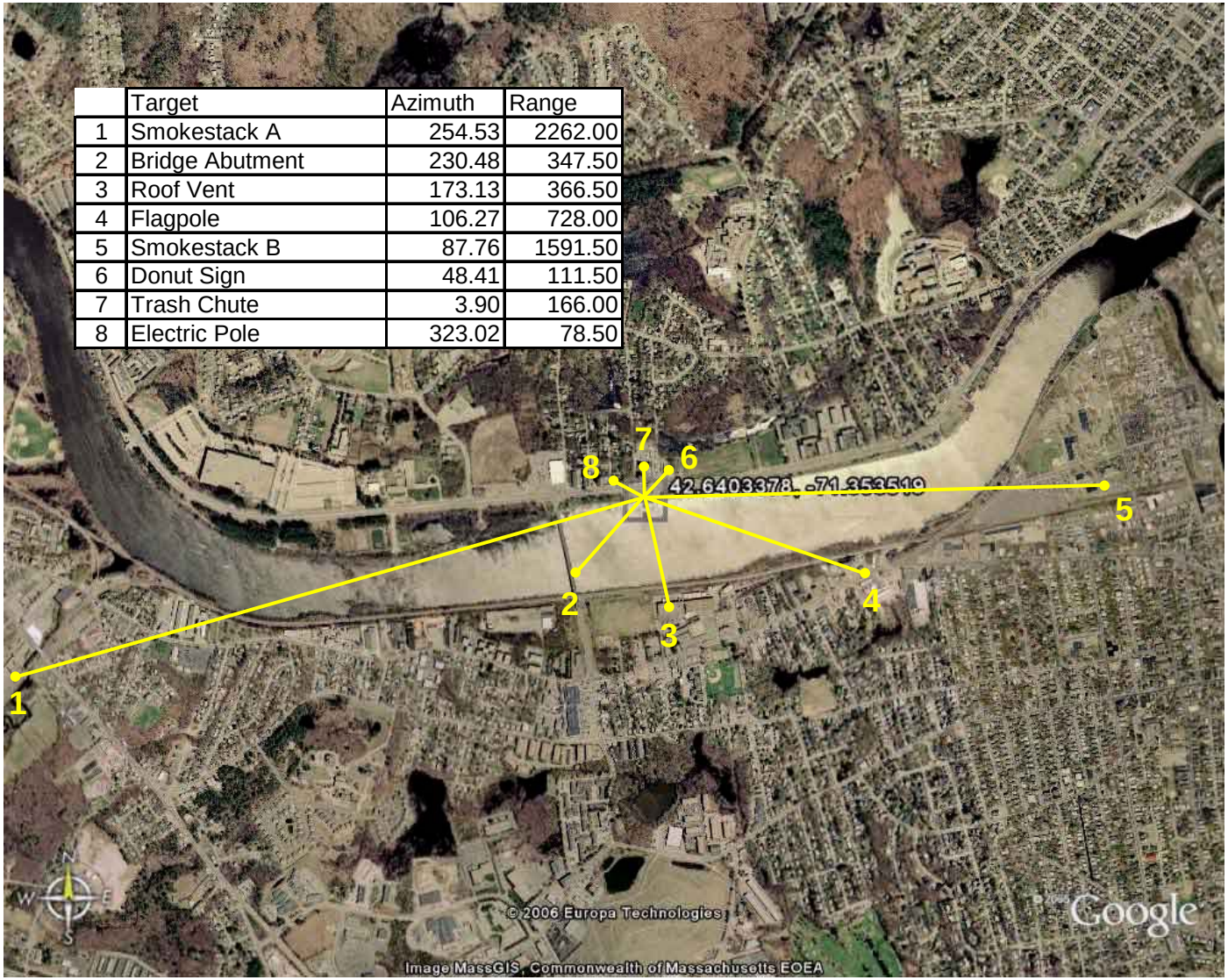
- GPS position of antenna is calculated
- Loran station position is known or can be sent to receiver via Loran data channel
- Loran signal amplitudes in both loop antennas are measured
- Amplitudes ratio is used to calculate azimuth

No GPS, 3 Loran Stations

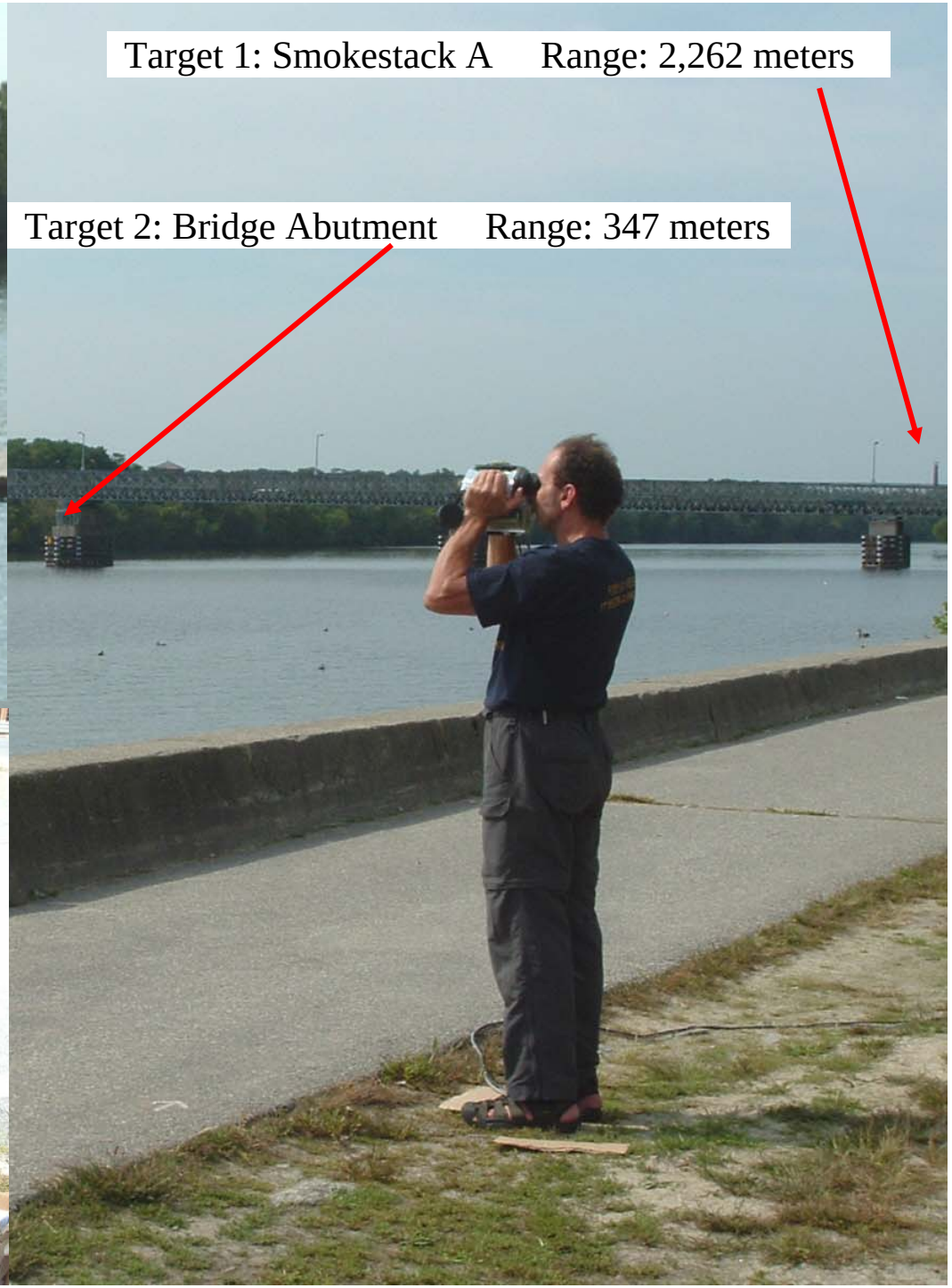


- Loran position of antenna is calculated
- Loran stations positions are known
- Loran signal amplitudes in both loop antennas are measured using station with strongest signal
- Amplitudes ratio is used to calculate azimuth

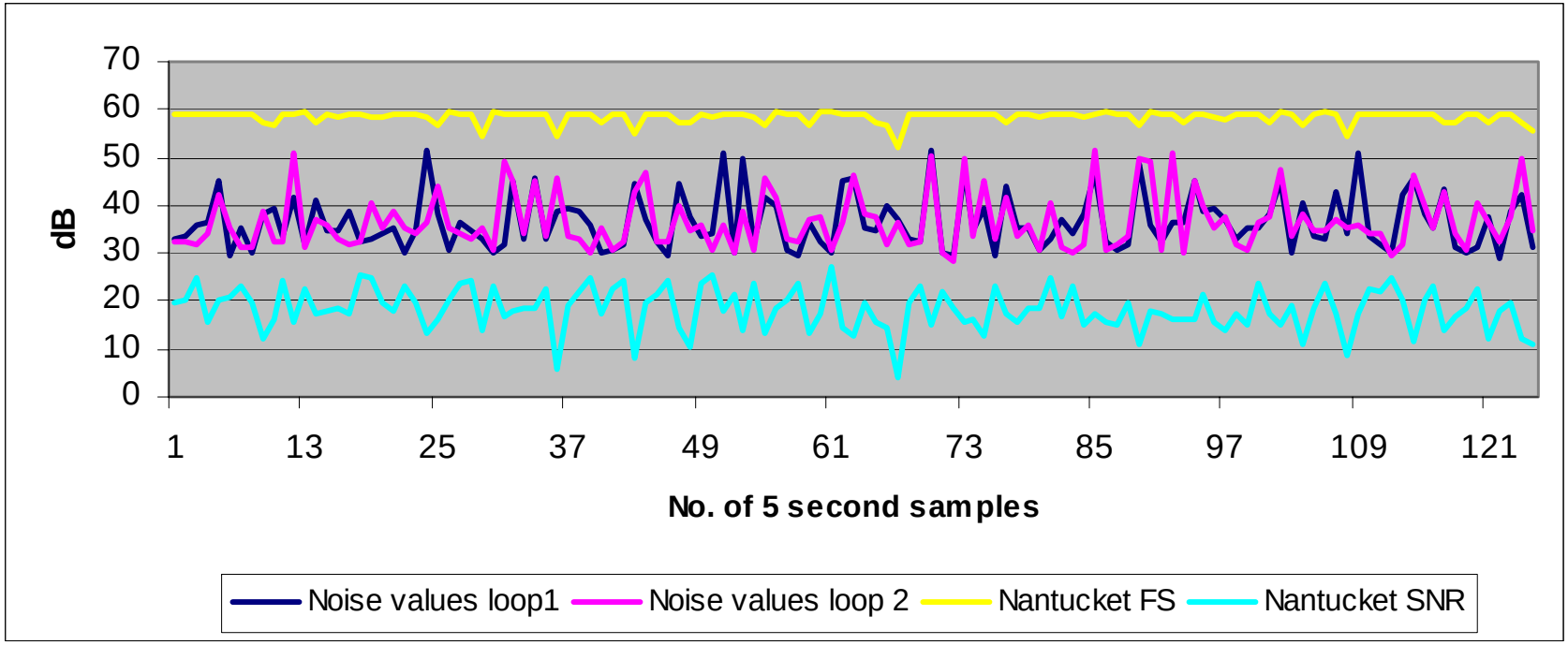
Merrimack Riverbank Test Site



	Target	Azimuth	Range
1	Smokestack A	254.53	2262.00
2	Bridge Abutment	230.48	347.50
3	Roof Vent	173.13	366.50
4	Flagpole	106.27	728.00
5	Smokestack B	87.76	1591.50
6	Donut Sign	48.41	111.50
7	Trash Chute	3.90	166.00
8	Electric Pole	323.02	78.50

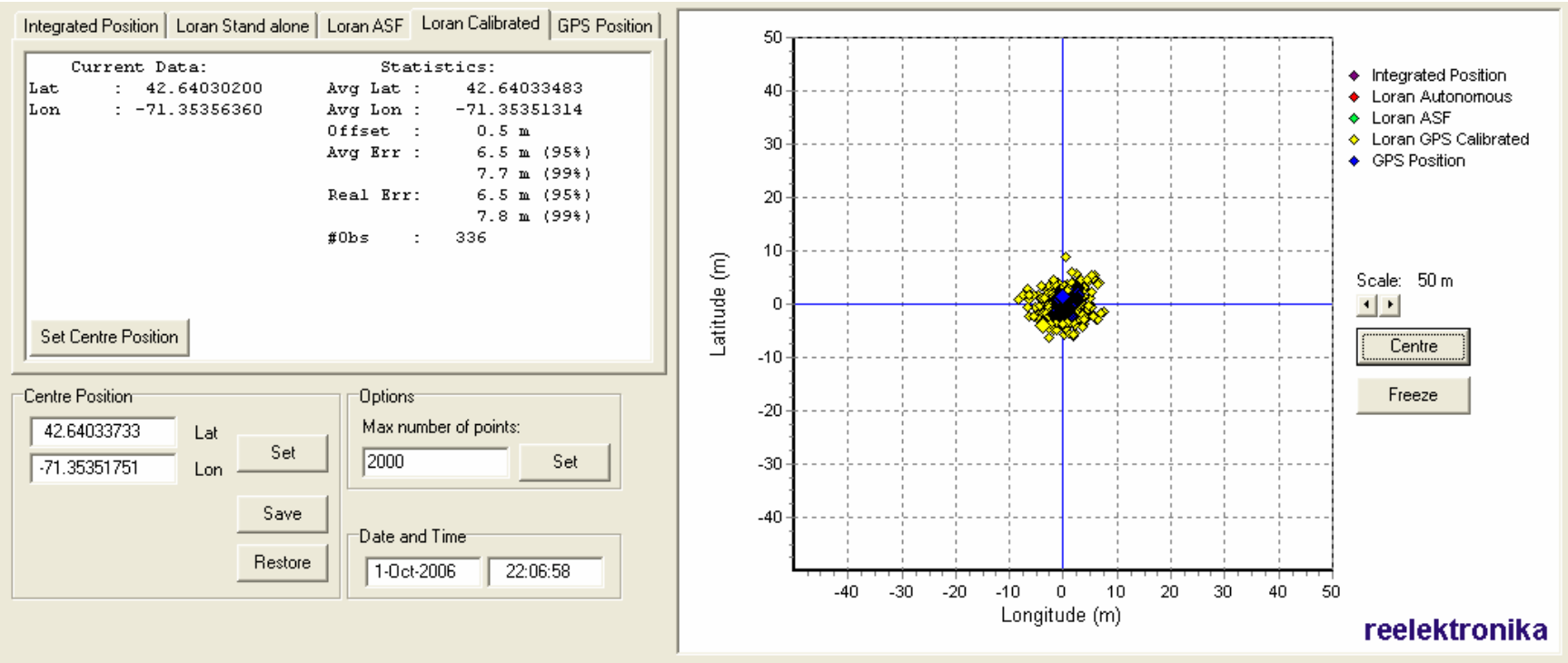

Target 1: Smokestack A Range: 2,262 meters
Target 2: Bridge Abutment Range: 347 meters

Signal Environment with M25 Stabilization Off



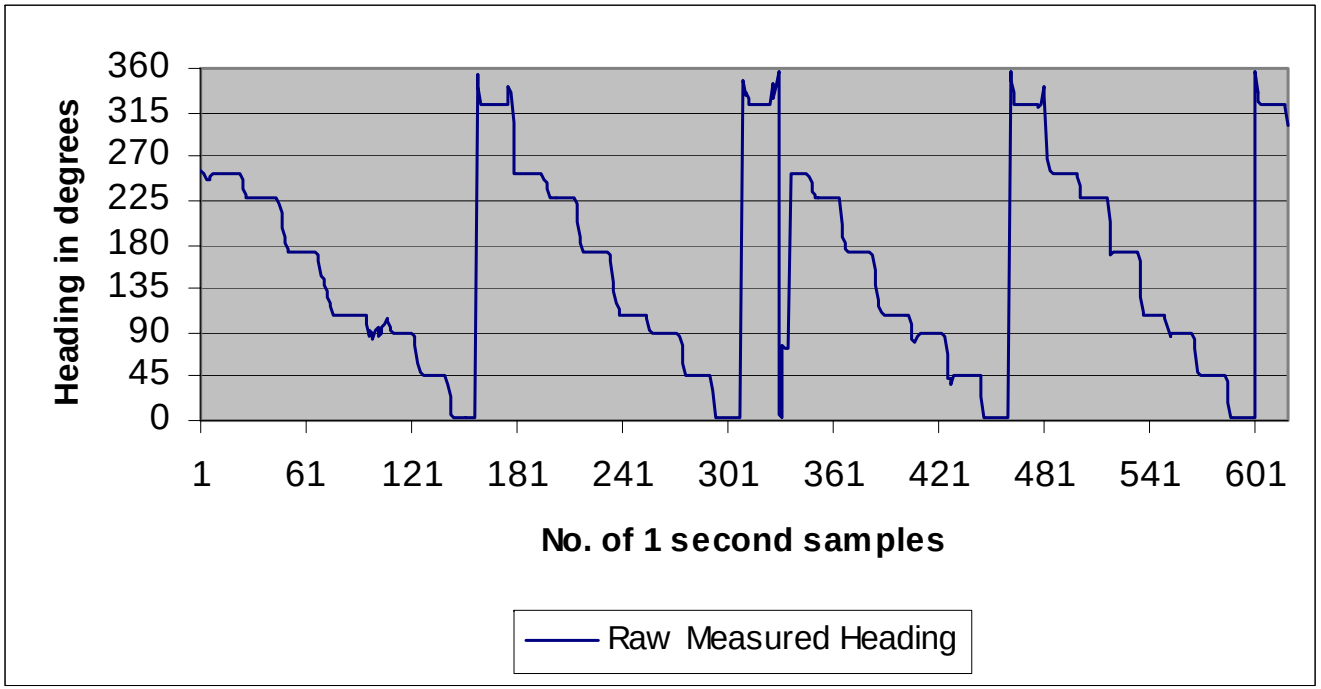
- Data from 18 Sept Handheld with M25 off
- Nantucket (400kW at 192km) Field Strength ~59 dB
- Average Loop Noise 36.5 dB balanced
- Average SNR 18.2 dB

Position Accuracy - GPS and Cal. Loran



- The “calibrated” Loran mode has an error of 6.5m, 95%. The calibrated mode uses GPS data to remove Loran range errors due for each Loran pseudo range. Because it is temporally stable a user can complete operations in the absence of GPS. Alternatives such as mapping or data channel produce similar results.

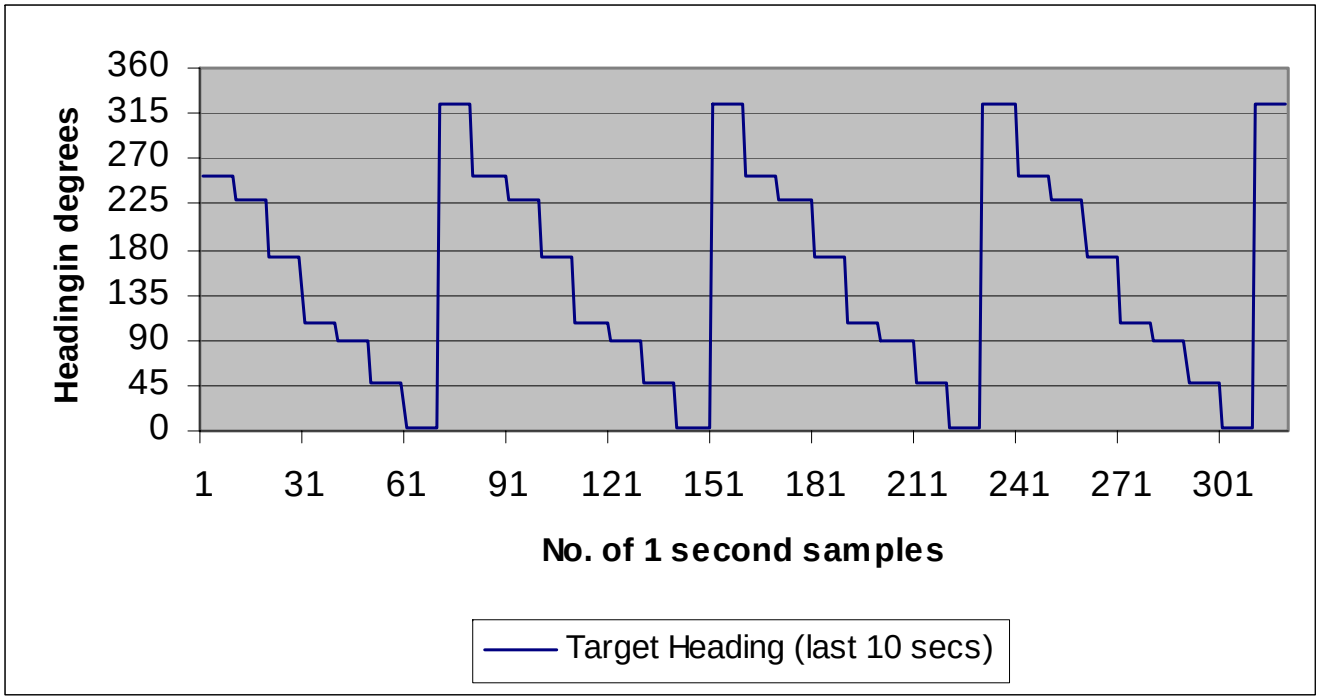
Handheld Targeting – All Data Points



- In the Handheld trial the spotter was asked to locate the target and hold it for ten seconds before proceeding to the next target in sequence. The plot above shows all heading measurements for 4 rotations x 8 targets (32 total) in just over ten minutes.

Handheld Test – Last 10 Sec. Data Only

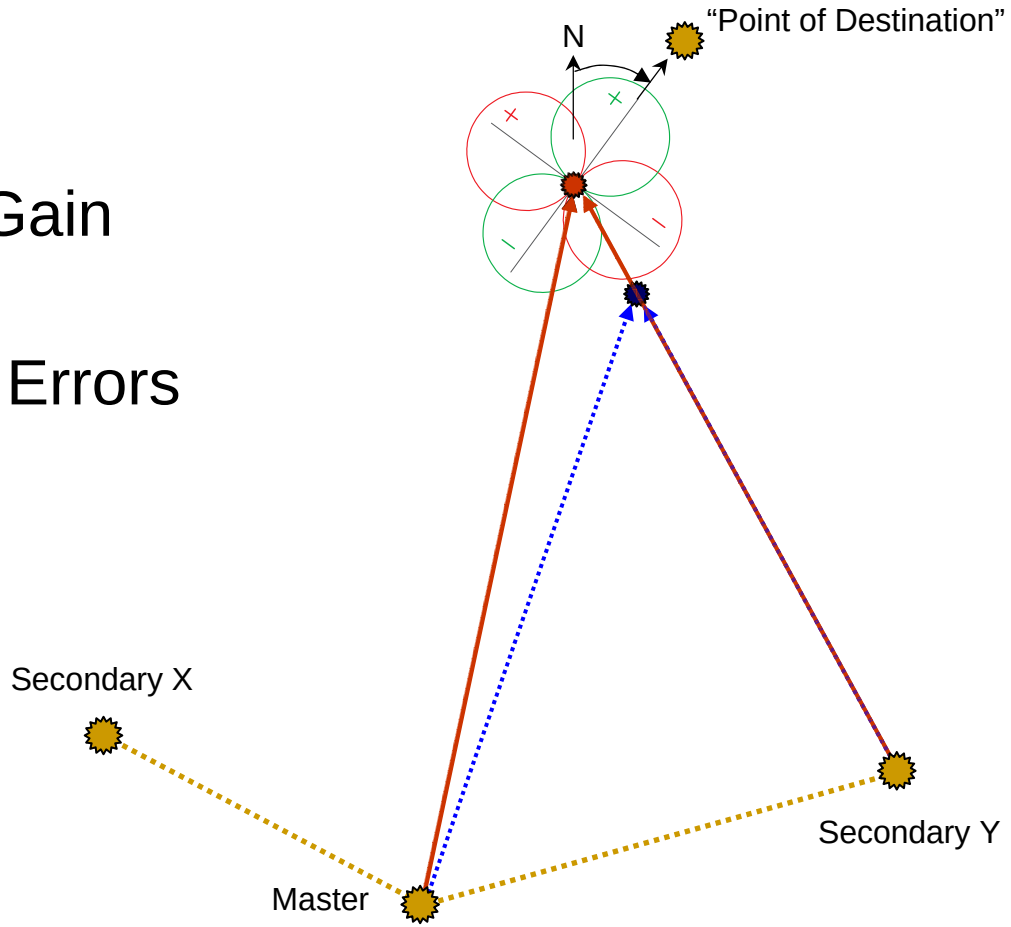
- The last ten seconds of data at each azimuth were extracted and form the edited data set below



- Repeatable Accuracy of headings averaged 0.12 degrees (~2mrad)
- Standard Deviation of Headings 0.06 degrees (~1mrad)

Azimuth Measurement Accuracy
Calibration and Sources of Errors

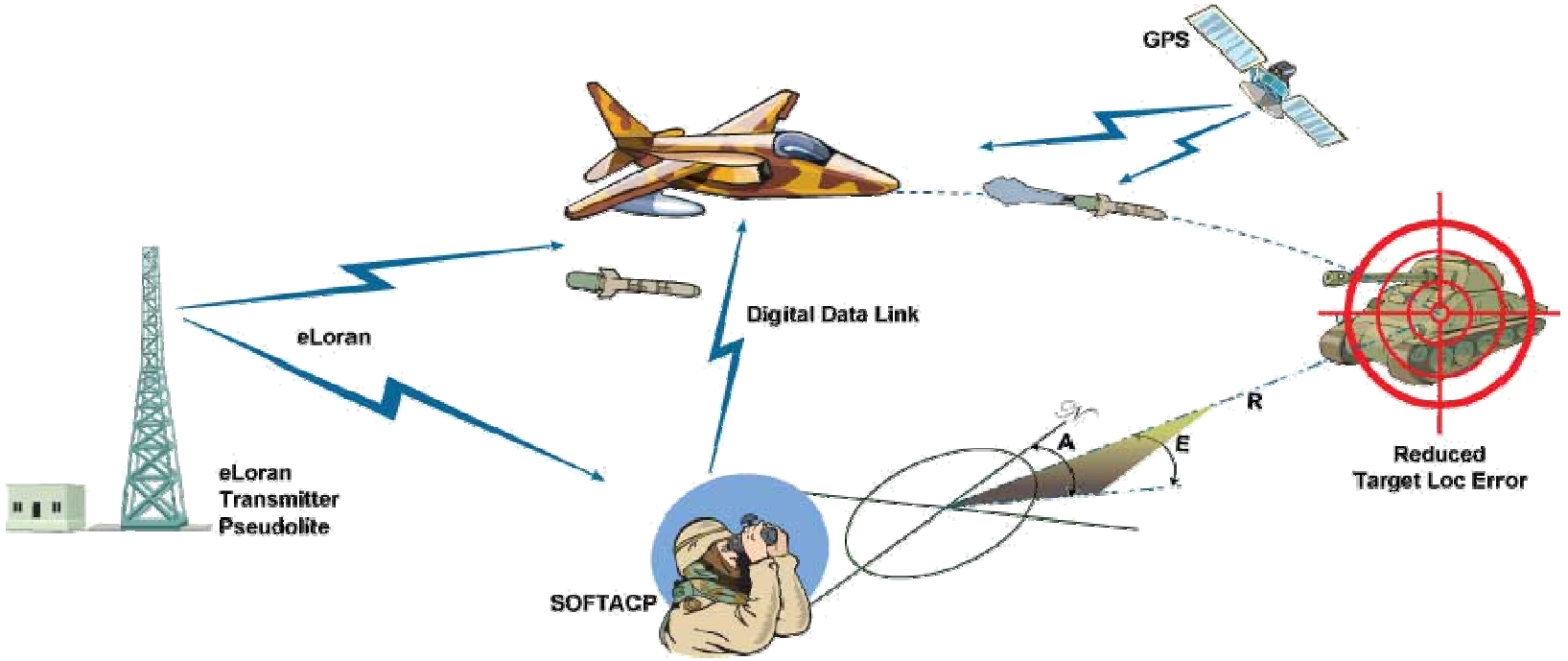
- Antenna Pattern
- Difference in Delay/Gain
- User Position Errors
- Transmitter Position Errors
- H-Field Distortions



Integrity of Heading Information

- The calibration of an antenna allows antenna pattern and differences in delay/gain to be minimized through a combination of manufacturing process and software compensation.
- Use multiple stations to confirm that beam steering solution is correct.
- Use GPS whenever available as second source plus for Loran calibration.
- Cycle identification flag to identify bad signals.
- Low SNR alarms.
- Place bound on std dev of azimuth calculation.

eLoran Benefits to the Warfighter



- eLoran substitutes for "absent" L1 for rapid P(Y) and M acquisition with its Stratum-1, <100nsec to UTC Timing accuracy.
- Provides correction and integrity information for GPS, extends coverage with high power, low frequency signal.
- True North Azimuth to 0.1 degrees within 20 seconds from cold start; while stationary; and with no field calibration required.
- Several schemes exist to deny adversary any benefit from either data channel or signal itself.

Applications Enabled

- Remotely operated and monitored surface movement
- Underwater (particularly fresh water) positioning and orientation
- Additional source of heading and rate of turn for maritime
- Dredging, ditching
- Extending GPS capabilities in machine control, agriculture
- “What is?” function linked to web services such as Google Earth
- Remote visual surveillance and digital image compilation
- Residential precise synchronization
  - Broadband services
  - Transaction security
  - Utility (water, elec) usage and metering
  - Home audio room to room synchronization
- Alignment of 1 Wood for fairways in regulation !!

Summary

- Loran, like GPS, is not just a navigation system. It is an electronic information service.
- New eLoran receivers make use of three basic information types: Position, Azimuth, and Time.
- There are affordable products with beneficial capabilities available today. The only barrier is an ambiguous system policy.
- Recent developments in eLoran, particularly highly accurate true north azimuth determination, can be leveraged for use by the warfighter.
- Compass functionality of a commercial receiver was shown to provide true north azimuth of ~2 milliradians
- In combination with a Loran Data Channel or with GPS, opportunities exist for loran sensor of reduced size, weight, and power.
- This in turn will enable future applications. The applications may expand the use and benefits of GPS, preserve the benefits of GPS, or create new products and services.