First International eLoran Standardisation Working Group Meeting, Seoul, 2025

Summary of Proceedings and Recommendations

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GNSS: THE INVISIBLE UTILITY

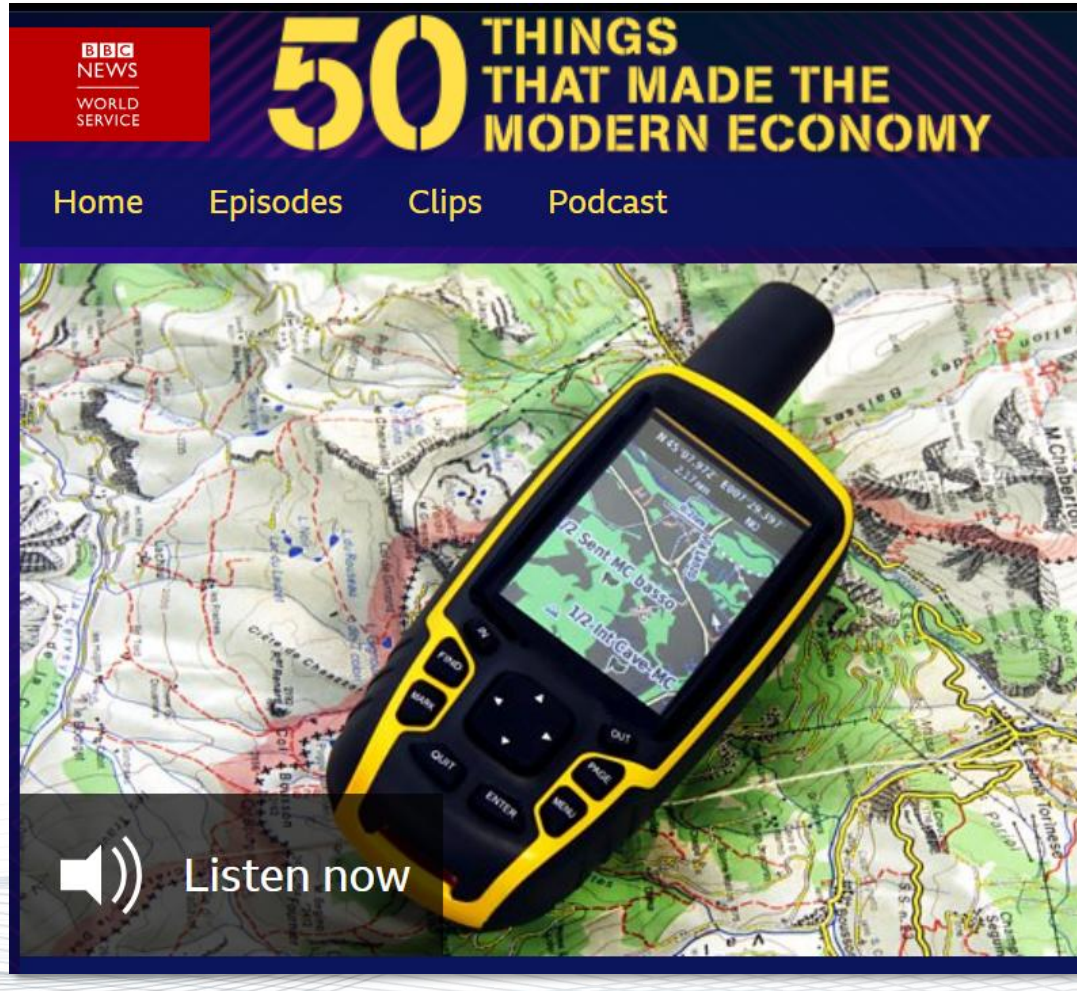
Part 1: Why are we here?

BBC's, *50 Things That Made the Modern Economy*: GPS featured alongside the iPhone, the shipping container and the limited liability company

GPS, Galileo, BeiDou, GLONASS: extraordinary feats of engineering delivering free global positioning and accurate timing to billions

Galileo – a landmark European achievement:

- First GNSS under civilian control
- SAR return link, authentication (OSNMA), high-accuracy service (HAS)



https://www.bbc.co.uk/programmes/w3csz2x0

WITH GREAT POWER COMES GREAT RESPONSIBILITY

THE VULNERABILITY

- GNSS signals received at:
  –160 dBW
  (0.000 000 000 000 000 1 W)
- Most civil signals lack authentication
- Easily jammed and spoofed

THE CONSEQUENCES

~£1bn/day

Cost of GNSS outage to the UK economy — across agriculture, aviation, emergency services, finance, maritime, rail and road. London Economics (2021)

69%

of pilots report 'very high or extreme' concern about GPS spoofing; flight systems degraded even after GPS restored. OPSGROUP (2024)

75%

of mariners say the interference situation is not improving; SOLAS-mandated equipment shown to be vulnerable. RIN (2026)

RESILIENCE REQUIRES A SYSTEM-OF-SYSTEMS APPROACH

No single technology can do it all

	Strengths	Limitations
GNSS	High accuracy, global coverage	Vulnerable to interference, even multi-frequency/multi-constellation
eLoran	Jam-resistant, wide-area coverage	Cannot match GNSS performance in benign conditions
R-Mode / Radar Positioning	Coastal navigation	Shorter range, less mature
INS / Dead Reckoning	Enhanced continuity	Requires periodic external updates to limit drift

The answer is a combination of dissimilar, independent PNT sources, where no single failure is catastrophic

Source: NAVISP MarRINav project

WHY ELORAN SURVIVES WHEN GNSS FAILS

Protected by physics

	GNSS	eLoran
Signal source	Satellites (≈ 26,000 km orbits)	Ground transmitters (~100s km)
Radiated power	≈ 100 W	≈ 10 kW – 1 MW
Frequency	L-band (1.2-1.6 GHz)	LF (100 kHz)
Wavelength	≈ 20 cm	3 km
Propagation	Line-of-sight	Ground-wave, indoor, underwater
Jammer efficiency	High – small antenna works	Very low – needs large ant. (10s – 100s m)

Independent infrastructure ▪ Dissimilar signal characteristics ▪ At 100 kHz (λ = 3 km), a portable jammer's antenna is hopelessly inefficient – eLoran is *'for all practical purposes, unjammable'*

Sources: Lo et al., "*Assessing the Security of a Navigation System*" (2009). IS-GPS-200.

WHAT MAKES ELORAN 'ENHANCED'

Same physics, modern engineering

KEY ENHANCEMENTS OVER LORAN-C

- UTC-locked transmissions (≤25 ns, 10 s avg.) – all-in-view, chain-independent operation
- Propagation corrections – ASF maps and real-time differential
- Loran Data Channel – corrections, integrity alerts, UTC, station ID
- Modern transmitters – higher efficiency, smaller footprint, remotely operable
- Software-defined receivers – advanced signal processing, multi-sensor integration
- Accuracy improves from ~0.25 NM for Loran-C to <20 m (95%) with eLoran

	Loran-C	eLoran
Maritime		
Ocean	✓	✓
Coastal Confluence Zone	✓	✓
Harbour Entrance (HEA)	✗	✓
Aviation		
EnRoute (RNP 1.0)	✓	✓
Terminal (RNP 0.3)	✗	✓
Non-Precision Approach (RNP 0.3)	✗	✓
Timing		
Stratum 1 Frequency (1×10^{-11})	✓	✓
UTC (few tens of ns)	✗	✓

Sources: Narins, *"Loran's Capability to Mitigate the Impact of a GPS Outage"* (2004). ILA, eLoran Definition Document (2007). SAE9990 (2018)

PART 2: THE SEOUL MEETING

Who was in the room

France ▪ Republic of Korea ▪ United Kingdom

Mix of government and research organisations

THE SEOUL COOPERATION FRAMEWORK

What was agreed

- **Practical, flexible and non-binding** expert forum – not a formal governance body
- **Meets regularly** – annually or alongside major international events
- **Technical secretariat** maintains records, actions and material between meetings
- **National liaison points** to be designated in each country
- **Open to expansion** as international interest in terrestrial PNT grows
- **ESA seen as a key enabler** – NAVISP projects; ESTEC as a technology hub

SCOPE OF COOPERATION

What the framework covers

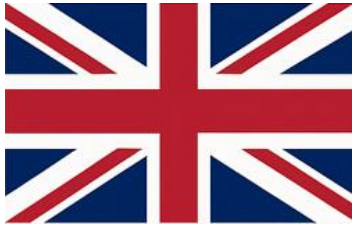
- Operational **information exchange** among eLoran-operating and interested states
- **Joint R&D**, demonstrations, field trials and validation exercises
- **Standardisation:** coordinated contributions to IMO, IALA, IEC, ICAO, ITU, RTCM, SAE, ICG
- **Capacity building:** training in radionavigation, geodesy, signal processing and precision timing
- Exploration of **new routes and applications**, e.g. Arctic navigation

POLICY & TECHNOLOGY LANDSCAPE

REPUBLIC OF KOREA

- Hundreds of reported GNSS jamming/spoofing cases annually – eLoran a national resilience priority
- Operational eLoran system since 2023: 3 transmitters, 2 reference stations
- Nationwide terrestrial PNT coverage by 2033
- A-eLoran programme underway:
  - AI-based ASF modelling
  - LDC+
  - Alternative pulse shapes
  - 150+ kW ERP transmission systems

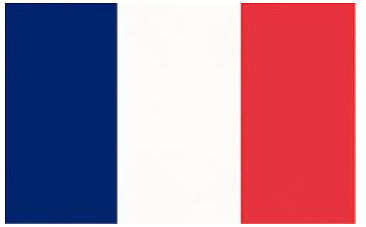
POLICY & TECHNOLOGY LANDSCAPE



UNITED KINGDOM

- Detects ~10,000 GNSS interference events per week
- CHAIN ODYSSEY: funding committed for sovereign UK eLoran
  - Initial capability: 3 transmitters on UK mainland
  - 6-station network by 2030
  - Exploring joint deployment with France
- URGENT COMPASS: deployable eLoran capability for defence applications, demonstrated by 2028
- National Timing Centre (NTC) / RETSI
  - Resilient national timescale independent of GNSS
  - eLoran as a delivery mechanism to end users

POLICY & TECHNOLOGY LANDSCAPE



FRANCE

- National GNSS dependency study across utilities, finance, transport and more – findings reinforce interest in resilient PNT
- ALS162 long-wave time signal: ~200,000 clocks across France benefit
- Spectrum monitoring suggests significant under-reporting of GNSS interference events by user sectors; GNSS interference awareness guide prepared
- European Radio Navigation Plan (ERNP) now explicitly recognises complementary PNT

OPEN QUESTIONS: SIGNAL SPECIFICATION

Links to all working groups this week

- **Common baseline eLoran signal specification** + **controlled evolution process** is a prerequisite for long-term interoperability
- **SAE9990** series as a starting point – but certain aspects require further study (e.g. new phase codes and their impact on skywave and cross-rate interference suppression)
- Future **signal enhancements**:
  - Alternative pulse shapes
  - New data channel techniques
  - Security provisions (authentication, encryption)
  - Innovative signal timing schemes for reduced cross-rate interference
  - Multi-frequency operation
- **Group Repetition Interval (GRI) management** requires global coordination – potential role for IALA or another international body
- Custodianship of the **eLoran Definition Document** and other eLoran documentation following ILA closure

OPEN QUESTIONS: MARITIME CERTIFICATION

Links to Session 4 (13:45 today) and the Maritime Working Group

NON-SOLAS (fishing, leisure, inland waterways)

- Quick deployment under an agreed technical specification
- Valuable operational experience

SOLAS (≥500 gross tons; >12 passengers)

- **Voluntary fitting** (medium-term)
  - **IMO performance standard** – options include:
    - Amend **Resolution A.818(19)** (Loran-C/Chayka)
    - Inclusion within the **Multi-system Shipborne Radionavigation framework (MSC.401(95))** – may not support an eLoran-specific carriage requirement
    - Develop a new **standalone eLoran performance standard**
  - Ensure consistent treatment with R-Mode in **IMO Resolution A.1046** (WWRNS)
  - **IEC type approval**: IEC 61075 (Loran-C) withdrawn; new standard needed; alignment with RTCM 12700.0?
- **Carriage requirement** (long-term)
  - **SOLAS V amendment**: lengthy process – begin to build case and coalition now

OPEN QUESTIONS: AVIATION CERTIFICATION

Links to Session 5 (14:15 today) and the Aviation Working Group

- eLoran demonstrated for EnRoute (RNP 1.0), Terminal (RNP 0.3) and NPA (RNP 0.3) – but **no ICAO certification pathway** exists
- Airborne receiver requirements are distinct from maritime – dedicated performance standards and operational procedures needed
- What is the **most appropriate ICAO mechanism** for recognising eLoran as a complementary terrestrial PNT source?
- ICAO signatory to **joint ITU/ICAO/IMO letter** to the UN Secretary-General on RNSS (Radio Navigation Satellite Service) interference – potential entry point for engaging ICAO on resilient PNT

OPEN QUESTIONS: TIMING & GEODETIC REFERENCE

Links to Session 6 (14:45 today) and the Timing Working Group

REFERENCE TIMESCALE

- UTC(k) alignment: national realisations or single/regional shared reference timescale(s)?
- How to handle inter-system offsets? Analogous to GNSS GGTO/KGTO – but message formats, update intervals and data structures remain to be agreed

TWO-WAY LOW-FREQUENCY TIME TRANSFER (TWLFTT)

- Measurement methods and achievable performance
- Practical solutions for near-field receiver saturation

UTC DISSEMINATION

- Leap second handling: including potential negative leap seconds, consistently across national systems

GEODETIC REFERENCE

- Common geodetic reference (e.g. WGS84) required for positioning interoperability

OPEN QUESTIONS: ASF GENERATION & DISTRIBUTION

Links to Session 2 (12:15 today) and all Working Groups

- Standard **ASF survey methodologies** and uncertainty characterisation
- **ASF consistency** across receiver implementations and waveform designs
- **Wide-area ASF modelling**: AI-based approaches promising; model training and validation requires more data – international sharing could accelerate progress (active UK–ROK collaboration)
- **Distribution mechanisms**: LDC, S-100 formats (S-245, S-246, S-247), national augmentation networks – which approach best serves different user sectors?
- **Challenging propagation environments**: e.g. re-radiation effects under bridges

PART 3: ACTION ITEM REVIEW

Actions from Seoul – status as of March 2026

#	Owner	Action	Status
AI1.1	UK	Cover letter for Meeting Minutes	Superseded
AI1.2	UK	Share Roke eLoran receiver details with ROK	Complete
AI1.3	UK	Examine options for sharing GLA IOC ASF datasets with ROK	Ongoing
AI1.4	UK	Facilitate ROK ASF team / Satellite Applications Catapult contact	Outstanding
AI1.5	ROK	Formal request for KPS reference station at Diego Garcia	Awaiting Session 4 (13:45 today)
AI1.6	FR/ROK/UK	Support on-going IMO work on revising Resolution A.1046	

INDICATIVE MARITIME STANDARDISATION TIMELINE

Part 4: Timeline and next steps

SHORT TERM

0-2 years

- National eLoran programmes progressing
- International coalition established
- IMO process initiated
- OEM receivers entering the market

MEDIUM TERM

2-5 years

- Regional transmitter networks operational
- Correction services established
- MSC work item established; IEC standards under development
- Port state / flag state acceptance of eLoran-equipped vessels

LONG TERM

5+ years

- Multiple Regional eLoran Zones operational (Europe, Middle East, Asia-Pacific)
- IMO eLoran receiver standard and IEC type approval achieved
- SOLAS V carriage requirement adopted
- High proliferation across SOLAS and non-SOLAS vessels

THE ROAD AHEAD

What are the objectives for this conference?

1. **Broaden the coalition**
   From trilateral working group to international conference
2. **Advance the three technical work streams**
   Maritime certification ▪ Aviation certification ▪ eLoran as national timescale
3. **Agree priority actions**
   Concrete deliverables for the period between now and the third meeting
4. **Signal collective intent**
   To relevant international bodies – demonstrate the coalition is real and growing