eLoran in Korea
– Current Status and Future Plans

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Location Privacy Concern

- Location privacy issue receives more attention as GPS tracking devices are widely available
  - "A Spy-Gear Arms Race Transforms Modern Divorce"
    – The Wall Street Journal (October 6, 2012)
    - "In suburban Atlanta, a private investigator said that his firm, which is handling roughly 80 spousal investigations, is currently tracking about five cars using GPS."
    - "LandAirSea sells a GPS Tracking Key—a matchbox-size, magnetized gizmo that can stick to cars—for $179 online"

[LandAirSea, GPS Tracking Key Pro]

PPDs for Sale Over the Internet

- How to protect location privacy?
  - Personal Privacy Devices (PPDs): small-size low-power GPS jammers

[L. Eldredge, "GNSS Program Status," 51st CGSIC, Sept. 2011]

[Dong-a Ilbo Newspaper, South Korea, 1 June 2011]

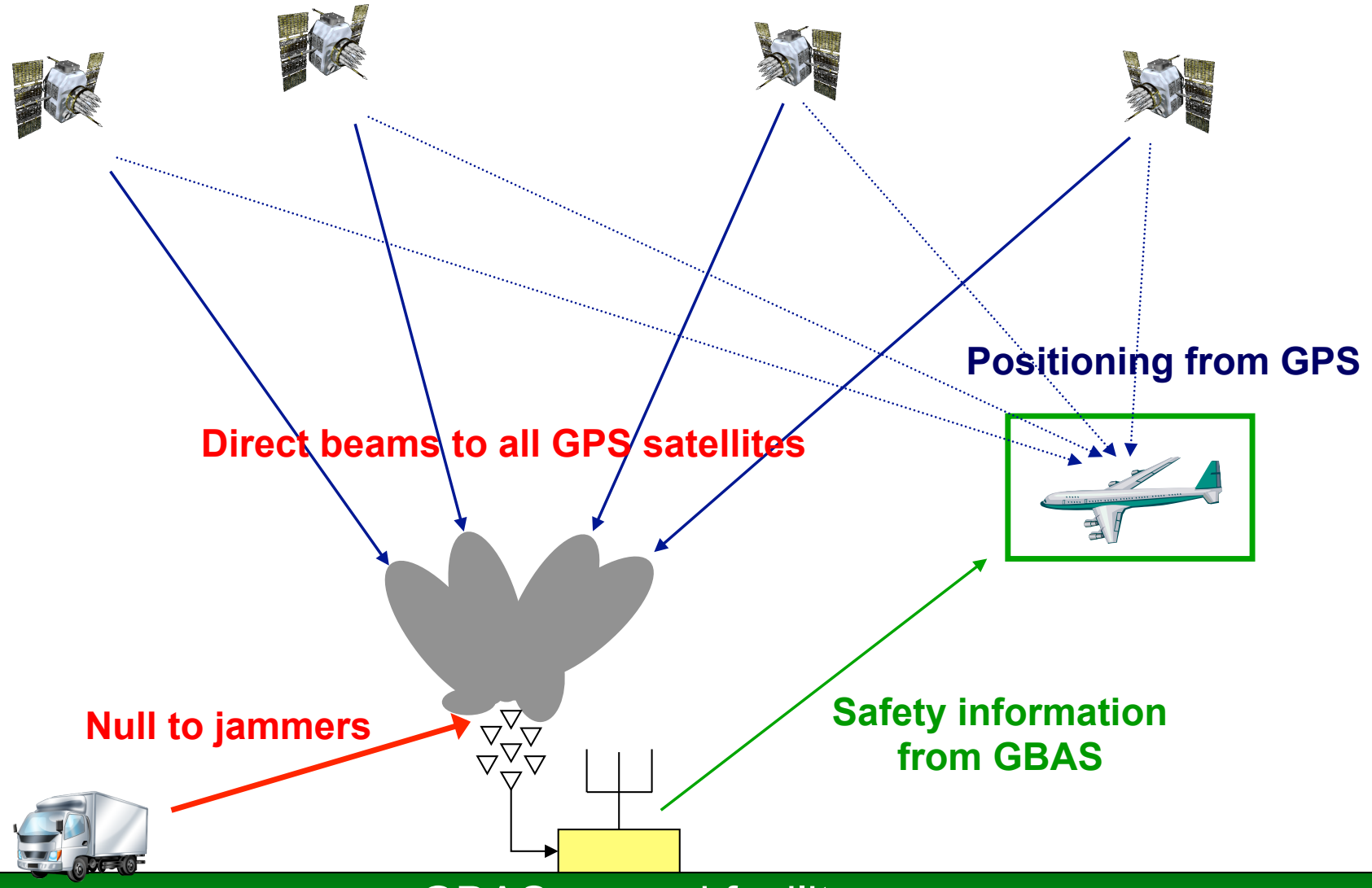
GPS RFI at Newark Airport

* A well-known example of GPS interference due to PPDs

Courtesy: Sam Pullen

GBAS Site at Newark (Near Freeway)

GPS Anti-Jam Technology such as CRPA
(Controller Reception Pattern Antenna)



* CRPA is effective under moderate-power jamming

[J. Seo, Y.-H. Chen, *et al.*, 2011]
[Y.-H. Chen, J. Seo, *et al.*, 2012]

Intentional High-Power Jamming

GPS disruptions for the past three years due to North Korean jamming

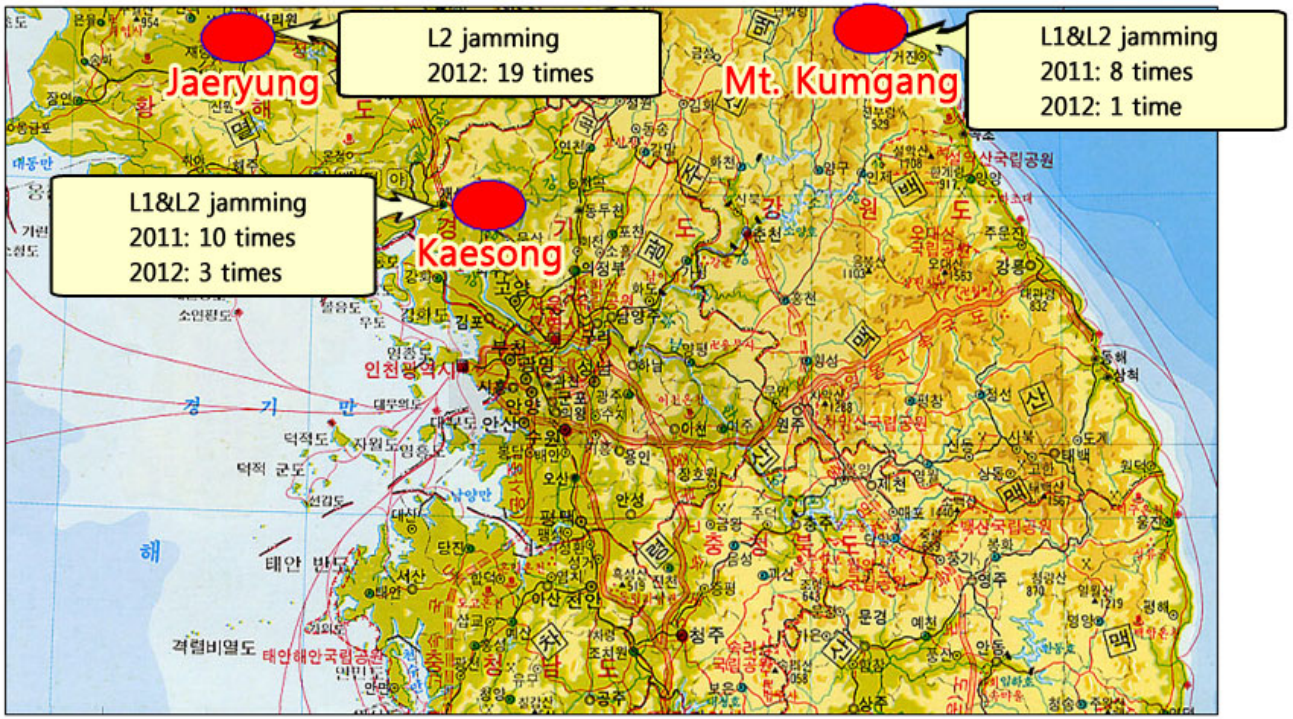
Dates	Aug 23-26, 2010 (4 days)	Mar 4-14, 2011 (11 days)	Aug 28 – May 13, 2012 (16 days)
Jammer locations	Kaesong	Kaesong, Mt. Kumgang	Kaesong
Affected areas	Gimpo, Paju, etc.	Gimpo, Paju, Gangwon, etc.	Gimpo, Paju, etc.
GPS disruptiions	181 cell towers, 15 airplanes, 1 battle ship	145 cell towers, 106 airplanes, 10 ships	1,016 airplanes, 254 ships

[The Central Radio Management Office, South Korea]

* Note that the durations of jamming have continuously increased

Intentional High-Power Jamming

The Electronics and Telecommunications Research Institute (ETRI) of South Korea observed and analyzed North Korean jamming in L1, L2, L5 bands



* Under this intentional high-power jamming, the benefit of anti-jam technologies such as CRPA is very limited

Expected Capabilities of eLoran

- Time: UTC synchronized with an accuracy of 50 ns
- Frequency: Achieves Stratum 1 quality
  i.e., maximum drift: 1×10^{-11} or less
  (fractional frequency offset)
- Navigation: Satisfies the HEA & NPA requirements

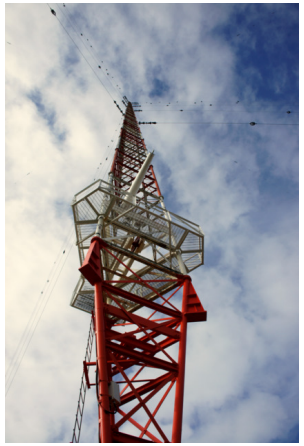
	Accuracy	Integrity	Availability	Continuity
Harbor Entrance and Approach (HEA)	20 m, 2drms	3×10^{-5}/h	99.7%	99.85% over 3 hours
Non-Precision Approach (NPA)	307 m	10^{-7}/h	99.9-99.99%	99.9-99.99% over 150 seconds
eLoran (expected)	8-20 m	10^{-7}/h	99.9-99.99%	99.9-99.99% over 150 seconds

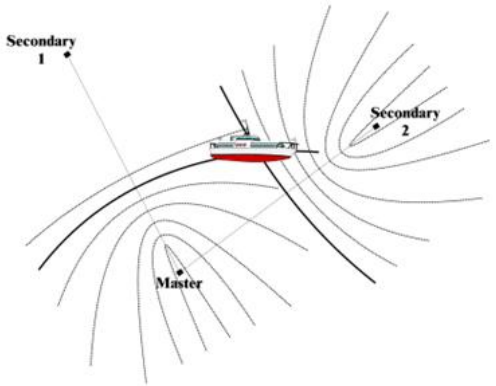
[eLoran Definition Document, 2007]
[S. Lo, *et al.*, 2007]

Korea Loran-C Chain (GRI 9930)

The Korea Loran-C chain consists of

- 2 stations in South Korea
- 2 stations in Japan
  (scheduled to be discontinued
  in December 2014)
- 1 station in Russia





[http://loran9930.go.kr]

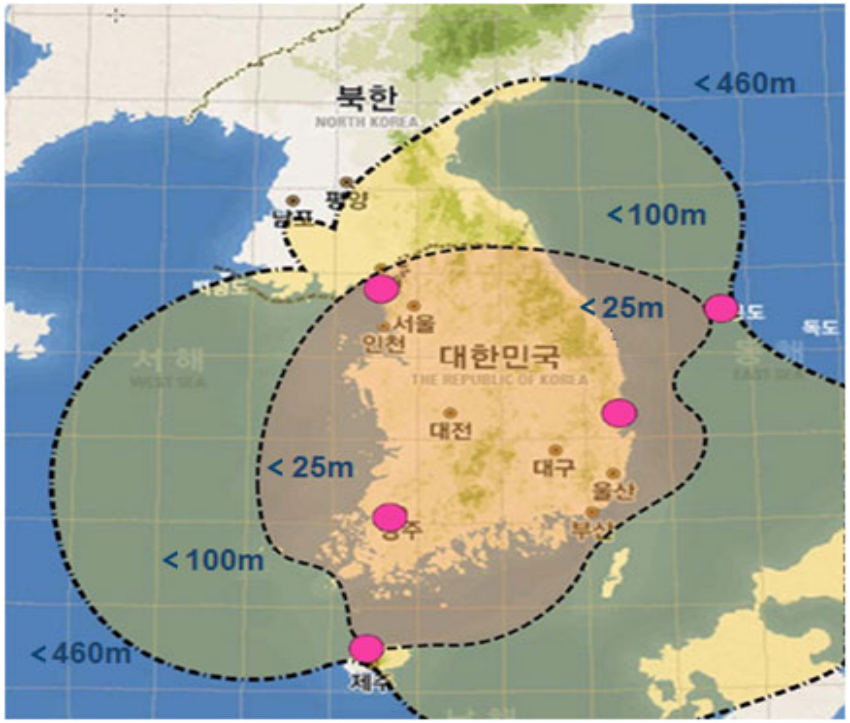
Korean eLoran System

The South Korean government recently completed the design development and construction documents for the Korean eLoran system in Feb 2013

* This talk is the first introduction of the Korean eLoran program at an international conference

- The Korean eLoran system will consist of five transmitter stations
  - Two Loran-C stations in Pohang and Kwangju will be upgraded to eLoran stations
  - Three new eLoran stations will be constructed
  - Control station will be at Pohang

Accuracy and Coverage Simulation

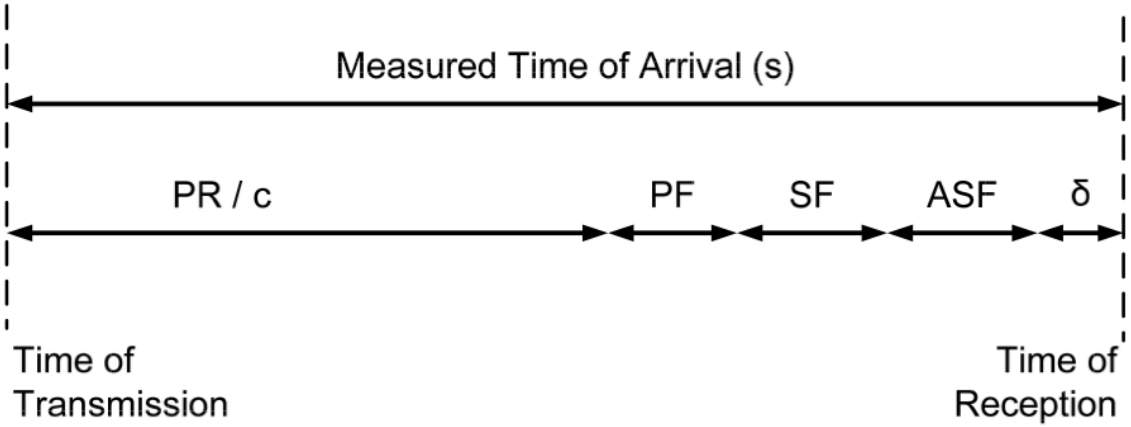


- Simulation result of the expected accuracy and coverage of the Korean eLoran system
  - Demonstrates satisfactory coverage including major harbors
  - Not the ideal best-case geometry, but a realistic alternative with minor performance degradation

Purpose of the Korean eLoran System

- To provide better than 20 m accuracy over the country including land, air, and sea as an effective complementary navigation system
  - Not just the HEA and NPA
  - Should be able to provide a 20 m accuracy inland as well
  - Conventional eLoran error mitigation techniques such as differential corrections and ASF maps will be utilized for land areas as well

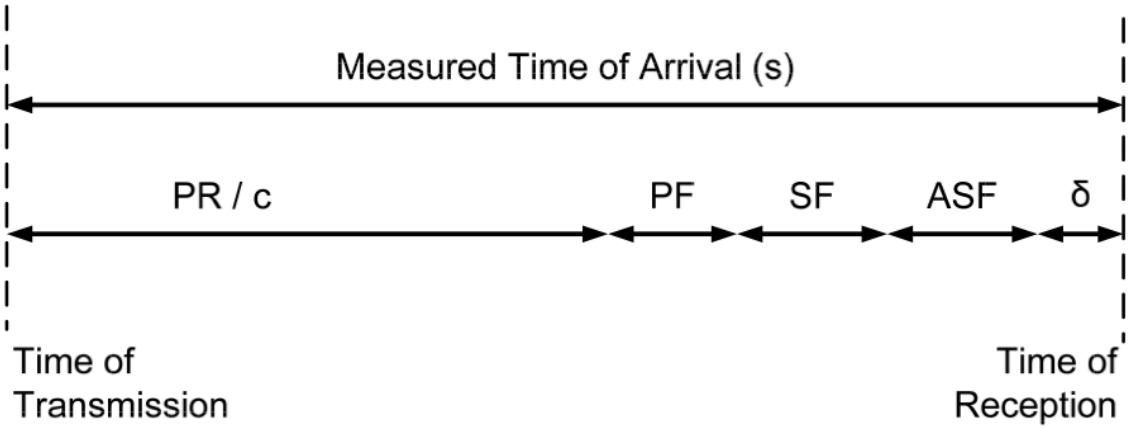
ASF (Additional Secondary Factor)



[S. Lo, *et al*., 2009]

- Primary Factor (PF)
  - The term that accounts for the time of propagation of the Loran signal through the **atmosphere** rather than the vacuum
  - RTCM SC127 decided to use the index of refraction in atmosphere to be 1.000338
  - Then, the speed of light in the atmosphere is 299,691,162 m/s

ASF (Additional Secondary Factor)

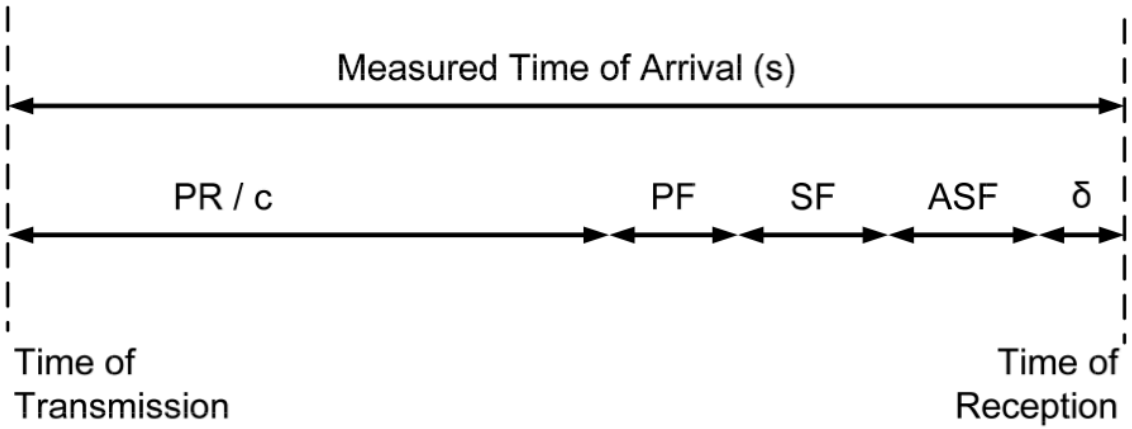


[S. Lo, *et al*., 2009]

- Secondary Factor (SF)
  - The term that accounts for the difference in propagation time from a Loran signal propagating over an **all seawater path** rather than through the atmosphere
- The Brunavs model accounts both the primary factor and secondary factor

$$\text{Brunavs}_{PF+SF}(m) = -111 + 98.2D + (13.0D + 113.0)e^{\frac{-D}{2}} + \frac{2.277}{D}$$

ASF (Additional Secondary Factor)

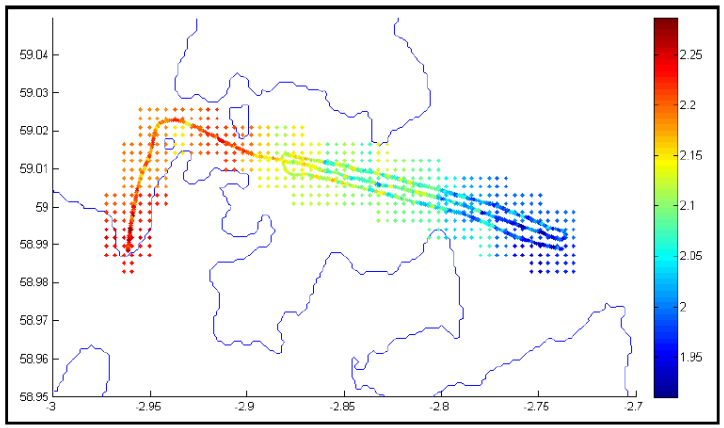


[S. Lo, *et al*., 2009]

- Additional Secondary Factor (ASF)
  - The term that accounts for the extra delay on the time of arrival of the Loran signal due to propagation over inhomogeneous **land path** rather than all seawater path
  - **ASF can vary significantly spatially and temporally**

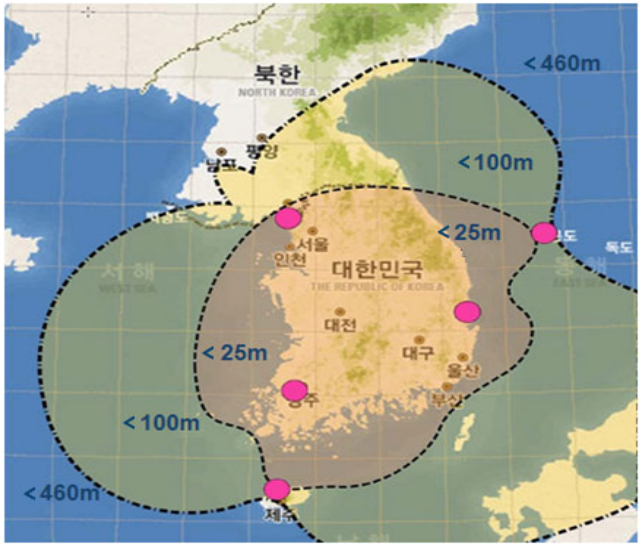
Spatial ASF Correction by ASF Map

* Example of ASF survey



[Hargreaves, 2010]

* ASF maps for land users would also be necessary for Korea



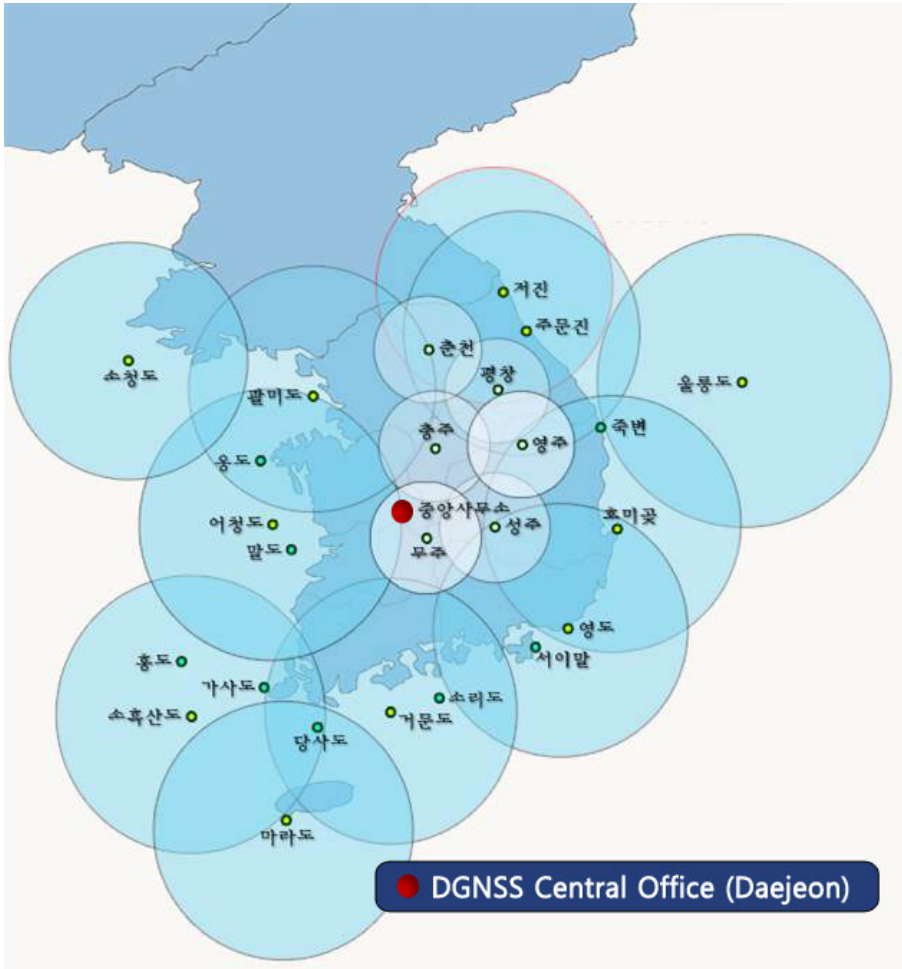
- Once spatial ASF variations are surveyed over a region—this is a one-time effort—eLoran receivers store the spatial ASF variation maps and apply the information as spatial corrections
  - Grid size of 500 m is generally acceptable for maritime users
  - Land users would experience more local variations due to re-radiation and bending of eLoran signals. A denser grid size may be necessary

Temporal ASF Correction by dLoran

- Temporal ASF correction by **differential eLoran (dLoran) corrections**
  - Account for the **residual ASF** not corrected for by the ASF map
  - Also account for **other slowly varying errors** such as the residual errors from our PF and SF models as well as some transmitter errors

- 43 differential eLoran stations would be deployed over the country
  - 30 km coverage of each differential station is assumed
  - Differential corrections are broadcast via eLoran Data Channel (LDC)

Current NDGPS Infrastructures



- South Korea provides National DGPS (NDGPS) service since 2009
  - 17 DGPS reference stations and 17 integrity-monitoring stations
  - Some dLoran stations plan to be collocated with the NDGPS stations

* DGNSS Central Office in Daejeon, Korea

Roadmap of the Korean eLoran Program

- 2013
  - Three sites for new eLoran stations in Gangwha, Jeju, Ulleung and 43 sites for differential eLoran stations have been selected, which will be secured by 2013
- 2014
  - Two legacy Loran-C stations in Pohang and Kwangju would be upgraded to eLoran stations
  - A new eLoran transmitter would be installed at the Gangwha station
  - 27 differential eLoran stations in Pohang, Kwangju, and Gangwha areas would be deployed
  - A prototype eLoran system would be ready with total 3 transmitter stations and 27 differential stations

Roadmap of the Korean eLoran Program

- 2015
  - Two more eLoran stations would be ready in Jeju and Ulleung
  - Remaining 16 differential stations would also be deployed
- 2016
  - ASF maps for 5 transmitters would be ready by 2016
  - The Initial Operational Capability (IOC) of the Korean eLoran system is expected in 2016
- 2018
  - After two years of test operations in 2016 and 2017, the Final Operational Capability (FOC) would be declared in 2018

Summary

- A complementary PNT service is necessary in South Korea especially due to the repeated GPS jamming from North Korea
  - A terrestrial high-power radio navigation system, eLoran, is selected as the best candidate for South Korea
- The South Korean government has recently completed the design development and construction documents of the Korean eLoran system
  - The system consists of 5 transmitters and 43 differential stations
  - The system plans to provide better than 20 m accuracy over the country
- The system will be procured through International Competitive Bidding (ICB)
  - Interested vendors are welcome to participate
- The IOC is expected in 2016 and the FOC is expected in 2018

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Thank you!

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