QUESTION: ALTERNATE POSITION, NAVIGATION, TIMING, APNT? ANSWER: ELORAN

Albert Helfrick, Embry-Riddle Aeronautical University, Daytona Beach, FL.

Have we “Put all our eggs in one basket?”

- GNSS is the major, in some case the sole, provider of navigation for performance based navigation and required navigation performance, PBN, RNP.
- PBN and RNP will be the only navigation choice in the future.
- Like any system GNSS has its vulnerabilities.
- Dependence on GNSS extends well beyond navigation.

GNSS Signal Degradations

- Atmospheric, (ionospheric) effects
- Interference
  - Deliberate
    - Mobile jammers
    - By hostile forces
  - Unintentional
    - On board avionics
    - Terrestrial transmitters
    - Errant sources of interference
    - Other space vehicles; “other satellites are your noise”

Other Degradations not Involving Signals

- Satellite system failures
- Incorrect parameters uploaded to satellites
- Satellites out of service

GNSS Signals have been Jammed

- North Korea is suspected of deliberately jamming S. Korea GNSS
- In-vehicle jammers are prolific and have jammed the GBAS system at Newark's Liberty Airport
- There are numerous reports of GPS jamming
- Notching jammers using adaptive antennas is impractical in many aircraft.

Satellites have Failed

- Bad ephemeris have been uploaded to the entire GLONASS constellation and brought down the entire system for hours.

Mitigating GNSS Interference

- Directed antenna patterns
  - Tend to be large
  - Are used in military systems
  - May be subject export restrictions
- Increased signal-in-space energy
  - Later satellites have increased radiated power
  - There are practical limits to just how much power a satellite can radiate.

Selecting an Alternate Position, Navigation and Timing, APNT System

- APNT system requirements:
  - Has the necessary accuracy, availability, continuity and integrity
  - Full global coverage or nearly global
  - Difficult or virtually impossible to jam
  - One with a history of success
  - Has international specifications already in place
  - Is affordable
  - Ideally, a system already operating on a large scale

eLORAN

- eLORAN has all the characteristics needed for APNT
- Because of the tremendous atmospheric noise at the 100 kHz operating frequency, eLORAN requires very high transmitter power.
- eLORAN electric field is about +10 to +90 dBμv/m; at 1500 km from an eLORAN transmitter
- H field antennas can be made that can null out interference without size or export restrictions

About LORAN

- LORAN is Long Range Navigation and was developed during WWII.
- LORAN-C is a “time difference of arrival”, TDOA, system that produces hyperbolic lines of position.
- LORAN-C is an improved LORAN made operational in the 1970’s.
- The original user of LORAN-C was maritime and the owner/operator was the Coast Guard.
- Aviation interests joined in the late 1970’s with the advent of inexpensive and easy-to-use equipment.
- The “mid continent gap” was filled after aviation began using LORAN-C

eLORAN Compared to LORAN-C

- Includes a data channel
- Modern transmitters
- Each station controlled by an ensemble of atomic clocks
- Entire system is a “stratum one” timing system
- Timing of pulses is by “time of transmission”, TOT
- “All in view” navigation is possible
- The 100 kHz channel is a protected frequency for navigation services.
- eLORAN can be received inside buildings.

Capabilities of eLORAN

- Accuracy (95%) 0.3 NM
- Availability 0.999 – 0.9999
- Integrity 10^{-7} per hour
- Continuity 0.999 – 0.9999 for 150 seconds
- Time dissemination 50 ns (stratum 1)

What the Data Channel Can Do

- Provide Differential Correction Data for eLORAN
- Provide Correction Data for GNSS
- The biggest hurdle for the data channel is data rate.
- The current data channel eLORAN in the US was designed to not affect the legacy LORAN receivers.
- More sophisticated data channels may not be compatible with legacy systems.

What a “Stratum One” Timing System can do

- More systems are relying on precision timing
  - Communications systems
  - ADS-B
  - Broadcasting
  - Research

The Need to Act Now

- The dismantling of US LORAN has already started but the latest Coast Guard appropriations bill in Congress includes a “promise” to not dismantle any more LORAN stations.
- The situation in Canada seems to be the same.
- There are proposals for other APNT systems but they can benefit from the return of eLORAN.
- An eLORAN restoration needs to be enacted soon before what remains of the stations is completely lost and allocated money is spent elsewhere.