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MARITIME RESILIENCE AND INTEGRITY OF NAVIGATION

CGSIC International Information Subcommittee

21 September 2020

PNT Architecture and MarRINav

Mr. Dana A Goward, Mr. Jonathan Turner and Dr. Alan Grant

PNT Architecture

& MarRINav

Mr. Dana A. Goward

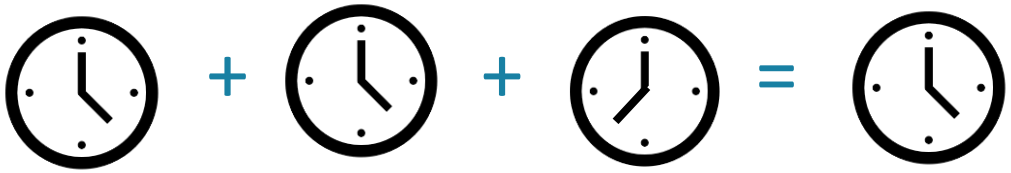
RESILIENT NAVIGATION and TIMING FOUNDATION
Speaking Up for GPS/GNSS Users

Safety Critical Systems

Failure or malfunction likely to cause

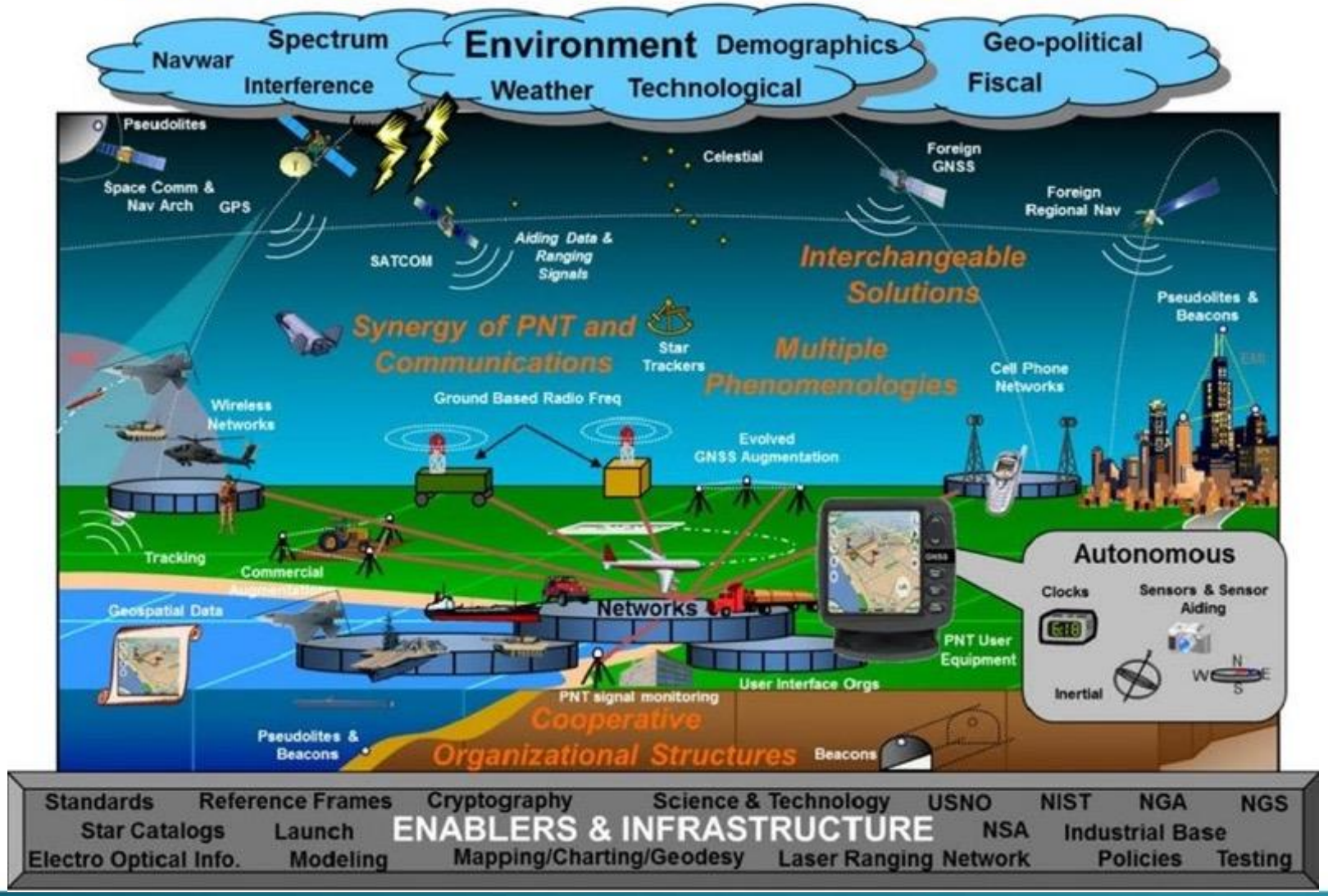
- Death or injury to person
- Significant loss of property/damage to equipment
- Environmental damage

Triple Modular Redundancy (TMR):

Voting → 

Resilience → f(p1, p2,p3) ≈ .99999

National PNT Architecture



Layered PNT Architecture Construct

Global	Space-based, Ubiquitous, 3-Dimensional Position and Precise Time
Regional	Space-based or Terrestrial, Non-global (National/International) Coverage
Local	Space-based, Terrestrial, and/or Autonomous, Localized by design/performance

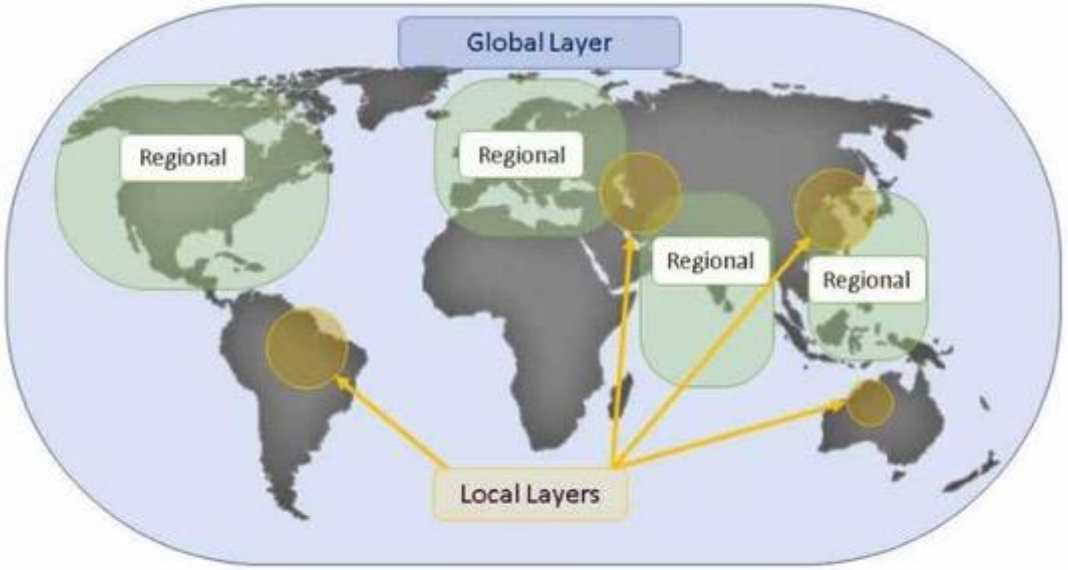


Figure 7 – Layered PNT Enterprise Architecture

Integrated PNT for the Joint Force

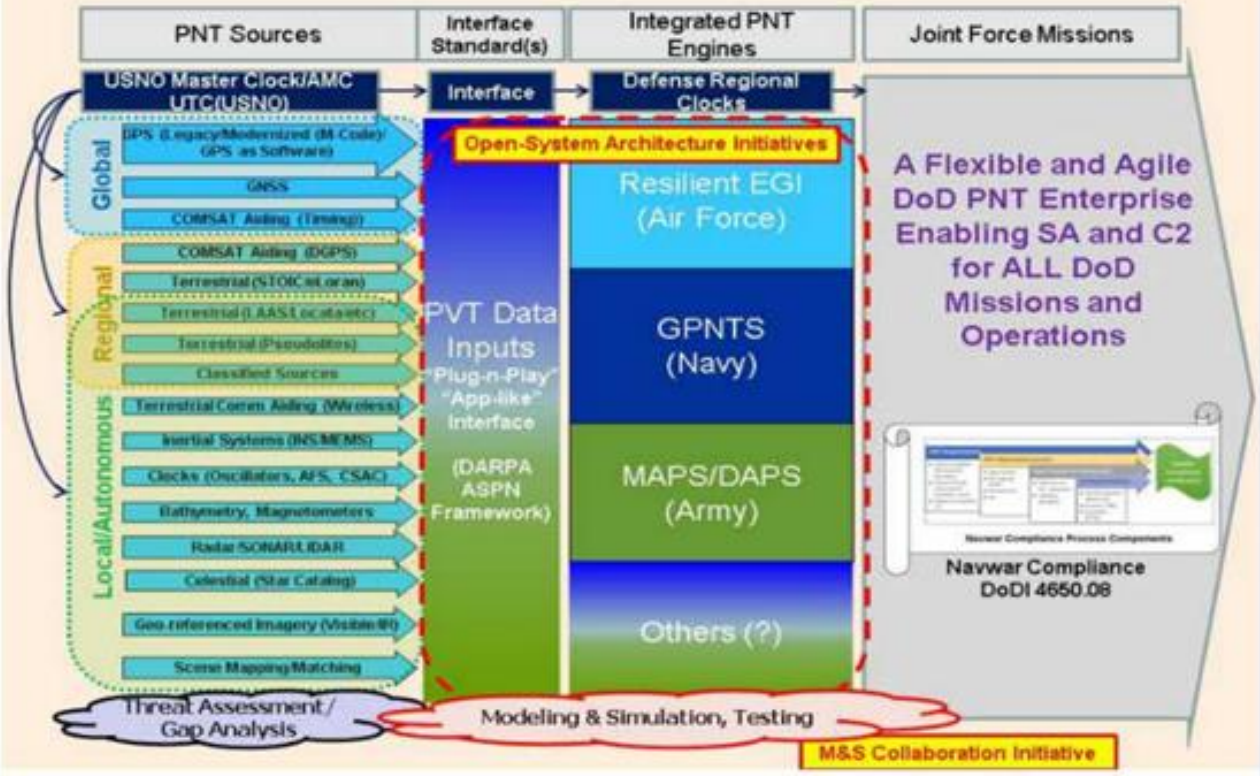


Figure 8 – Notional Capabilities-to-Applications Process

Strategy for the Department of Defense Positioning, Navigation, and Timing (PNT) Enterprise

Unclassified Version, Public Release 14 August 2019

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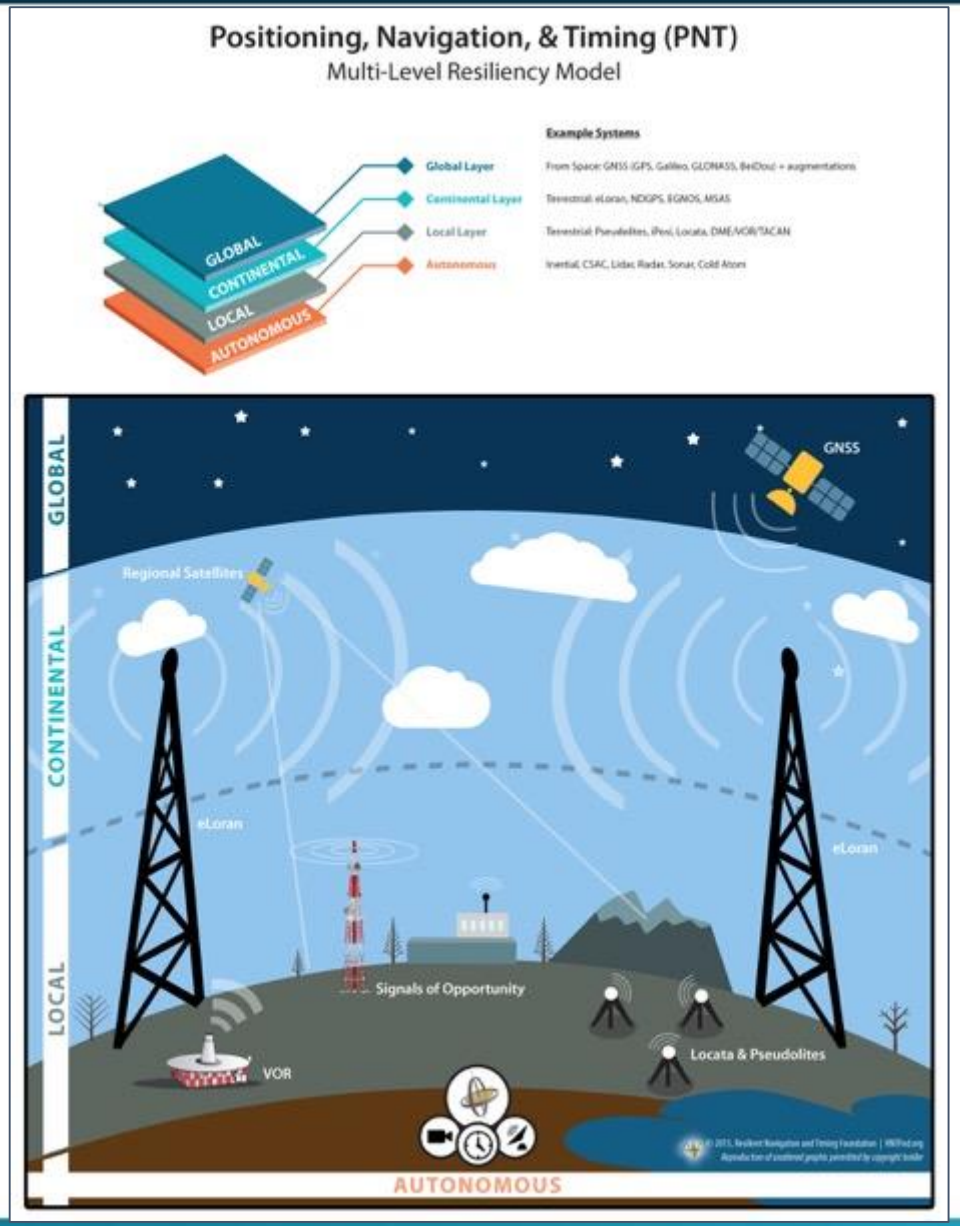

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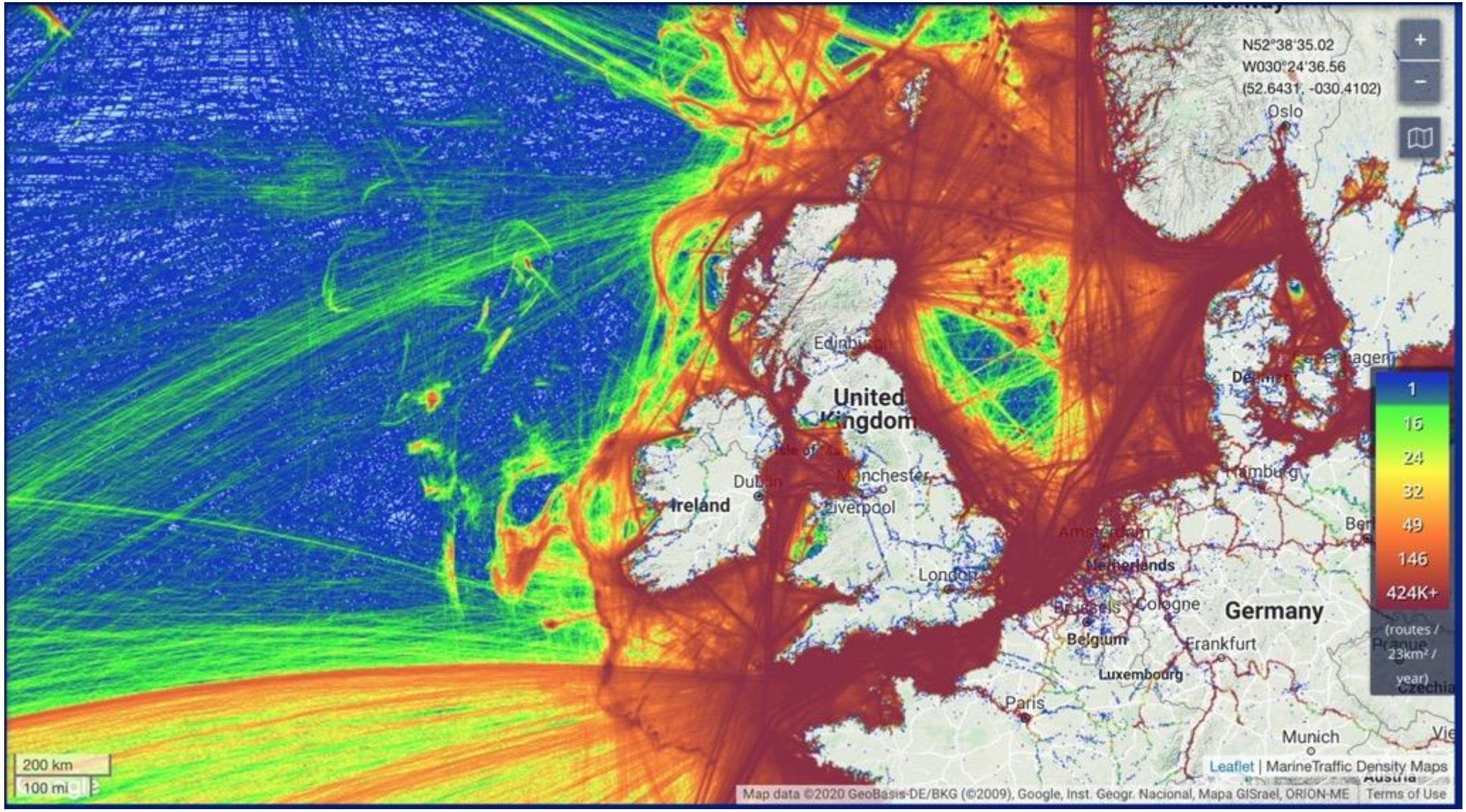
Phase 1 project overview

Mr. Jonathan Turner



Map utilised with the kind permission of www.marinetraffic.com

HMM Algeciras, currently the world's largest container ship (source: kentonline.co.uk)

FinFerries
FALCO

SWEDEN
NORWAY
Oslo
Stockholm
Lake Vänern
Skagerrak
North Sea
Baltic Sea
SCOTLAND
Glasgow
Edinburgh
DENMARK
Copenhagen
UNITED KINGDOM
Belfast
Manchester
Leeds
Dublin
IRELAND
Hamburg
NETHERLANDS
Amsterdam
The Hague
Berlin
POLAND
Birmingham
WALES
Cardiff
London
ENGLAND
GERMANY
Brussels
Cologne
BELGIUM
Frankfurt am Main
Prague
CZECHIA
Katowice
Nuremberg
Luxembourg
Stuttgart
Paris
St Helier
SLOVAKIA
Vienna
Bratislava
Budapest
Munich
AUSTRIA
Zurich
SWITZERLAND
HUNGARY
FRANCE
SLOVENIA
Ljubljana
Zagreb
Lyon
Bay of Biscay
Bordeaux
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), Mapbox, © OpenStreetMap contributors, and the GIS User Community

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Knowledge Transfer Network

BMT

TERRAFIX

WP 0 Project Management
WP 1 Maritime Context & Requirements
WP 2 GNSS Integrity (SBAS & Beacons)
WP 3 PNT R&I Technologies & Integration
WP 4 Conceptual PNT Infrastructure
WP 5 Outline Cost Benefit Analyses
WP 7 Roadmap and Planning
WP 6 Stakeholder Engagement

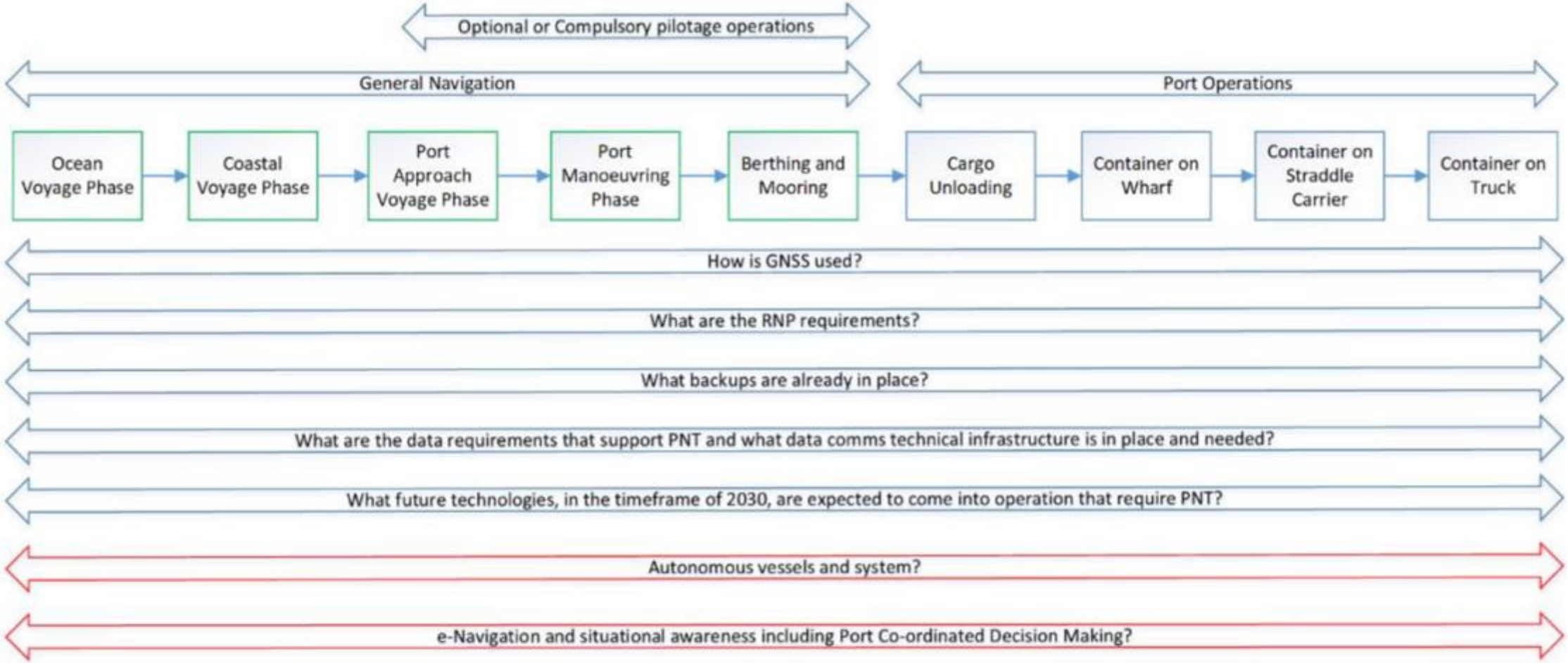


Figure 10: Scenario of linked Use Cases for maritime analysis.

Position, navigation and timing systems considered:

Global
- GNSS
- Satelles (STL), subject to confirmation of performance

Wide area
- eLoran

Local area
- VDES Ranging Mode (R-Mode)
- Radar Absolute Positioning
- LOCATA™

Onboard
- Traditional and/or inertial Dead Reckoning
- Multi-system receiver (MSR)

Detail on each system is available in MarRINav report D4

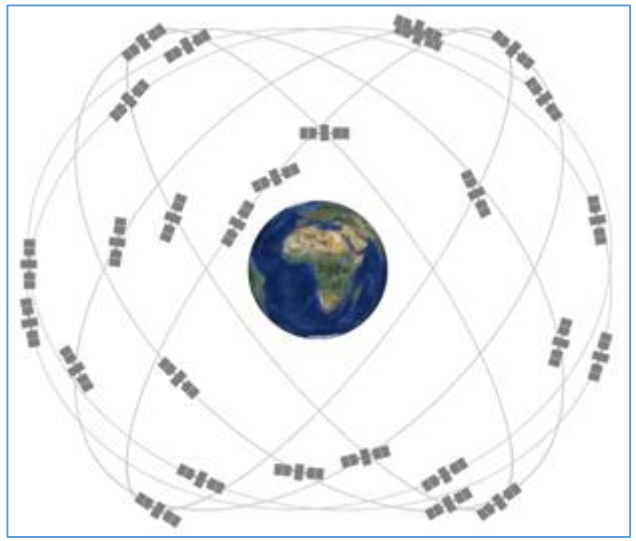
Requirement set (arbitrary numbers)	1	2	3	4	5	6
Accuracy (95%)	1000 m	100 m	100 m	10 m	10 m	10 m
Integrity Limit with 10^{-5} risk	2500 m	250 m	250 m	25 m	25 m	25 m
Distance from coast	Any	<100 km	Any	<10 km	<100 km	Any
GNSS	Yes	Yes	Yes	Yes	Yes	Yes
Differential eLoran	No	Yes	Note 1	Yes	Note 3	No
Differential eLoran with VDES R	No	Yes	Note 1	Yes	Note 3	No
eLoran	No	Yes	Note 1	No	No	No
eLoran with VDES R-mode	No	Yes	Note 1	No	No	No
MF, VDES or MF/VDES R-mode	No	Note 1	No	No	No	No
Coherent radar ranging with DR	No	No	No	Note 2	No	No
Dead Reckoning (DR) for 15 min	Yes	Yes	Yes	No	No	No
Dead Reckoning (DR) for 3 hours	Yes	No	No	No	No	No
DR + Star Tracker	Yes	No	No	No	No	No

- Note 1: Theoretically possible, but impractical to achieve this level of coverage.
- Note 2: Subject to maturity of the technology
- Note 3: Requirements are met within 30 km of the coast, but not in the 30-100 km range

Table 3: Comparison of selected PNT technologies with various user requirements.

Further information is available in MarRINav report D6

Proposed solution for UK CNI

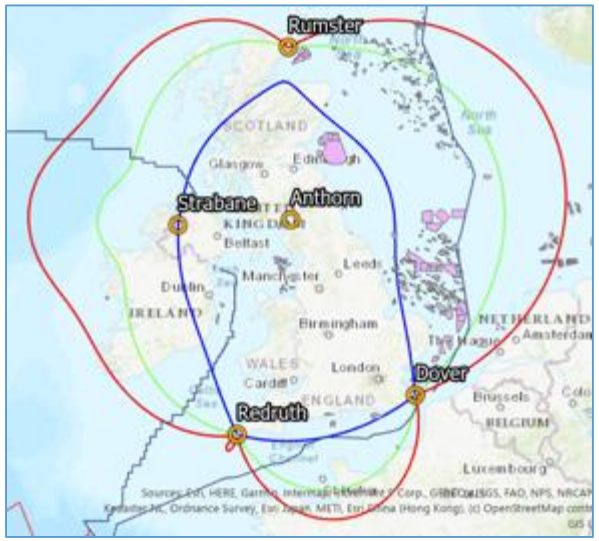


GNSS

Source: GPS.gov

(EGNOS V3 for user level integrity)

+



eLoran

+

R-Mode (VDES)

+ DR

- DR supported by Radar absolute positioning
- Port operations supported by Locata™
- Resilient PNT & I is achieved through a system-of-systems approach

Staged Project Approach

Phase 1
Research, Design, Simulate

Phase 2
Demonstrate and Implement
Build a ‘system of systems’
system by system

Phase 3
Explore new sectors and geographies

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More information and detail at

www.marrinav.com

www.navisp.esa.int

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Phase 1 project highlights

Dr. Alan Grant