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The Impact of GPS Jamming on the Safety of Navigation

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Presented to the Civil GPS Service Interface Committee, Savannah GA, 15 September 2008

Presentation Context

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- The GLAs value highly the operational and safety benefits of GPS and it is a vital component in our Radio Navigation Plan[1]
- GPS will remain the primary radio navigation means of position fixing from berth-to-berth for at least another ten years
- The introduction of GPS has encouraged mariners to navigate in areas where, and under conditions in which, they had not previously ventured
- The introduction of e-Navigation will further change the way that ships operate
- As part of this, we need to understand what happens when key e-Navigation components (e.g. GNSS) are unavailable

1. *GLA Radio Navigation Plan*. General Lighthouse Authorities of the United Kingdom and Ireland, May 2007

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Pentland Firth
16 knot tidal
current

South-West
Wave Hub

e-Navigation

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- The harmonised collection, integration, exchange, presentation and analysis of maritime information on-board and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security and sea and protection of the marine environment
- The case is based on the need to reduce the impact of human error through improved on-board systems and closer co-operation with VTM authorities
- Positioning fixing systems will need to meet user needs in terms of accuracy, integrity, reliability and system redundancy in accordance with the level of risk and volume of traffic
- Enhanced navigation system resilience, leading to improved reliability and integrity, is expected to support improved safety and thereby better protection of the environment

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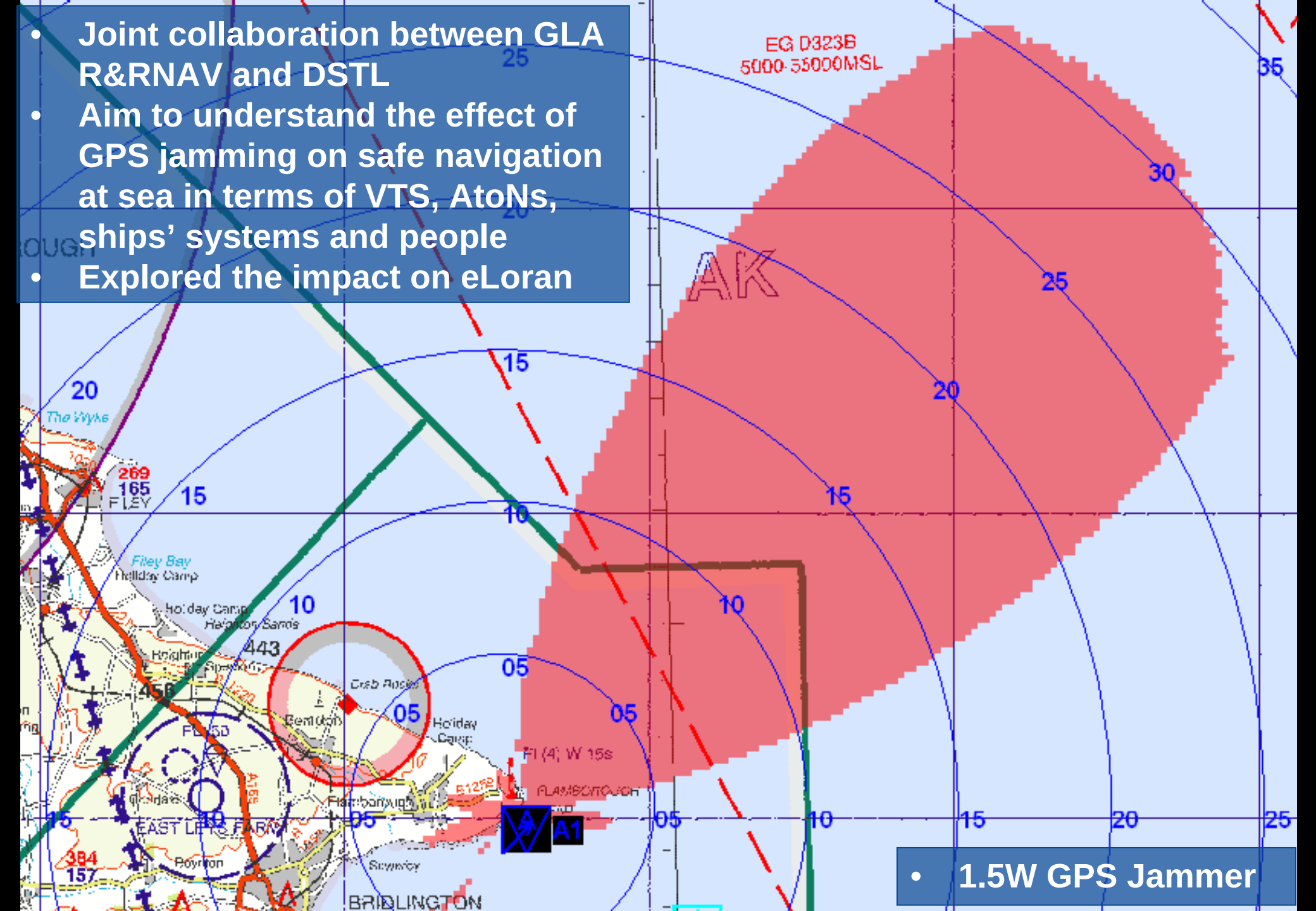

- Joint collaboration between GLA R&RNAV and DSTL
- Aim to understand the effect of GPS jamming on safe navigation at sea in terms of VTS, AtoNs, ships' systems and people
- Explored the impact on eLoran

- 1.5W GPS Jammer

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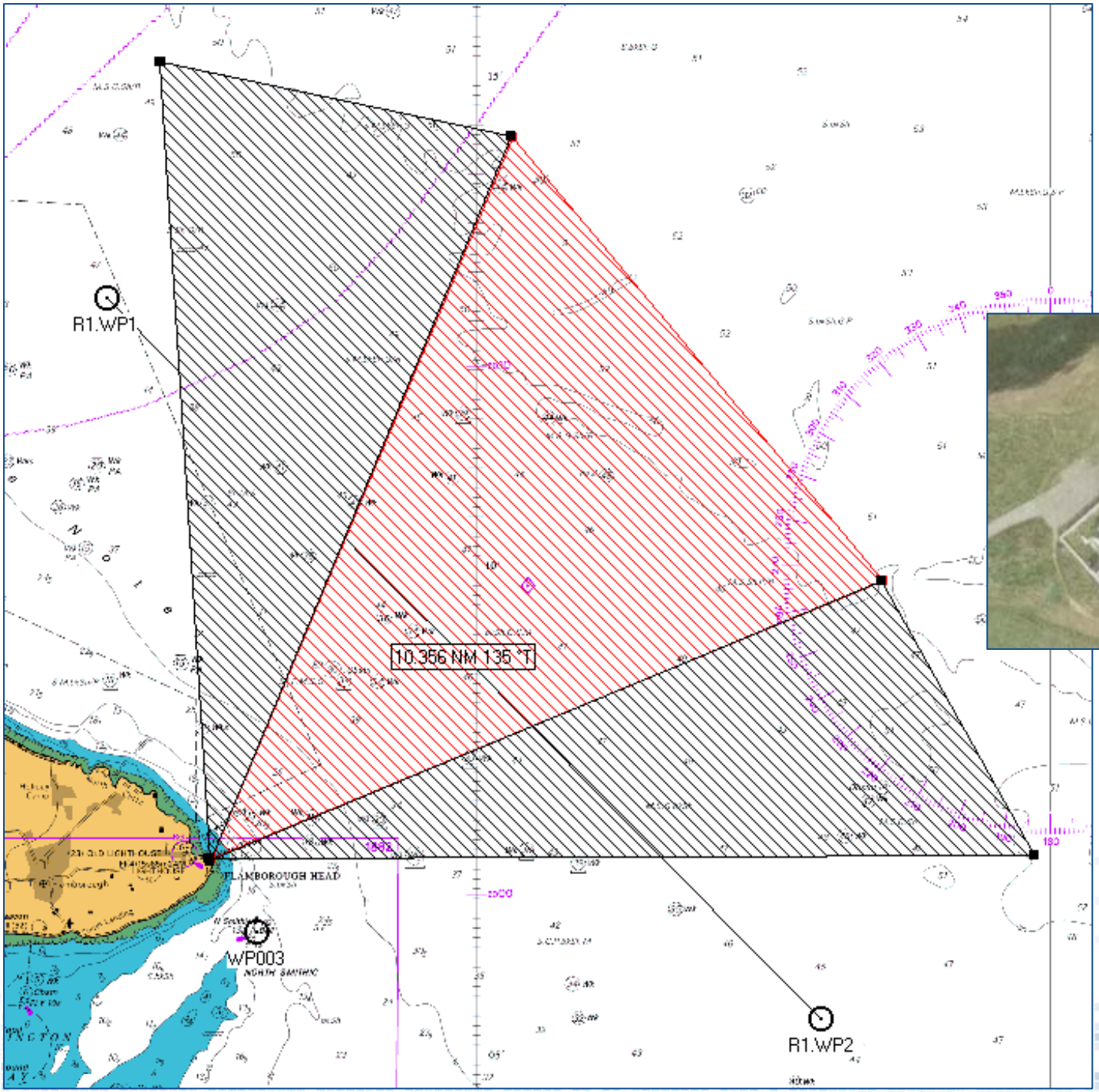

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Impact of jamming - on GPS/DGPS

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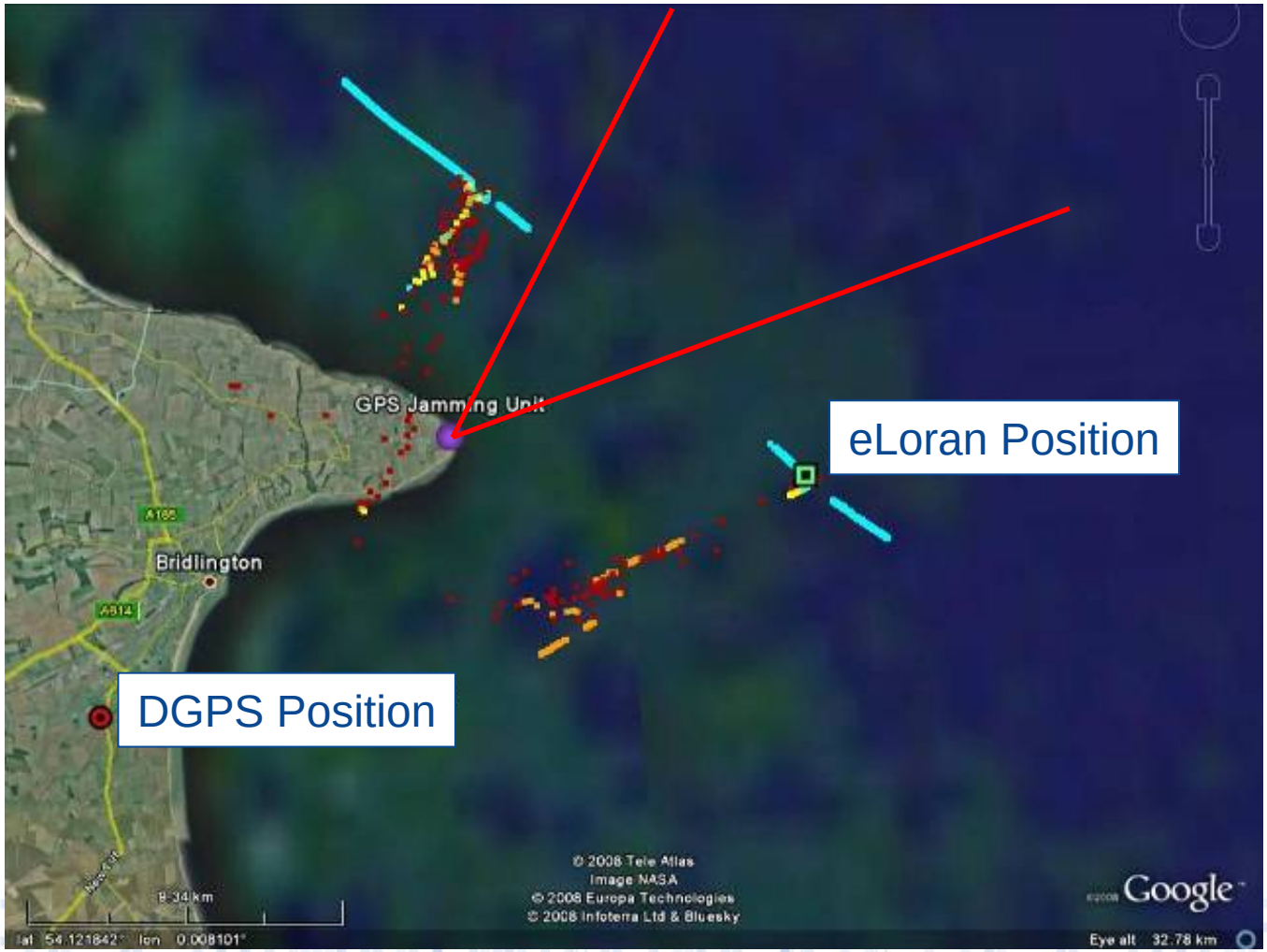
DGPS reported position is inland and 22km away from true position (eLoran).



Colours indicate reported speed: blue <15knts, yellow< 50knts, orange <100knots and red >100knts

Impact of GPS jamming - on eLoran

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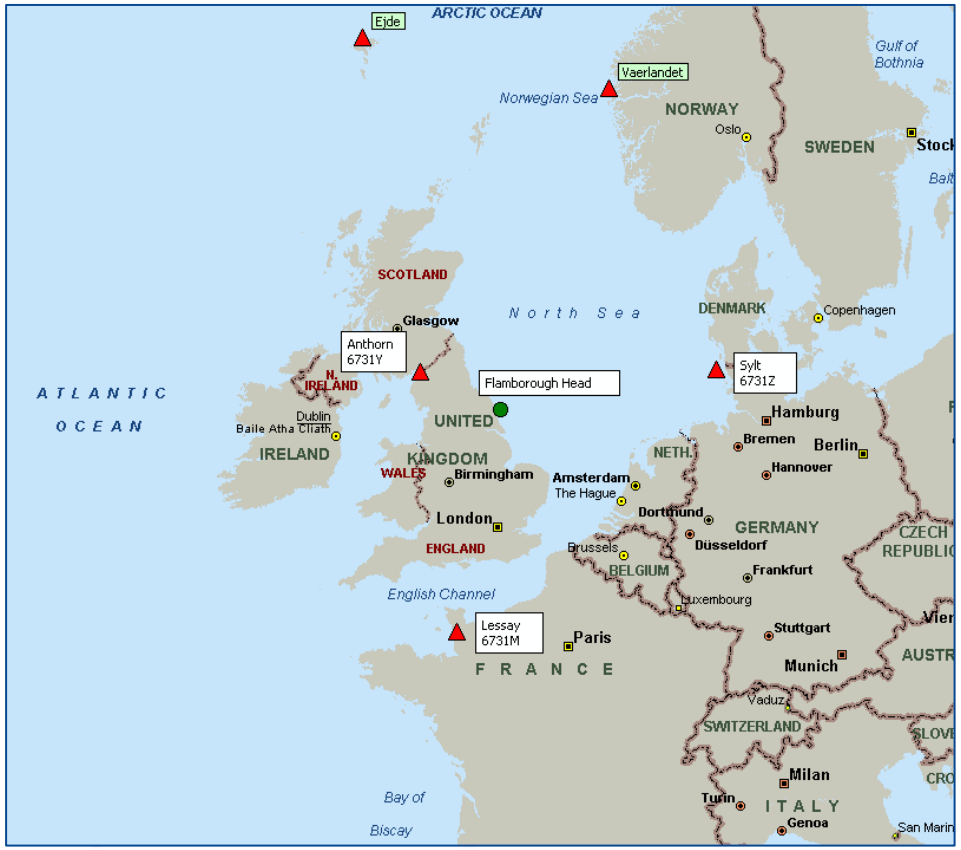
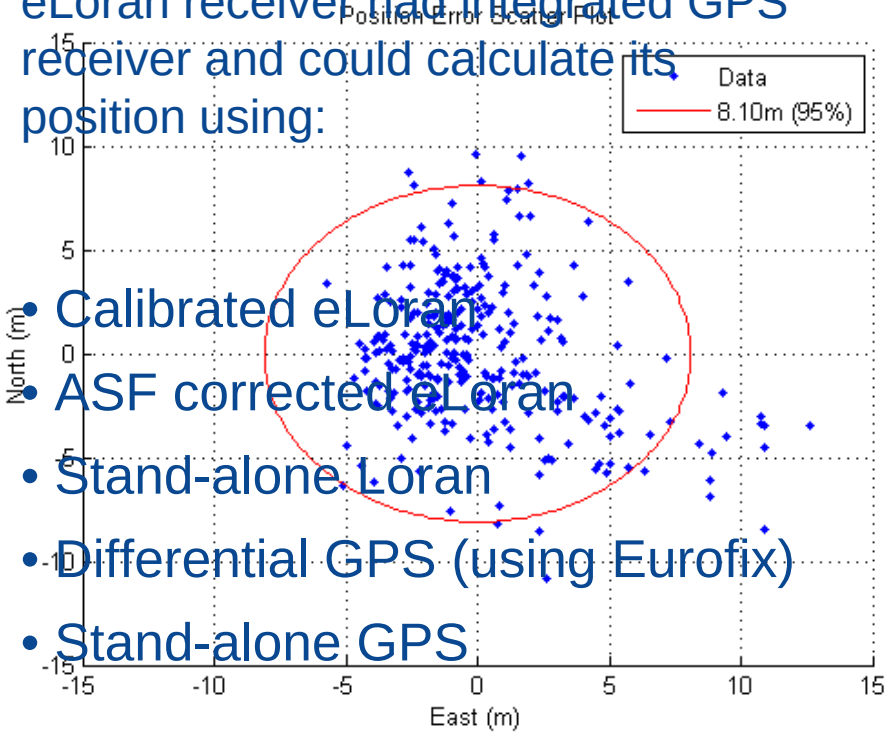


Map showing the Loran stations used in the position solution.

eLoran receiver had integrated GPS receiver and could calculate its position using:

- Calibrated eLoran
- ASF corrected eLoran
- Stand-alone Loran
- Differential GPS (using Eurofix)
- Stand-alone GPS



Loran v DGPS positions shows a Loran accuracy of 8.1m(95%).

Impact of GPS jamming - on eLoran

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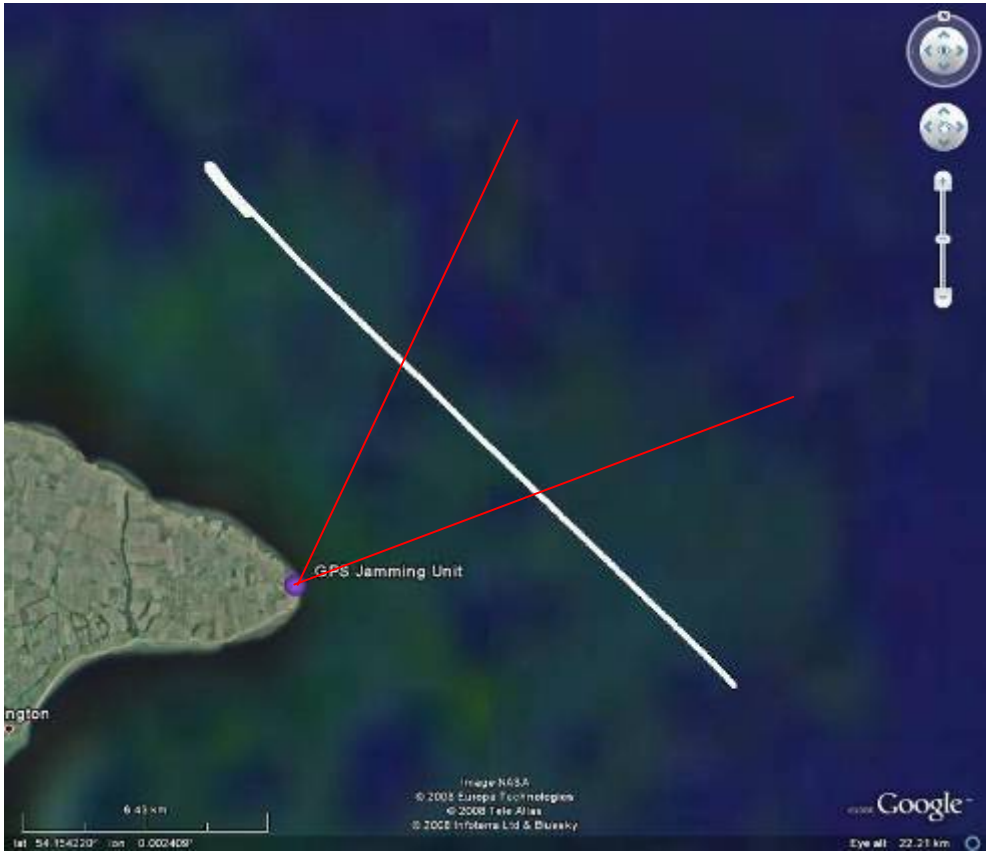
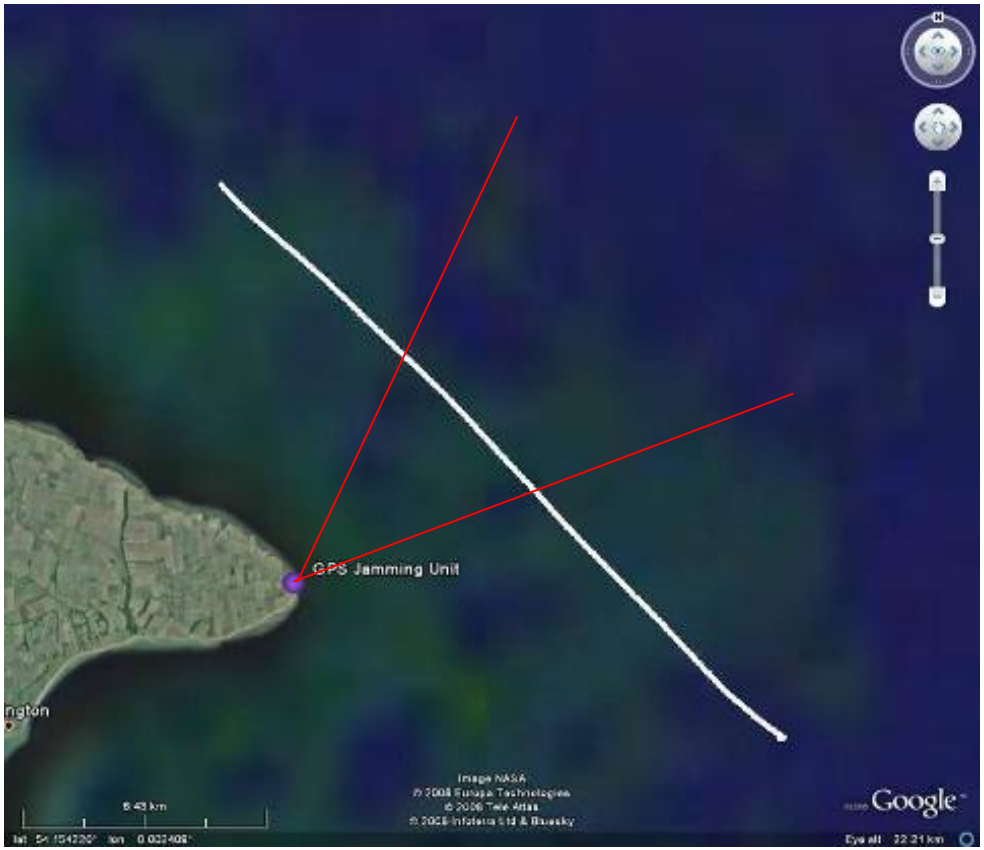


Reported position from eLoran receiver operating in DGPS eLoran mode during control run with no jamming



Reported position from eLoran receiver operating in Calibrated eLoran and ASF corrected eLoran modes with jamming enabled

Impact on maritime safety - Shore

The marine picture presented to Vessel Traffic Services (VTS) will be confused as AIS information with erroneous positions and high-velocities conflicts with the radar information

It is unclear how VTS operators would respond during a real event with high levels of ambiguity

Impact on maritime safety - AtoNs

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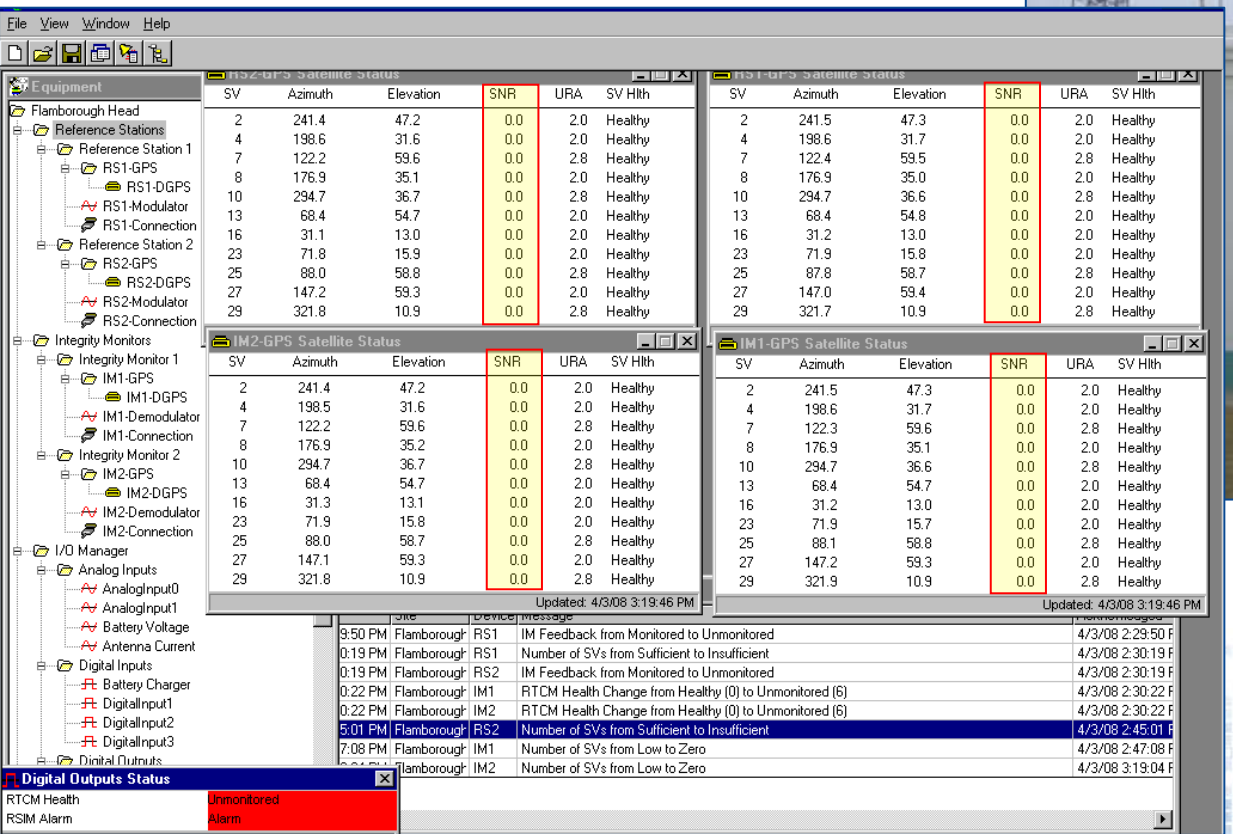
The GLAs' DGPS reference station at Flamborough Head was intentionally jammed.



The result was the station failed to observe any usable satellites and declared a fault.

Impact on maritime safety - AtoNs

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- DGPS reference stations can be jammed resulting either in the absence of or faulty DGPS corrections and integrity information broadcast to users over a very large geographical area
- The automatic identification system (AIS) used as an AtoN may broadcast incorrect information
- Synchronised lights may not be synchronised, thus having an adverse impact on visual conspicuity

Impact on maritime safety
- On ships

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- Navigation, situational awareness, chart stabilisation and Digital Selective Calling emergency communications will be lost if they are based on GPS
- It is unclear how integrated bridge systems will react when the autopilot is being used – the results are potentially extremely hazardous
- Continuation of navigational safety is dependent on mariners' abilities to recognise GPS service denial and to operate effectively using alternative techniques (e.g. radar parallel-indexing)
- Increased use of Electronic Chart Display Information Systems (ECDIS) will increase the attendant risks

Impact on maritime safety - People

- People are conditioned to expect excellent GPS performance
- When ships' crews or shore staff fail to recognise that GPS service denial is occurring and/or there is a loss of familiarity with alternative methods of navigation or situational awareness, there may be significant impact on safety and security
- In this trial, despite the fact that the *Pole Star's* crew was forewarned, problems were experienced with the ECDIS
- The number of alarms that can sound on the bridge can be distracting
- Moving to other navigation techniques can cause an increase in bridge workload

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Conclusions

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- GPS is vulnerable to service denial by intentional interference using low-power jammers
- These results can be extended to GPS service denial by unintentional interference including:
  - spurious harmonics from active TV antennas
  - damaged GPS antenna cables
  - ionospheric effects (e.g. due to the eleven-year sun-spot cycle)
- eLoran is unaffected by GPS jamming and can be used to detect erroneous positions and high velocities that may occur during GPS service denial
- GPS, Galileo and eLoran will provide a robust and resilient PNT (positioning, navigation and timing) foundation for e-Navigation to reduce the impact of human error and improve safety, security and protection of the marine environment

Thought #1 - Diversity & Redundancy

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- The strategic requirement is for “Always-On PNT” based on diverse, redundant systems that allows users to maintain a single concept of operations for as long as possible
- In this context, the US Policy Announcement on eLoran is highly relevant

Mitigation	Concept of Operations	Example
Redundant Systems	No Change	Galileo, eLoran
Backup Systems	Change	Parallel Indexing, Physical Aids to Navigation (lights, buoys …)
Contingency Systems	Change	Advice from VTS

Thought #2 - Benefits

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- Redundancy based on diverse systems will help to mitigate the impact of low probability / high cost events that might otherwise disrupt normal concepts of operations

- Introducing diverse systems will act as a catalyst for innovation and enable new applications / services that will fuel economic benefits
  - Virtual buoys will be useful for the emergency marking of wrecks and may be useful for marking open channels and ice hazards in Arctic waters
- eLoran will secure the benefits we enjoy from GPS today and in the future