Building International Collaboration with Singapore

Engagement from the Maritime Cyber Threats Research Group, Riscocity®, and the wider Marine Institute

Kevin Forshaw

Director of Industrial & Strategic Partnerships

Faculty of Science & Engineering

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The University of Plymouth

- The first and largest Marine Institute in UK, with over 3000 staff and students looking at the Ocean
- Three-time winner of the Queen's Anniversary Prize for Higher and Further Education, UK Top 25 for Teaching Quality & World Top 25 for Research Citations
- 1st in the world for research towards SDG 14 (Life Below Water), Times Higher Education 2021

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THE University of the Year

https://www.plymouth.ac.uk/about-us/the-home-of-marine

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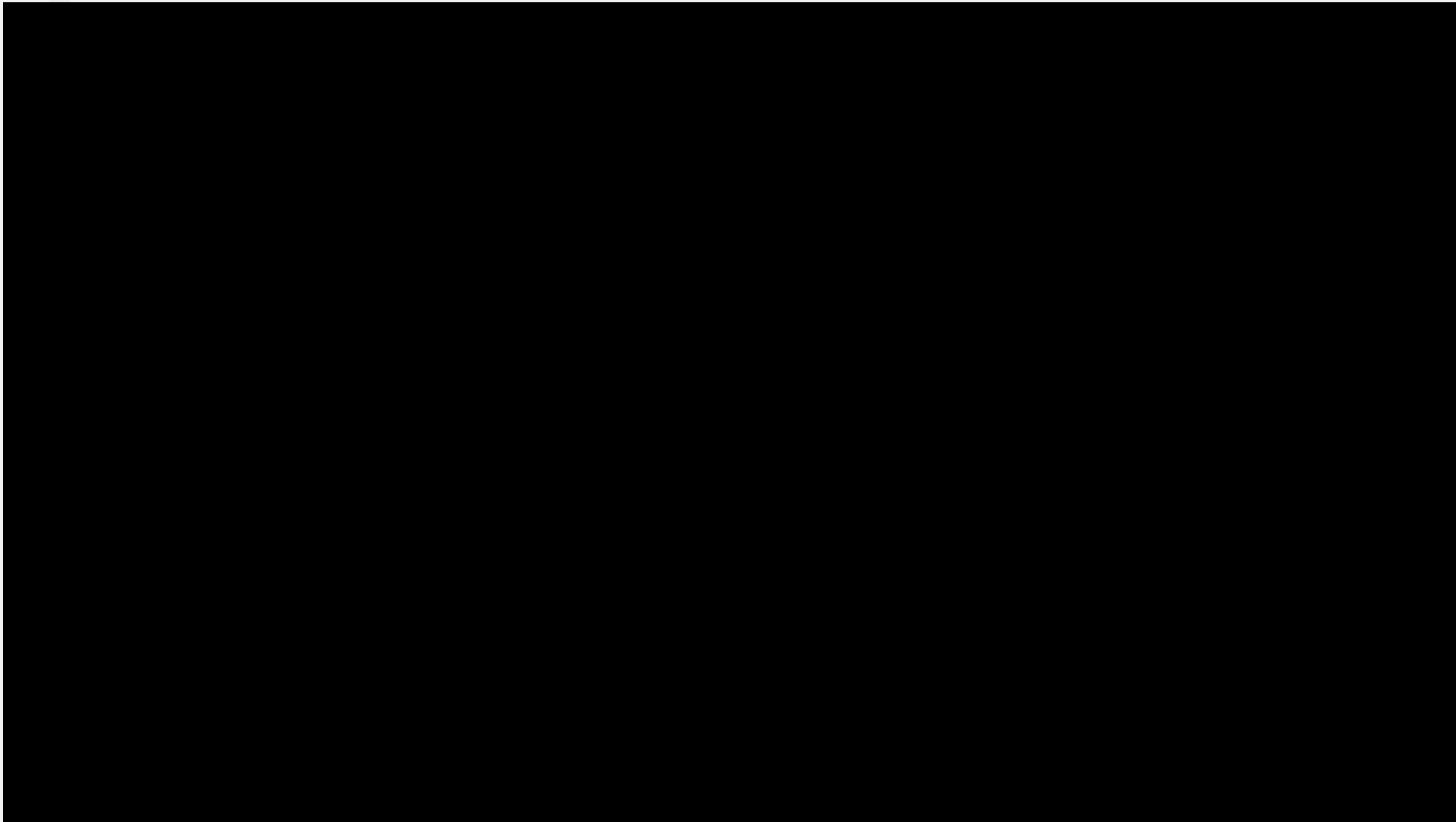

Research Specifics

- The **Maritime Cyber Threats Research Group** is the largest of its kind globally, with its unique Cyber-SHIP Laboratory, and leading insight into multi-parameter optimization risk-assessment frameworks
- The University has one of the largest fleets of **Marine Autonomous Systems** of any University, and a formal partnership with the UK Royal Navy
- The University is supplementing its suite of Wärtsilä Bridge Simulators with a new Kongsberg, Full-Mission DP Simulator
- **MaCRA®** was winner of the **Lloyd's Science of Risk** prize, and **NCSC Cyber Den** in 2021

ROYAL NAVY

Congratulations to this years Cyber Den winners...

MaCRA

CYBERUK 2021 ONLINE 11-12 May 2021 National Cyber Security Centre

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Navigation Suite at the University

- Existing Wartsila Ships' Bridge Simulator, and additional 8 stations
- £600k Capital Investment for a Full Mission DP Simulator
- This being provided by Kongsberg
- Key to optimise
  - Installation
  - Operational maintenance inspection
  - Use of South West port facilities

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UNIVERSITY OF EXETER

CATAPULT Offshore Renewable Energy

Wave Hub

European Union
European Regional Development Fund

University of Plymouth's lead in Marine Renewables

Research

- Leading UK University for Marine Engineering
- Director of Supergen ORE Hub

Facilities

- State of the art wave and current basin for physical testing housed in the COAST building
- Recently added Wind Generation capability placing us at the forefront of Floating Wind Energy Research

Supergen Offshore Renewable Energy

UKRI Engineering and Physical Sciences Research Council

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Objectives for visiting Singapore

1. To establish research collaborations with Singapore Universities relating to Maritime, and wider Infrastructure related **Cyber-Physical Security**
2. To explore the potential for collaboration and connections between Research Laboratories and Facilities relating to **Cyber-Physical Security**, **Marine Autonomy** and **Navigation Simulation**
3. To explore the potential for joint course development and delivery in Marine and Maritime more generally
4. To also engage with Shipping Operators and Port Authorities (MPA) to discuss engagement on **Maritime Cyber Security, Smart Ports and Marine Autonomous Systems**

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Maritime Cyber Security

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Cyber-SHIP Lab

SECURING MARITIME

Software
Hardware
Information
Protection

- Unique £3.2 million **hardware-based** platform: cyber risk-assessment of critical ships' systems
- **Configurable** research and training facility – physical twin
- Combines maritime tech with leading-edge cyber security research and practice to provide real-world solutions to real-world problems

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Cyber-SHIP Lab

SECURING MARITIME

Software
Hardware
Information
Protection

- Fully functioning lab with a growing number of bridge and critical control system configurations
- Custom built scale physical test rigs for steering and propulsion systems
- Set of standard tests providing basic vulnerability assessment
- Custom crafted malware
- Commercial consultancy to provide standard vulnerability reports

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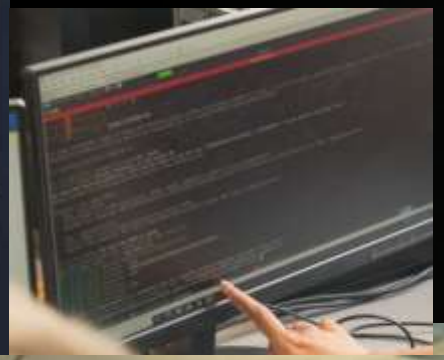
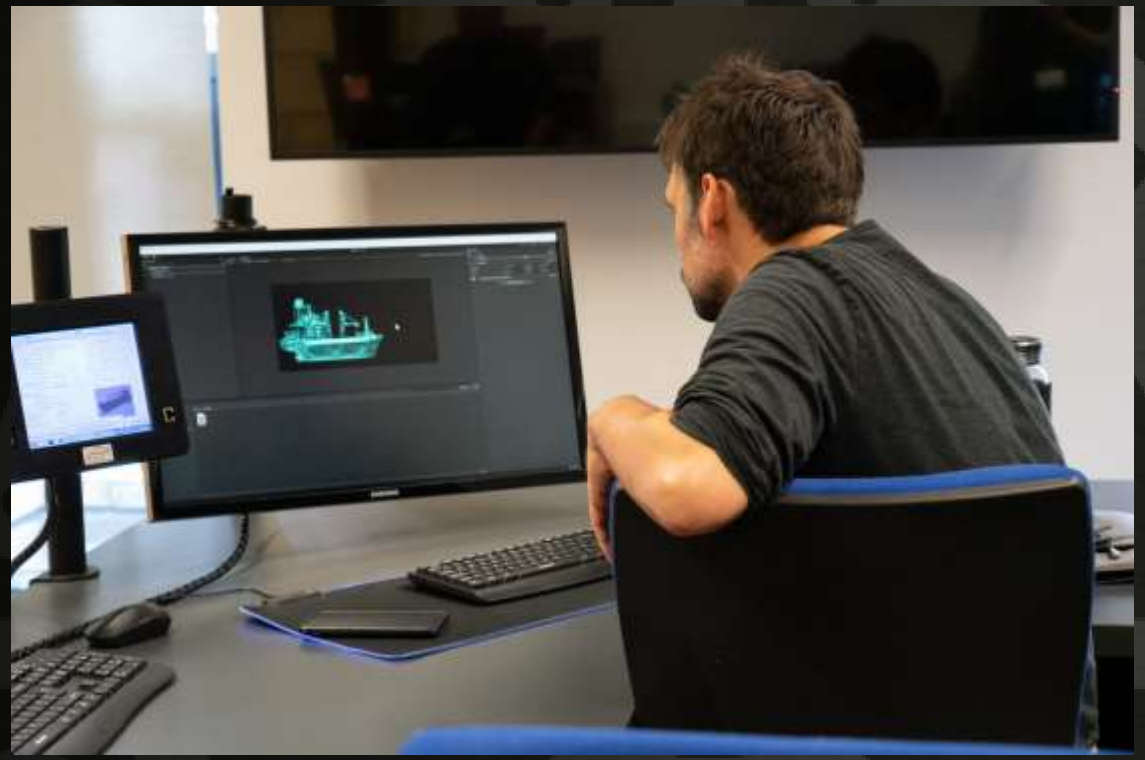
The Consol Room



Visualisation of data
Physical hardware visualisation of attacks
Pen-testing
Research Project development
Development of custom electronics and software
Teaching/training



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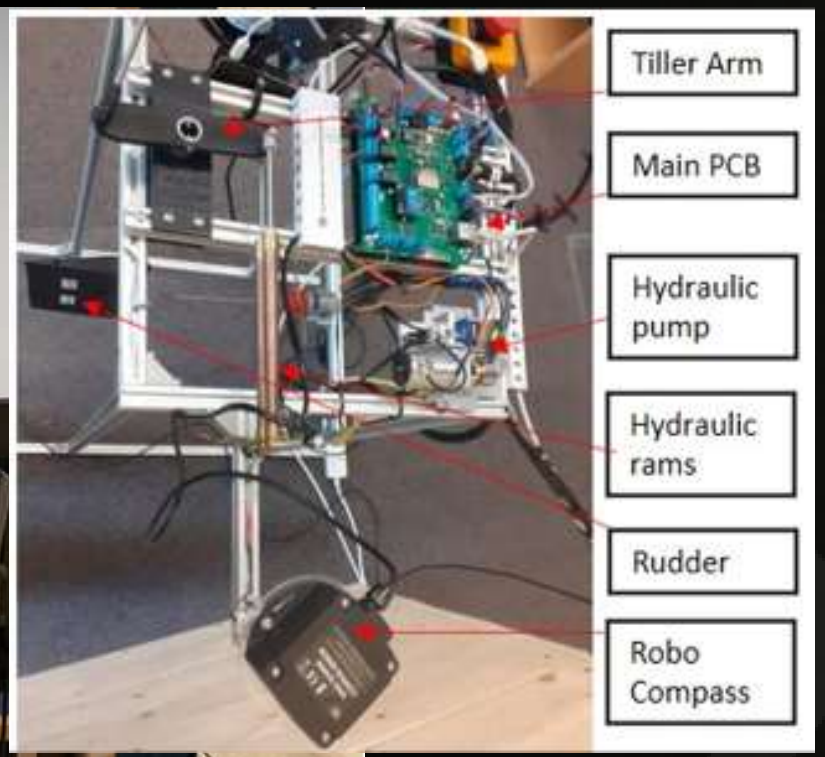
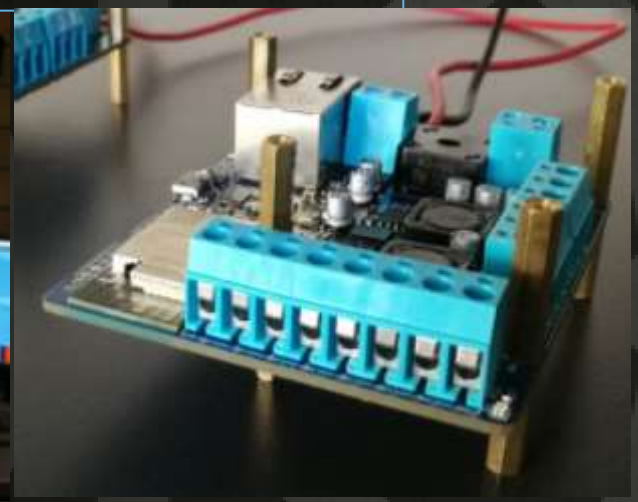


Bespoke electronics design work

Custom built, in-house physical model of rudder and propulsion system simulator



The Vault

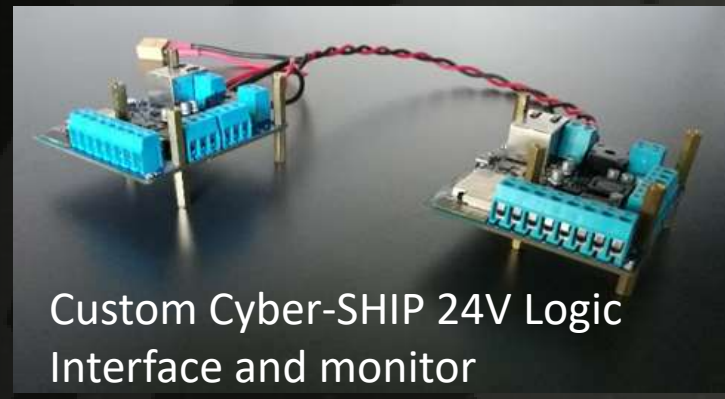

Drones and USVs


Radar equipment


Custom Power Distribution


VDRs and NAVTEX


AIS receivers


Custom Cyber-SHIP 24V Logic Interface and monitor


USV equipment

Cyber-SHIP Lab

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NMEA2000/0183
Devices


Serial- IP converters


Serial- IP converters


Data recovery from
ECDIS


AIS


Satcom


NAVTEX/AIS

Riscocity® and MaCRA®

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Riskocity

MaCRA

The MaCRA® Solution for increasing Maritime Cyber Threat

- **MaCRA®** uniquely provides **dynamic, multi-dimensional risk assessment tooling**
- This uniquely addresses both **IT** and **OT (Operational Technology)** elements of a specific vessel System
- Taking known **System** vulnerabilities and then cross-referencing them with threats associated with **Cargo transported,** and **Route** operated
- MaCRA® giving real-time, operation-specific maritime cyber risk assessment

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Riskocity

MaCRA

MaCRA® USPs

- Multi-dimensional risk assessment enables a range of end-users to distil complexity into meaningful risk insight
- Dynamic Risk Assessment making this fully customisable to specific operation
- Giving operators unique ability to prioritise activity and spend that will genuinely mitigate risk to their business

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Marine Autonomous Systems

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Developments with the UK Royal Navy

- MoU around use of Marine Autonomy for Hydrography agreed
- This has seen two Marine Autonomous platforms on long loan from the RN, with further investment into sub-surface platforms
- Vice Admiral Burns (Commander of the Fleet) visited in June 2021 to see Cyber-SHIP and Marine Station
- UoP also delivered a ‘Marine Science Day’ at the NATO Anti-Submarine Warfare Conference in May

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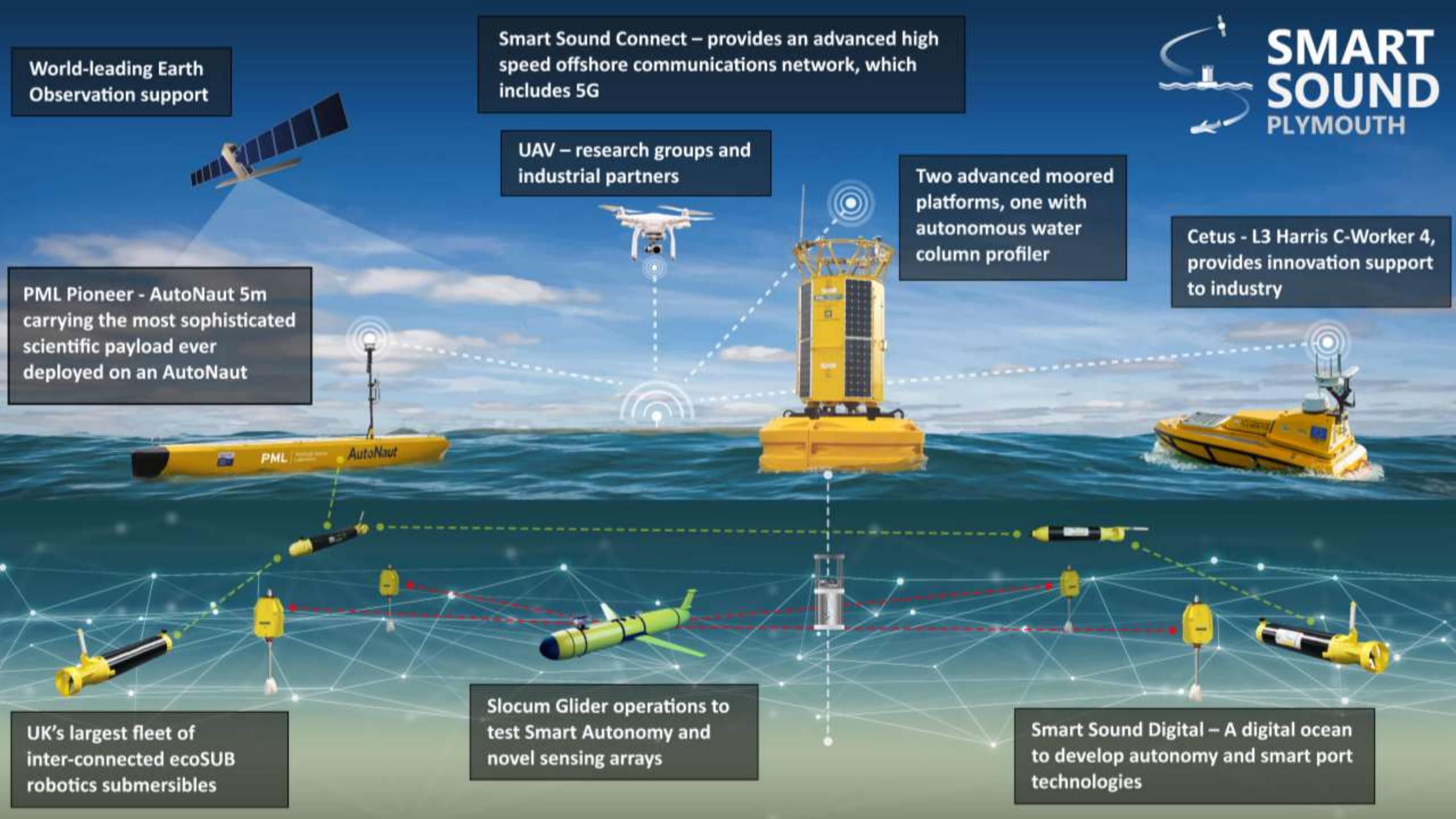
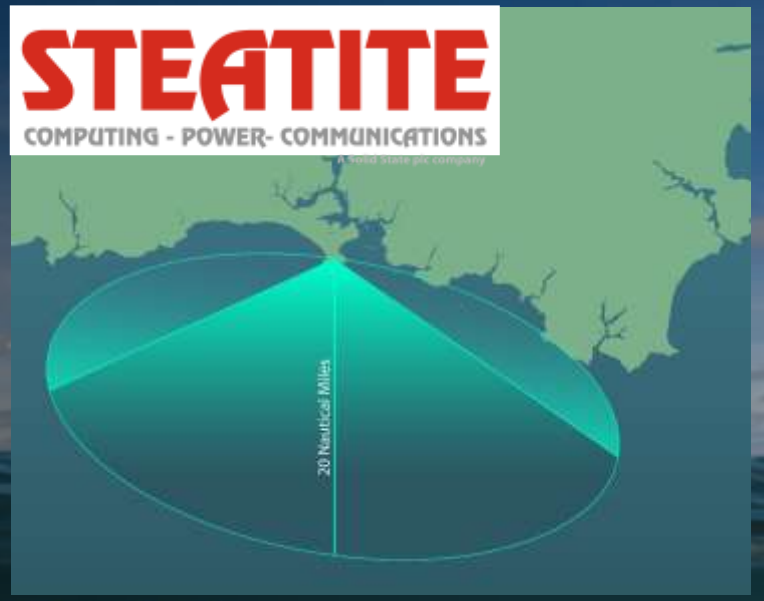
ROYAL NAVY


World-leading Earth Observation support
Smart Sound Connect – provides an advanced high speed offshore communications network, which includes 5G
SMART SOUND PLYMOUTH
UAV – research groups and industrial partners
Two advanced moored platforms, one with autonomous water column profiler
Cetus - L3 Harris C-Worker 4, provides innovation support to industry
PML Pioneer - AutoNaut 5m carrying the most sophisticated scientific payload ever deployed on an AutoNaut
PML
AutoNaut
UK's largest fleet of inter-connected ecoSUB robotics submersibles
Slocum Glider operations to test Smart Autonomy and novel sensing arrays
Smart Sound Digital – A digital ocean to develop autonomy and smart port technologies

Smart Sound Connect

£1.8m investment to deliver an advanced private marine comms network to Smart Sound.



- Vodafone & Nokia to deliver the 5G/4G private network across the port.
- 5G coverage in pre-agreed autonomy trials areas.
- Control hubs to be housed at Oceansgate and PML.
- Steatite to provide Wave Relay offshore marine network, coverage over 20 miles offshore.
- Integrated networks.
- Operated by PML and free use of the network until March 2023.
- Coastal 5G highway.

PML | Plymouth Marine Laboratory

The Plymouth "ecosystem"

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Shipping operators (civil and defence), equipment manufacturers, regulators, insurers

Cyber-range labs

Exploits Tools

Cyber-SHIP Lab

Database

Ship simulators

Scenarios Training

Smart Sound

Autonomous/Remote control

Drones MAS

Profiles Reports Risk assessment

Shipping operators (civil and defence), equipment manufacturers, regulators, insurers

Cyber-SHIP Lab

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Faculty of Science & Engineering

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Ranked First Globally for contributions to UN SDG 14 ‘Life below water’

14 LIFE BELOW WATER

Cyber-MAR: A Real World Attack Scenario

Cyber-MAR project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 833389. Content reflects only the authors' view and European Commission is not responsible for any use that may be made of the information it contains.

Setting the Scene -- Introduction to Port of Valencia

The port of Valencia is a major European port, handling over 6 million tonnes of cargo a year. The port also serves as an important regional hub, handling a large number of the imports, exports and transhipments that take place in the region.

The port handles a wide variety of cargo including liquid bulk, dry bulk, containerised cargo and vehicular traffic. In addition to this, the port also hosts a number of passenger ships each year, including cruise ships. Due to the importance of this port to the European economy, it is of utmost importance to EU trade.

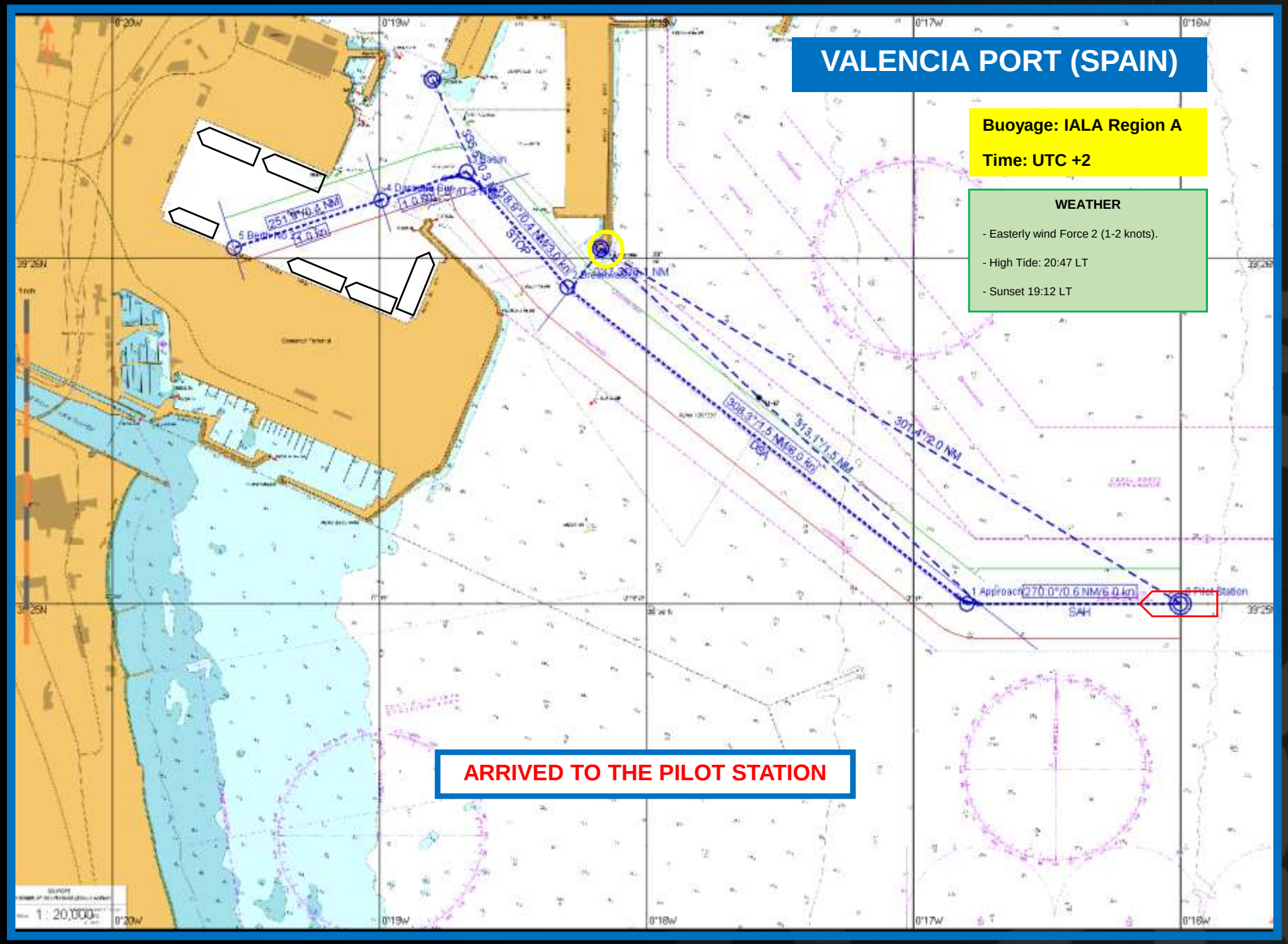
Setting the Scene - Introduction of the Ship

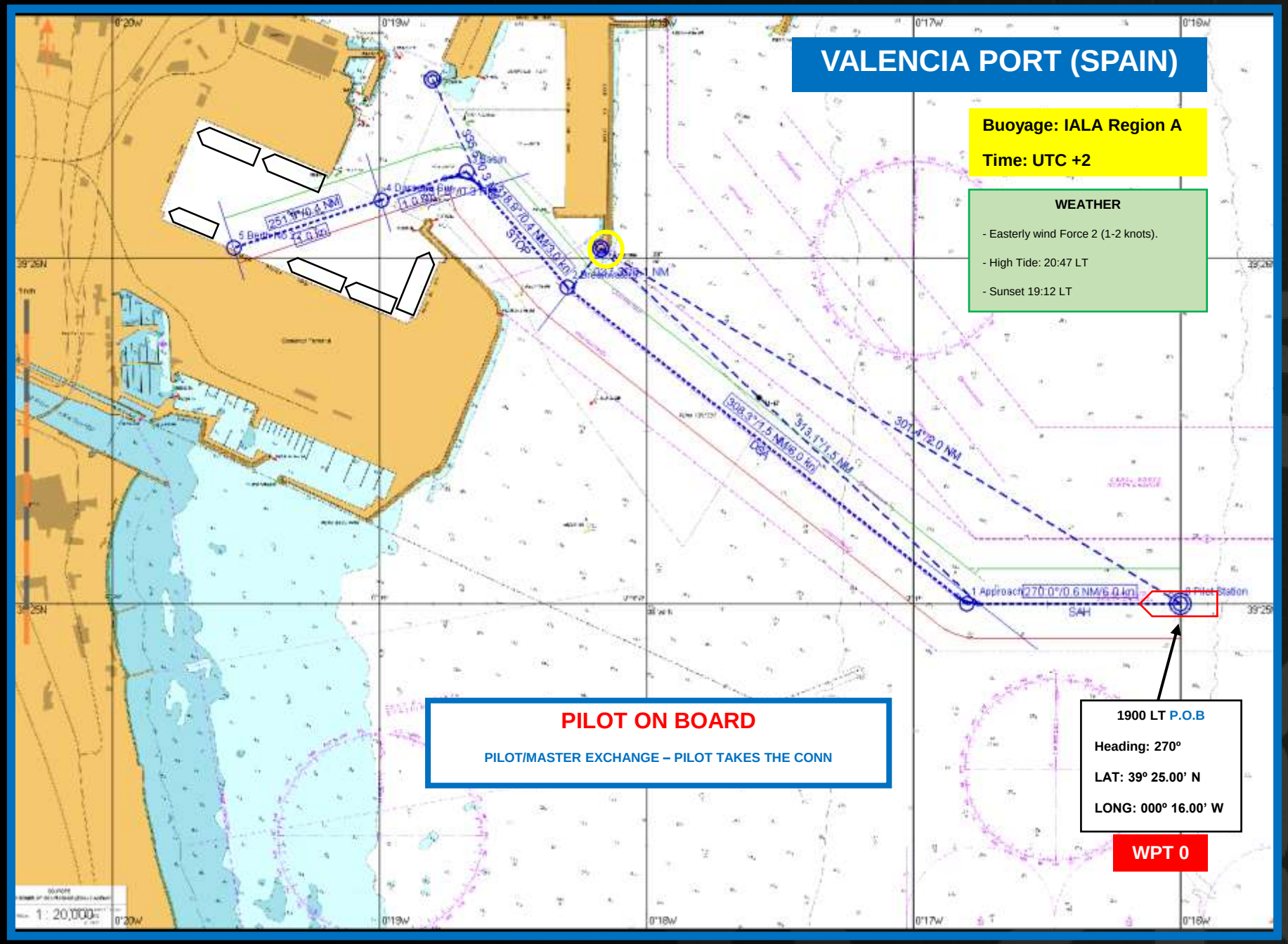
Length	397 m (1,302 ft 6 in)
Beam	56 m (183 ft 9 in)
Draught	16.02 m (52 ft 7 in)
Depth	30 m (98 ft 5 in) (deck edge to keel)
Speed	25.5 knots (47.2 km/h; 29.3 mph)
Capacity	•14,770+ TEU

Valencia Attack Walkthrough

Stage 1 – Downloading and Propagation of Attack (DTM)

- Maintaining Maritime Systems
  - 3rd party service company
  - Receives the malicious email
  - Clicks the link and downloads the firmware
- Transferring the firmware to the ship
  - On board scanner will not pick up malware
- Good security practices throughout


VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
ARRIVED TO THE PILOT STATION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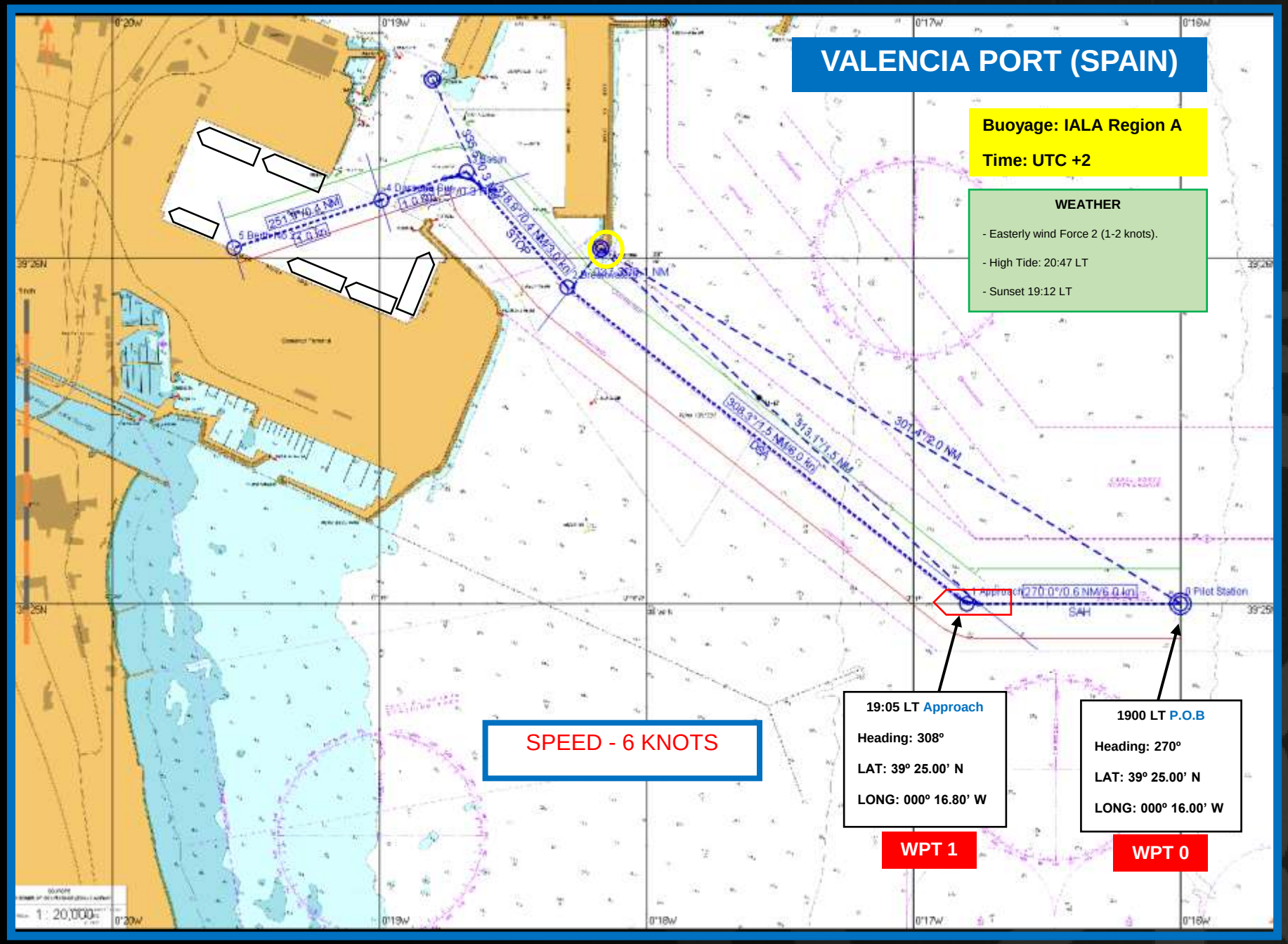
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
PILOT ON BOARD
PILOT/MASTER EXCHANGE – PILOT TAKES THE CONN
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0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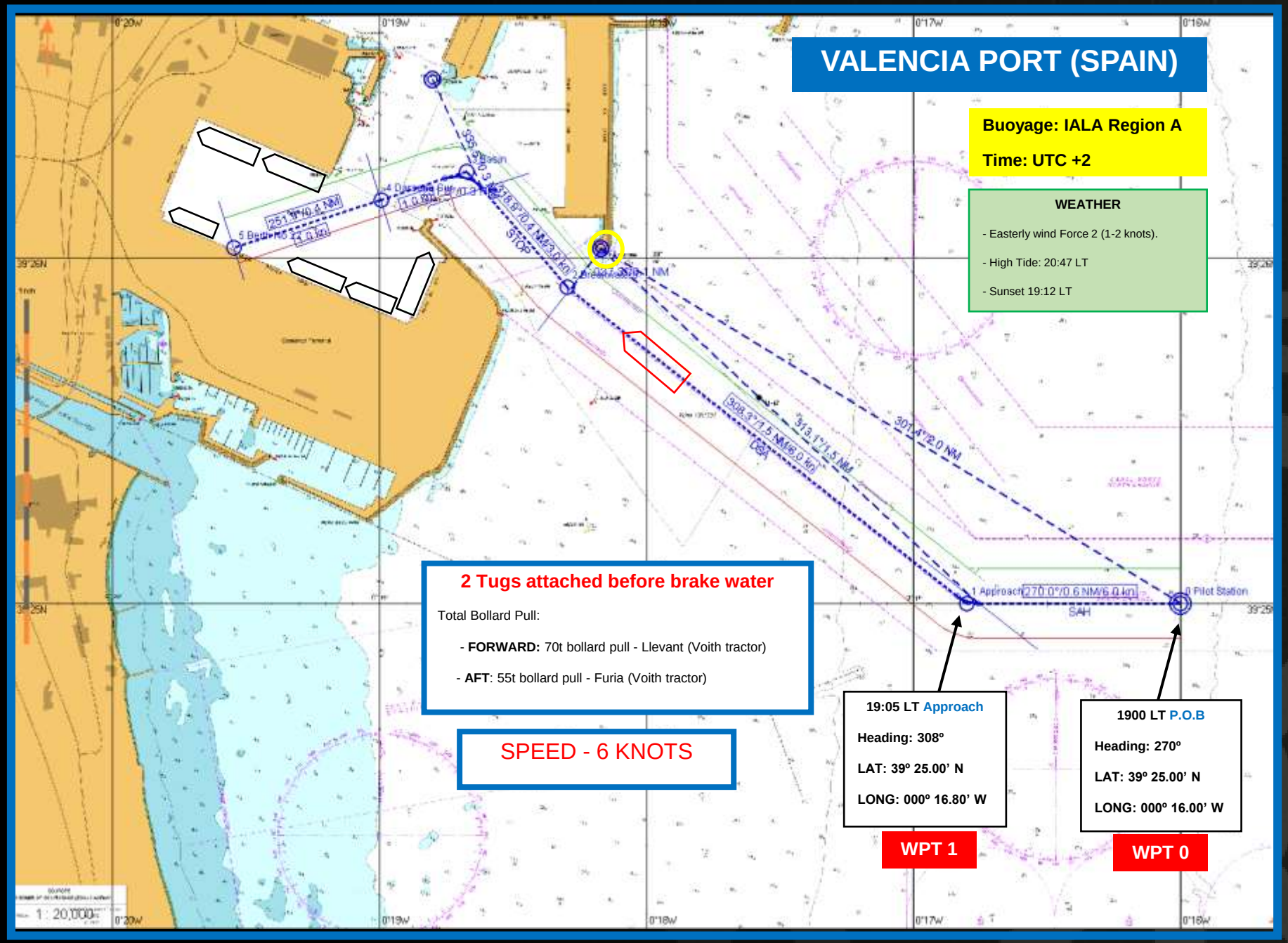
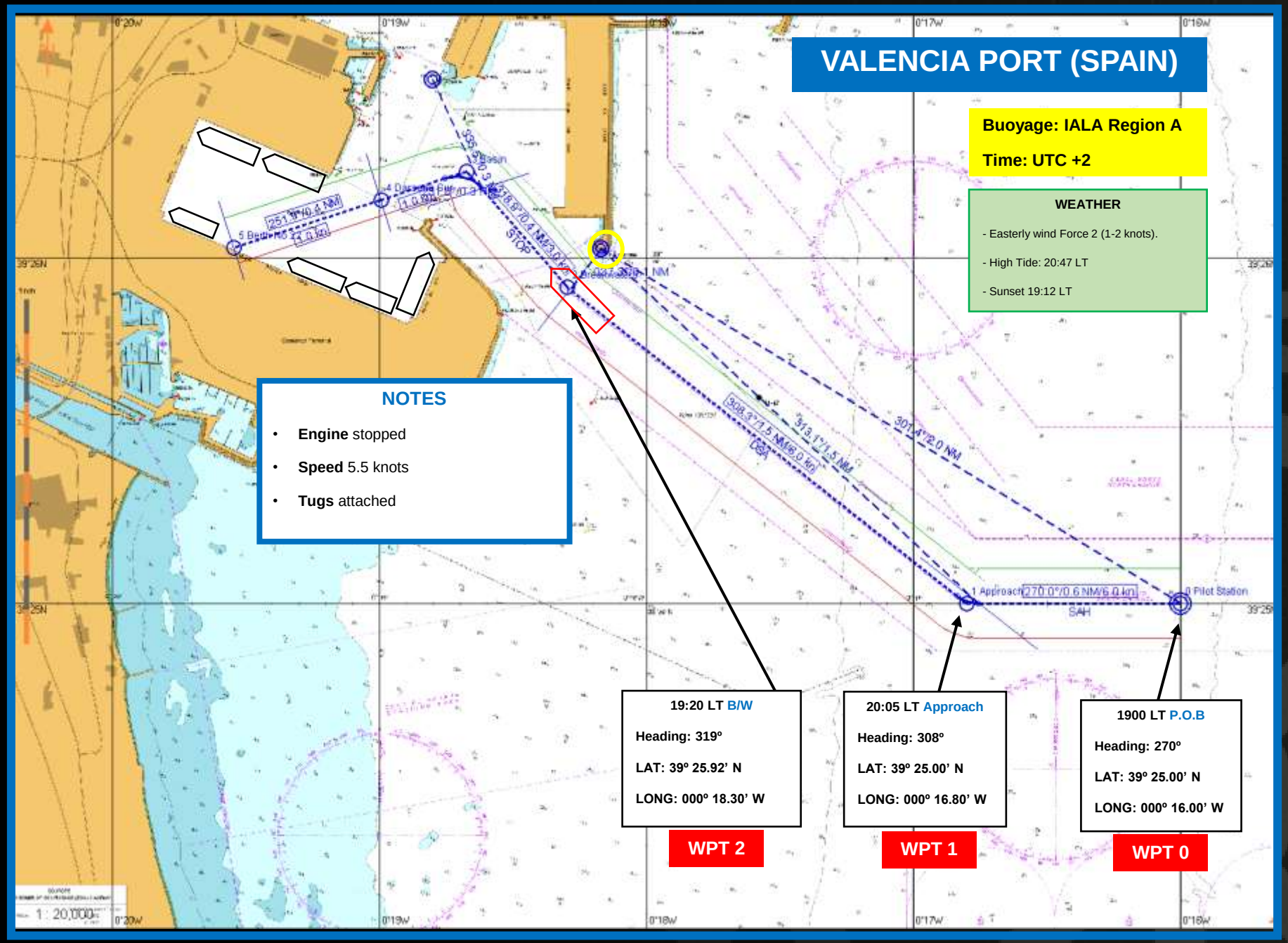
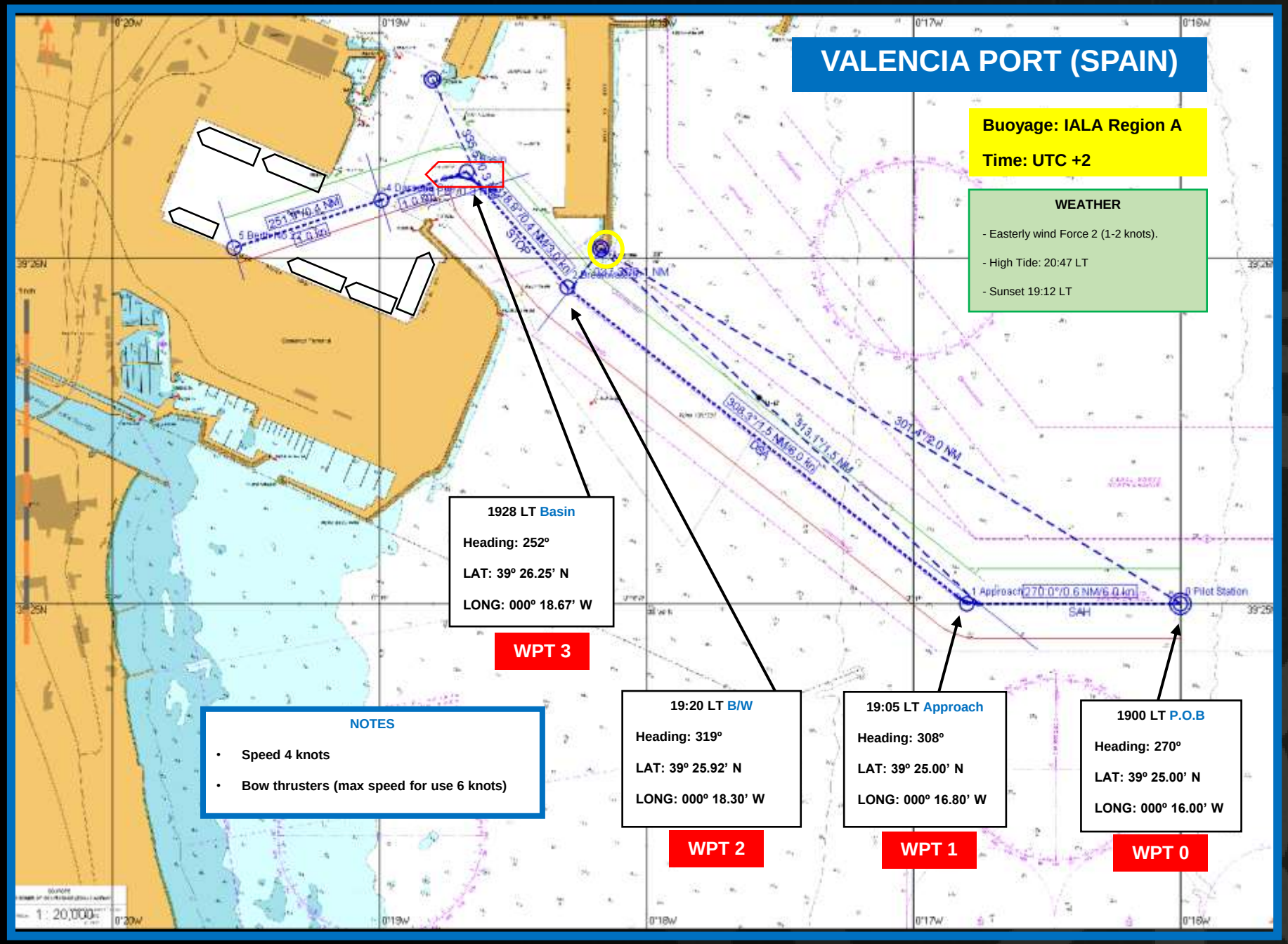
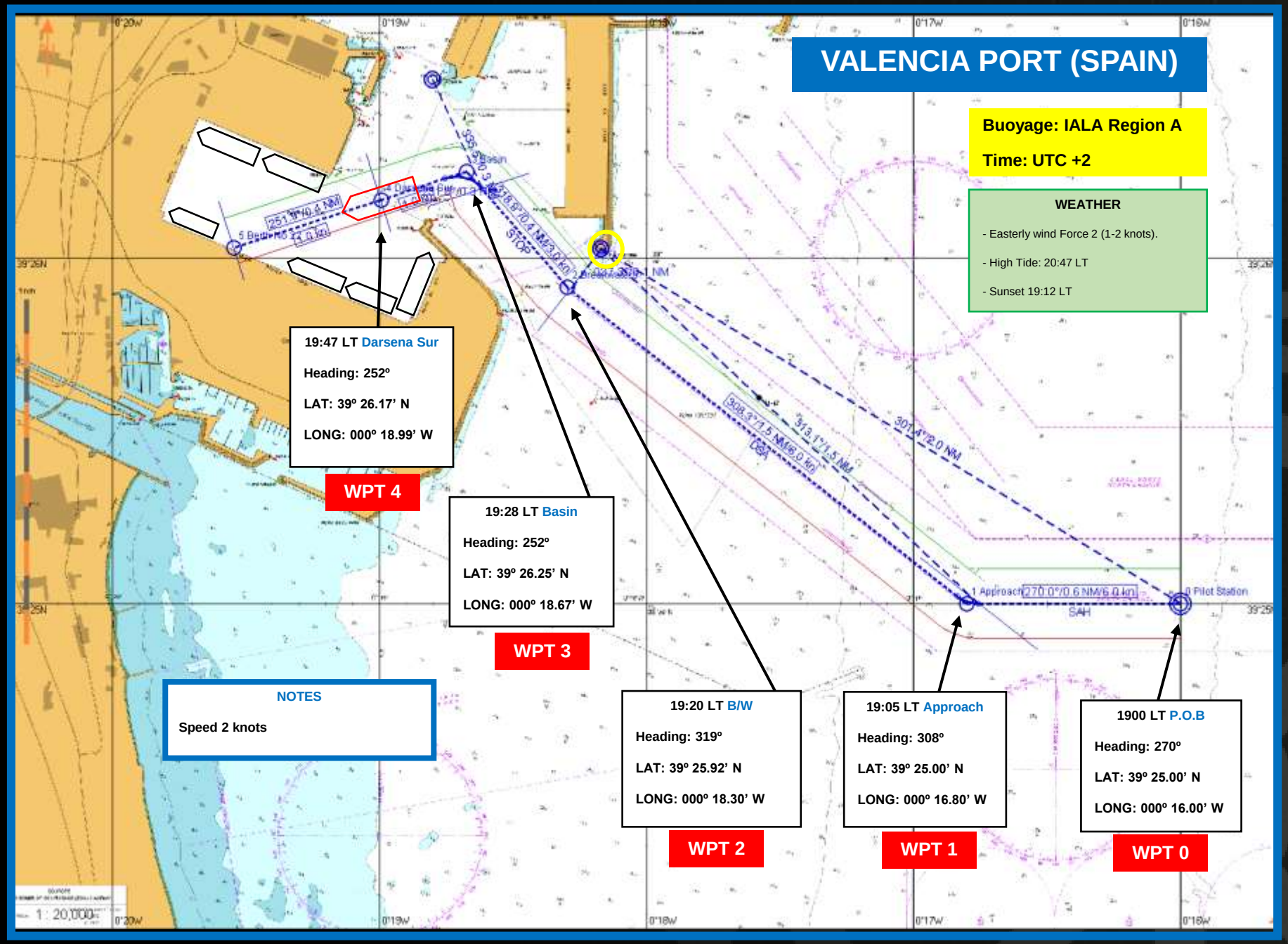
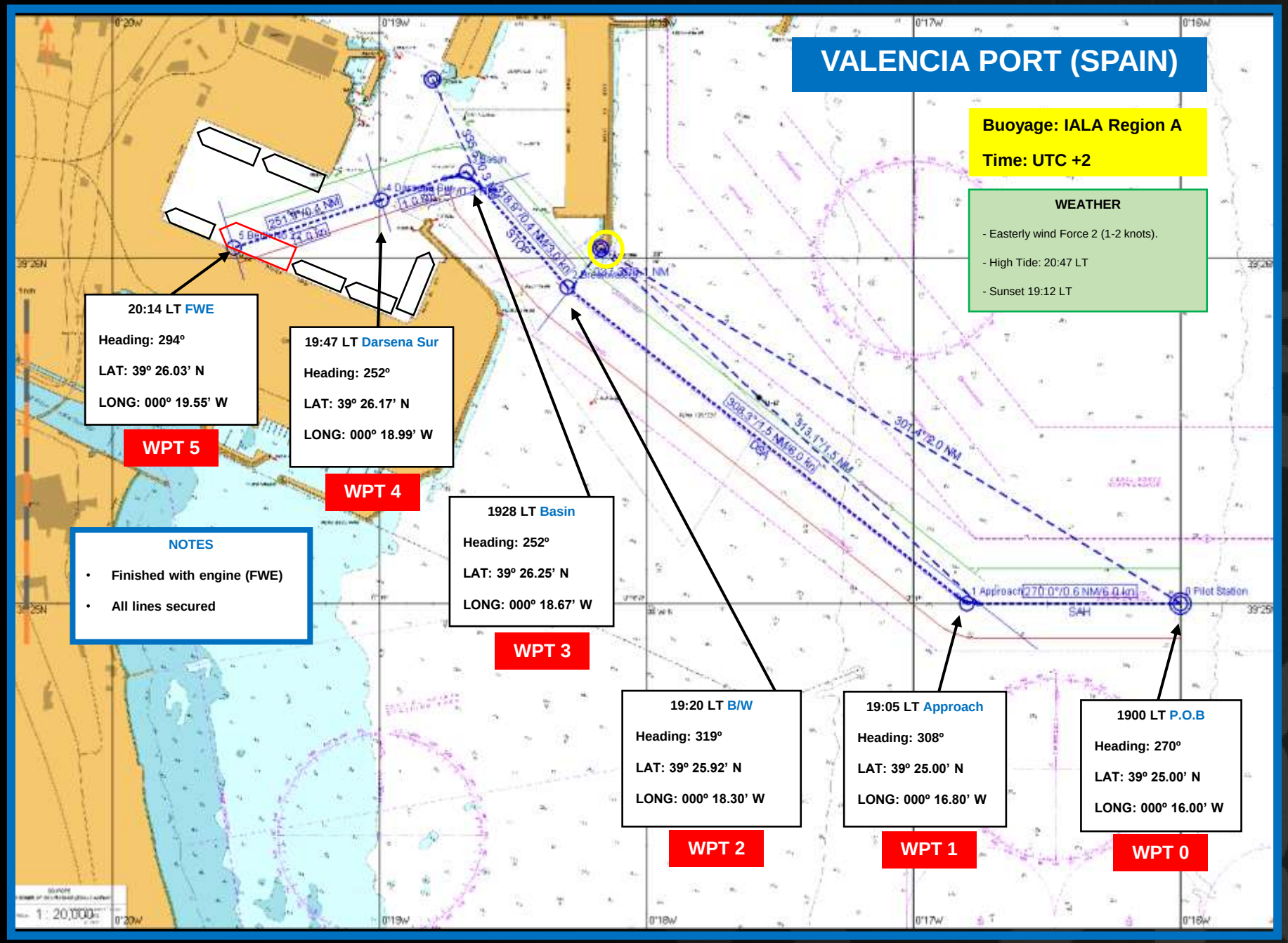
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
SPEED - 6 KNOTS
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0


VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
2 Tugs attached before brake water
Total Bollard Pull:
- FORWARD: 70t bollard pull - Llevant (Voith tractor)
- AFT: 55t bollard pull - Furia (Voith tractor)
SPEED - 6 KNOTS
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0
1 Approach 270.0°/0.6 NM/6.0 km
0 Pilot Station
301.4°/2.0 NM
313.1°/1.5 NM
308.3°/1.5 NM/6.0 km
SAH
1 : 20,000


VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
NOTES
• Engine stopped
• Speed 5.5 knots
• Tugs attached
19:20 LT B/W
Heading: 319º
LAT: 39º 25.92' N
LONG: 000º 18.30' W
WPT 2
20:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0
1 Approach
0 Pilot Station
SAH
1 : 20,000


VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
1928 LT Basin
Heading: 252º
LAT: 39º 26.25' N
LONG: 000º 18.67' W
WPT 3
19:20 LT B/W
Heading: 319º
LAT: 39º 25.92' N
LONG: 000º 18.30' W
WPT 2
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0
NOTES
• Speed 4 knots
• Bow thrusters (max speed for use 6 knots)


VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
19:47 LT Darsena Sur
Heading: 252º
LAT: 39º 26.17' N
LONG: 000º 18.99' W
WPT 4
19:28 LT Basin
Heading: 252º
LAT: 39º 26.25' N
LONG: 000º 18.67' W
WPT 3
NOTES
Speed 2 knots
19:20 LT B/W
Heading: 319º
LAT: 39º 25.92' N
LONG: 000º 18.30' W
WPT 2
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0


VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
20:14 LT FWE
Heading: 294º
LAT: 39º 26.03' N
LONG: 000º 19.55' W
WPT 5
19:47 LT Darsena Sur
Heading: 252º
LAT: 39º 26.17' N
LONG: 000º 18.99' W
WPT 4
NOTES
• Finished with engine (FWE)
• All lines secured
1928 LT Basin
Heading: 252º
LAT: 39º 26.25' N
LONG: 000º 18.67' W
WPT 3
19:20 LT B/W
Heading: 319º
LAT: 39º 25.92' N
LONG: 000º 18.30' W
WPT 2
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
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WPT 1
1900 LT P.O.B
Heading: 270º
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LONG: 000º 16.00' W
WPT 0

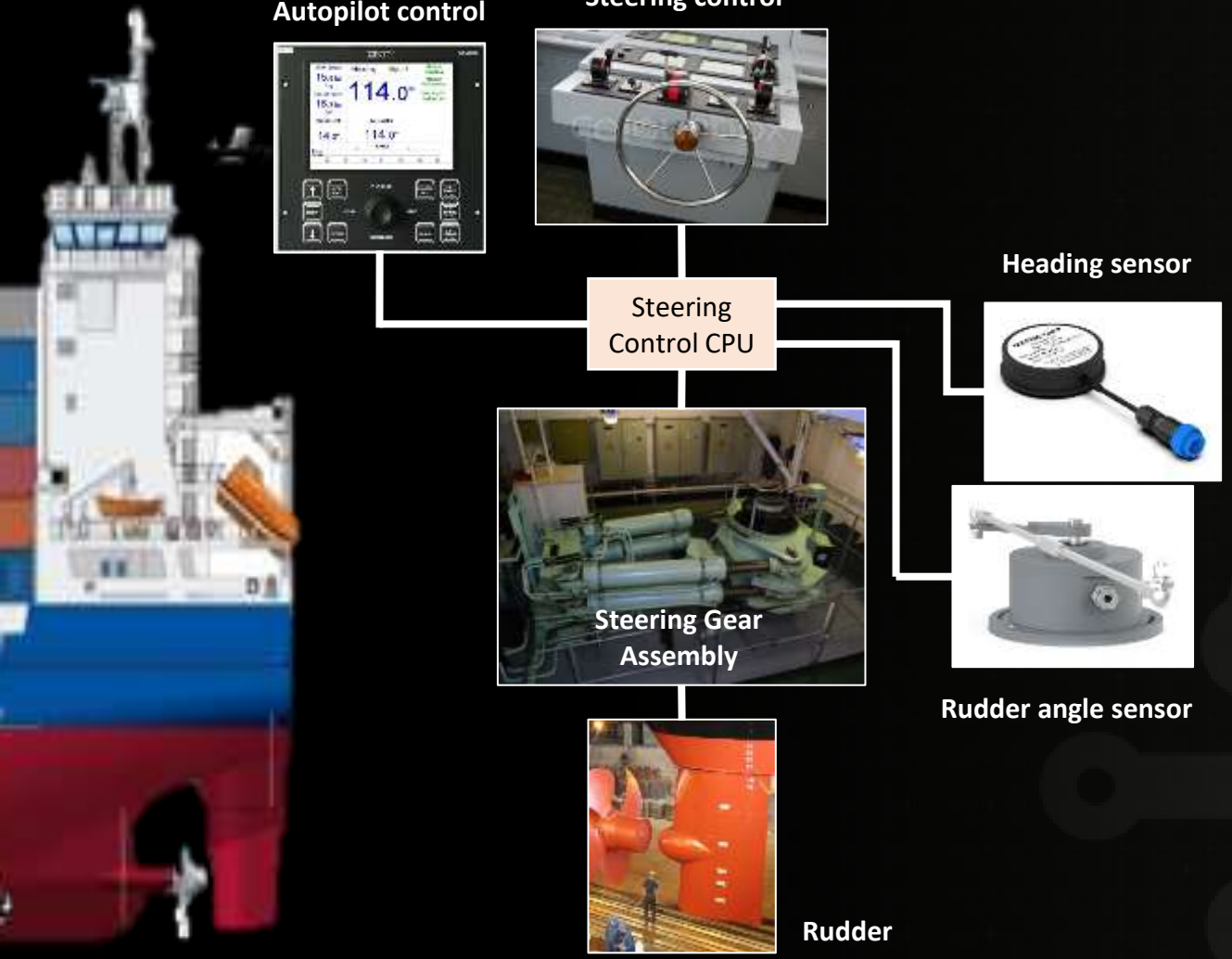
Vessel Attack Walkthrough

Stage 2 – Initiating the Attack on Vessel (UoP)

- Installing malicious firmware (on propulsion and/or rudder control systems)
- Rudder control system malfunction (incorrect data)
- During Initiation of attack – there is a difference in expected and actual rudder angles
- Demonstrate the final outcome of the attack

Cyber attack | Vessel navigation attack

Cyber-SHIP Lab



- The attack manipulates data close to the physical mechanisms
- We see physical changes, not observable on the bridge.

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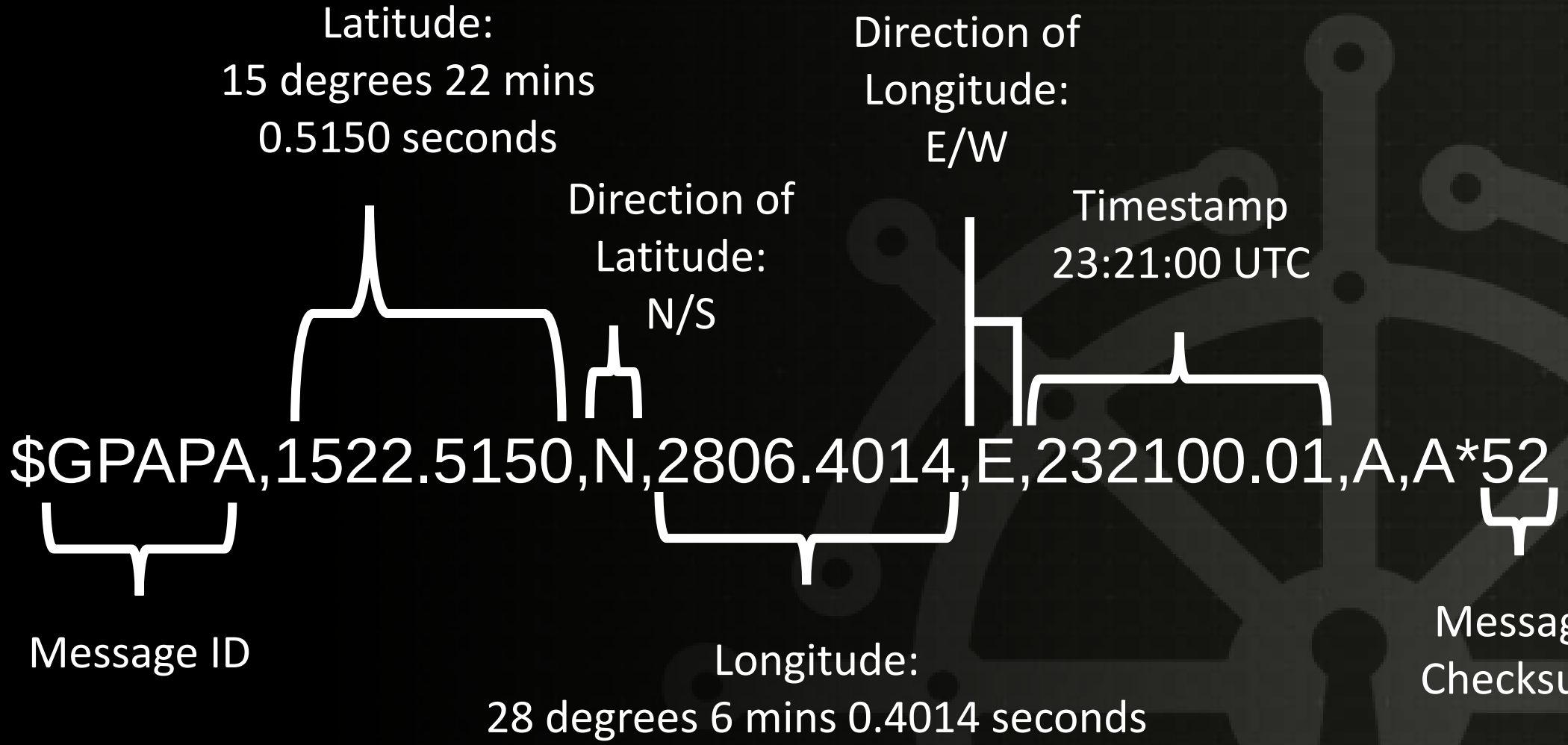
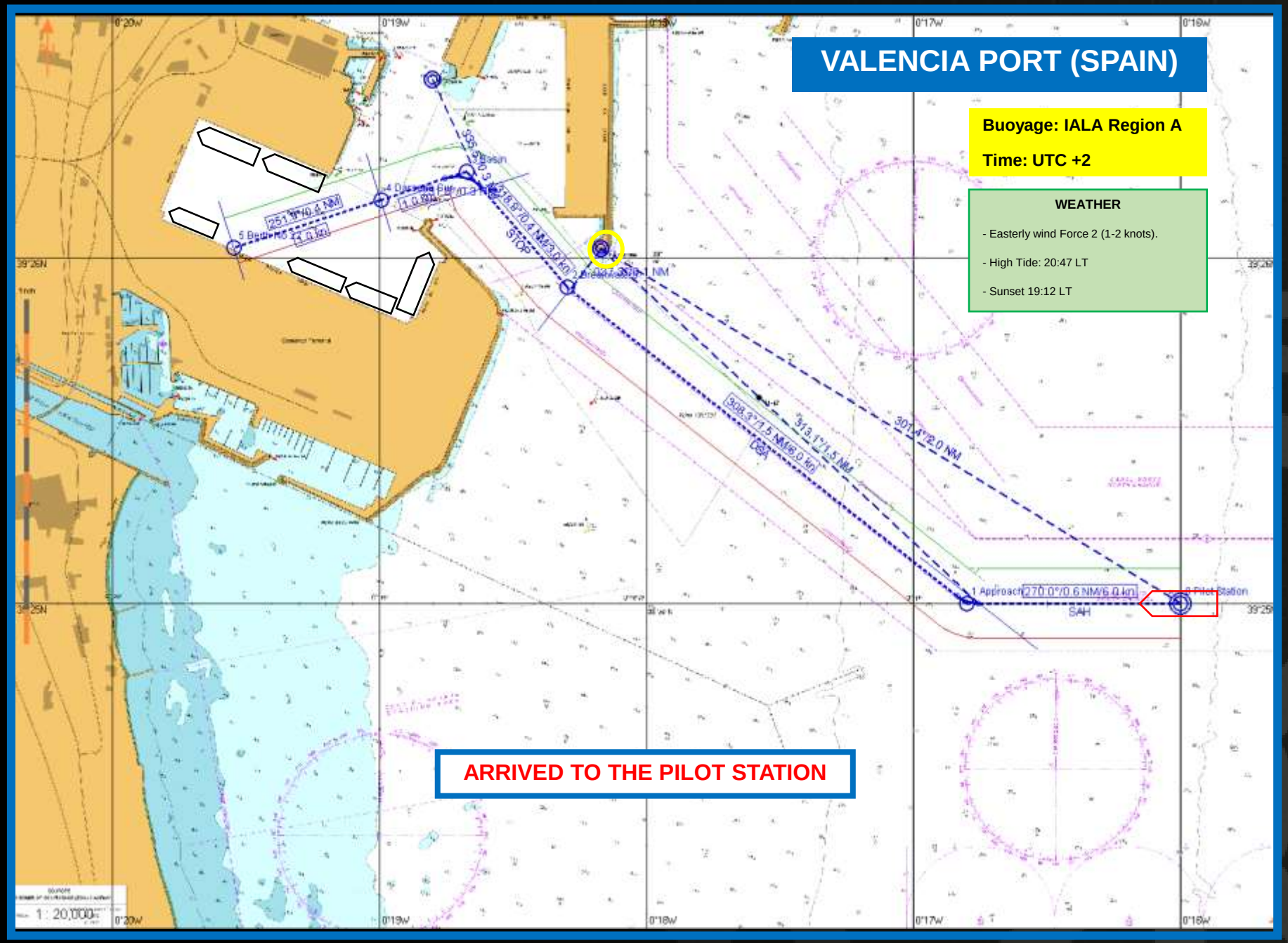
Decoding NMEA Ethernet messages

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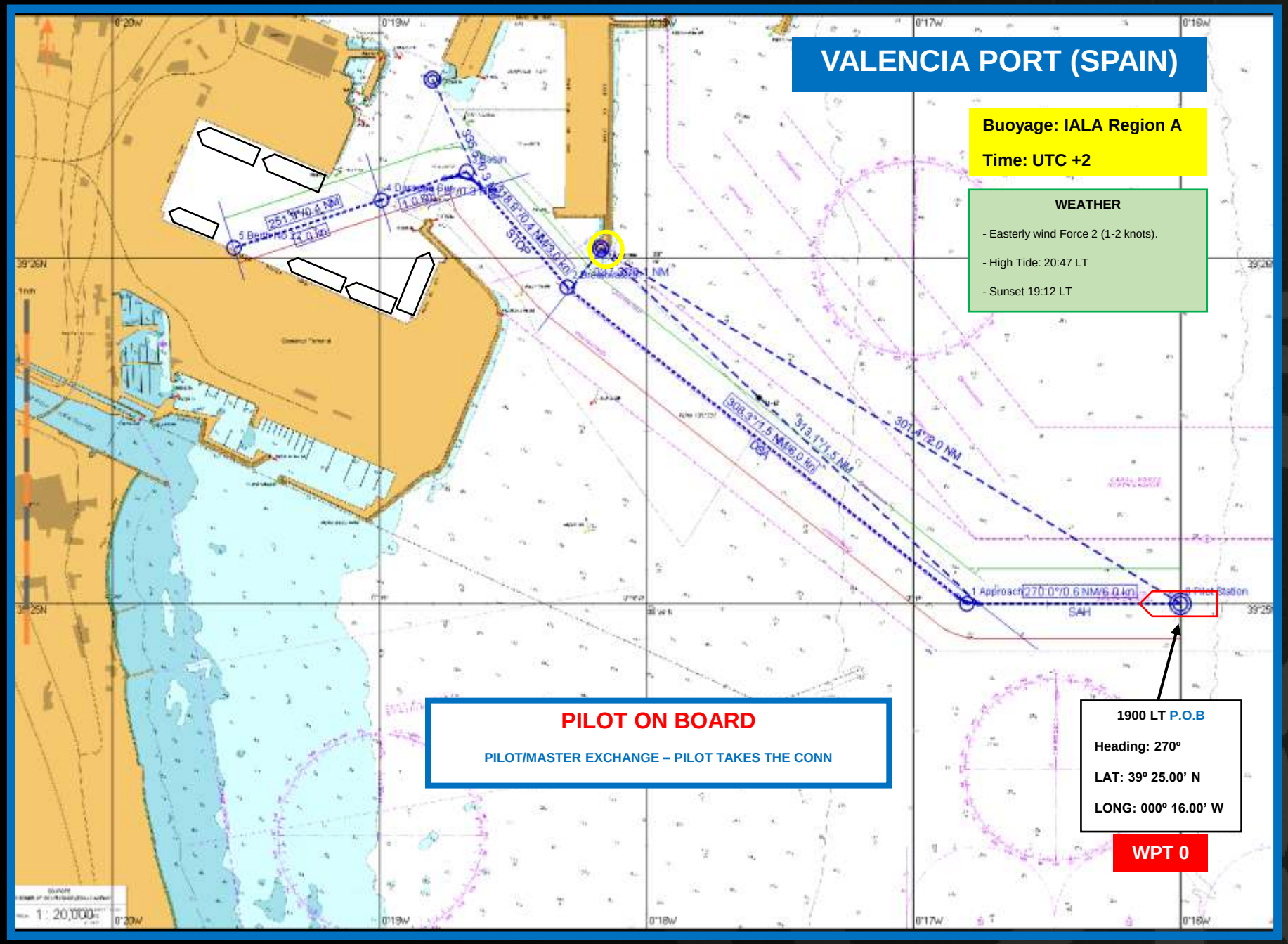
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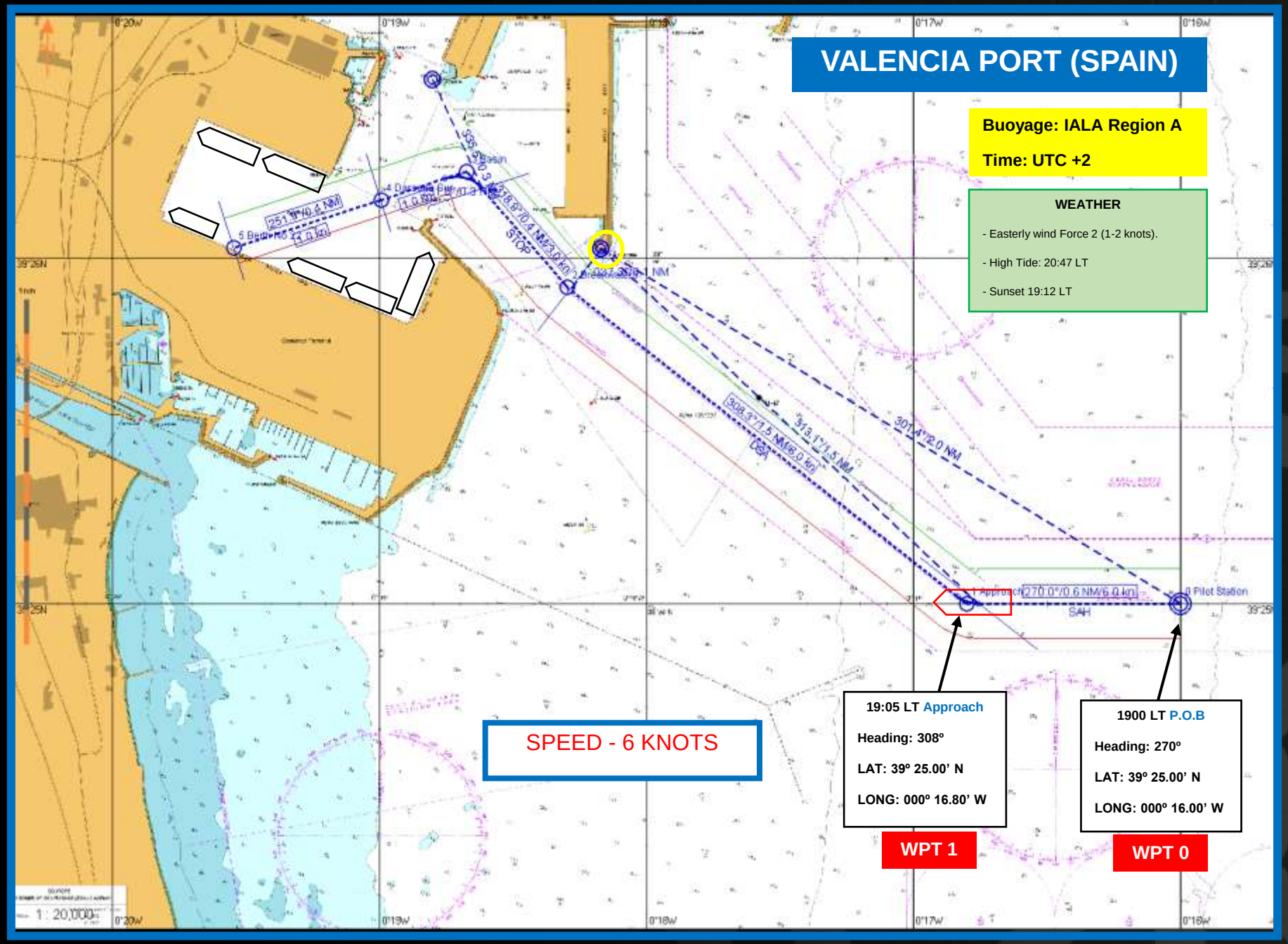
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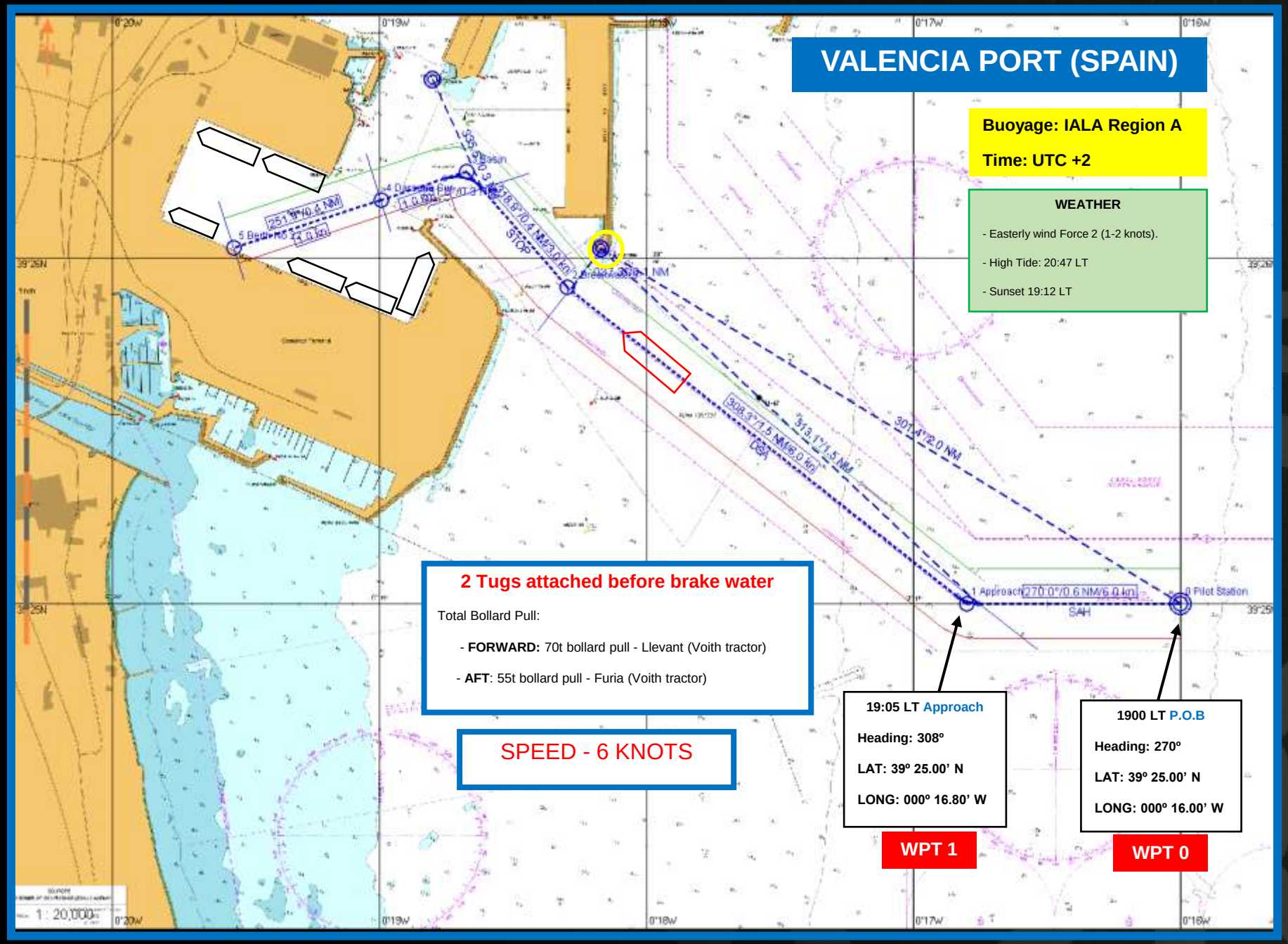
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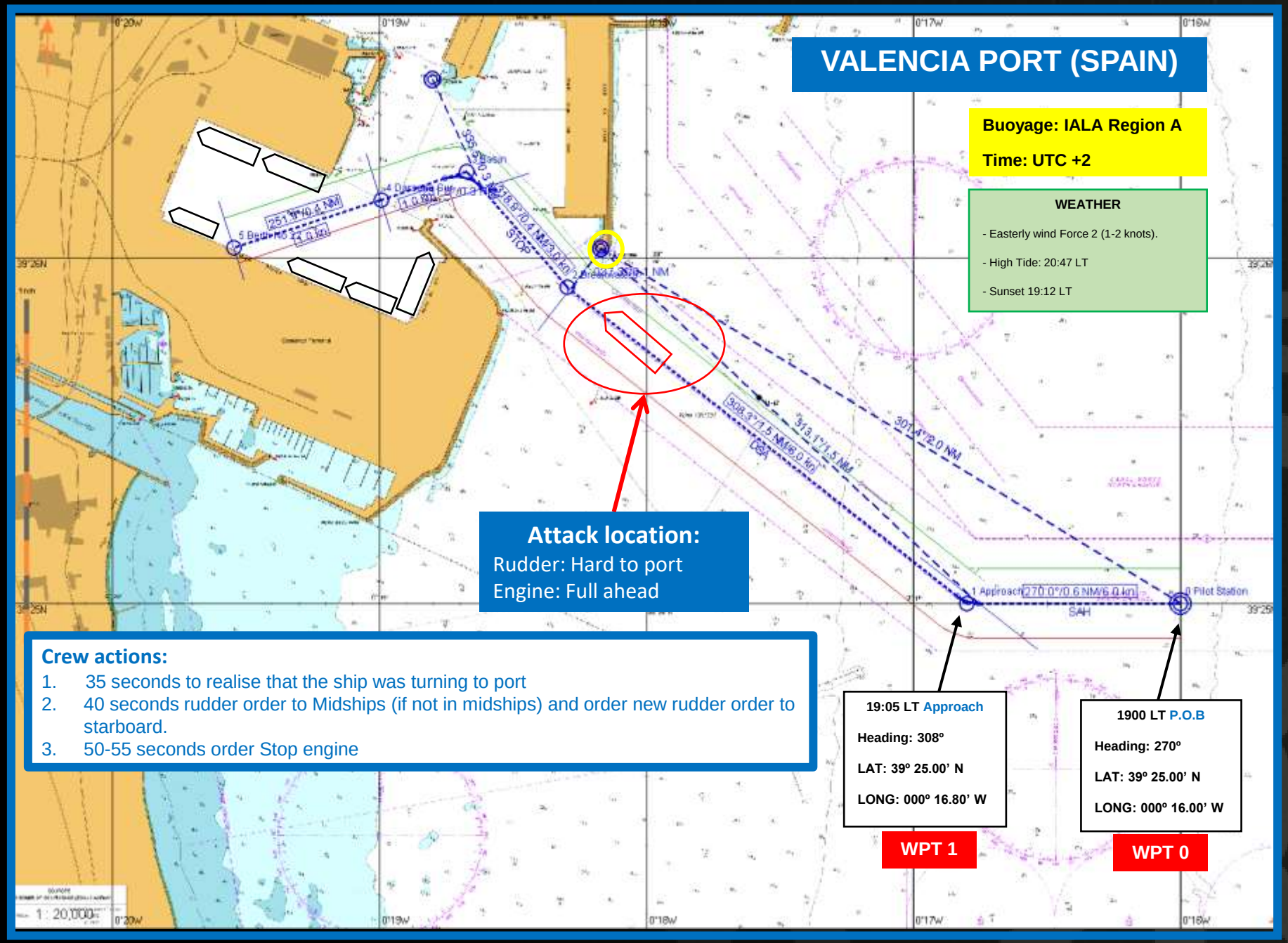
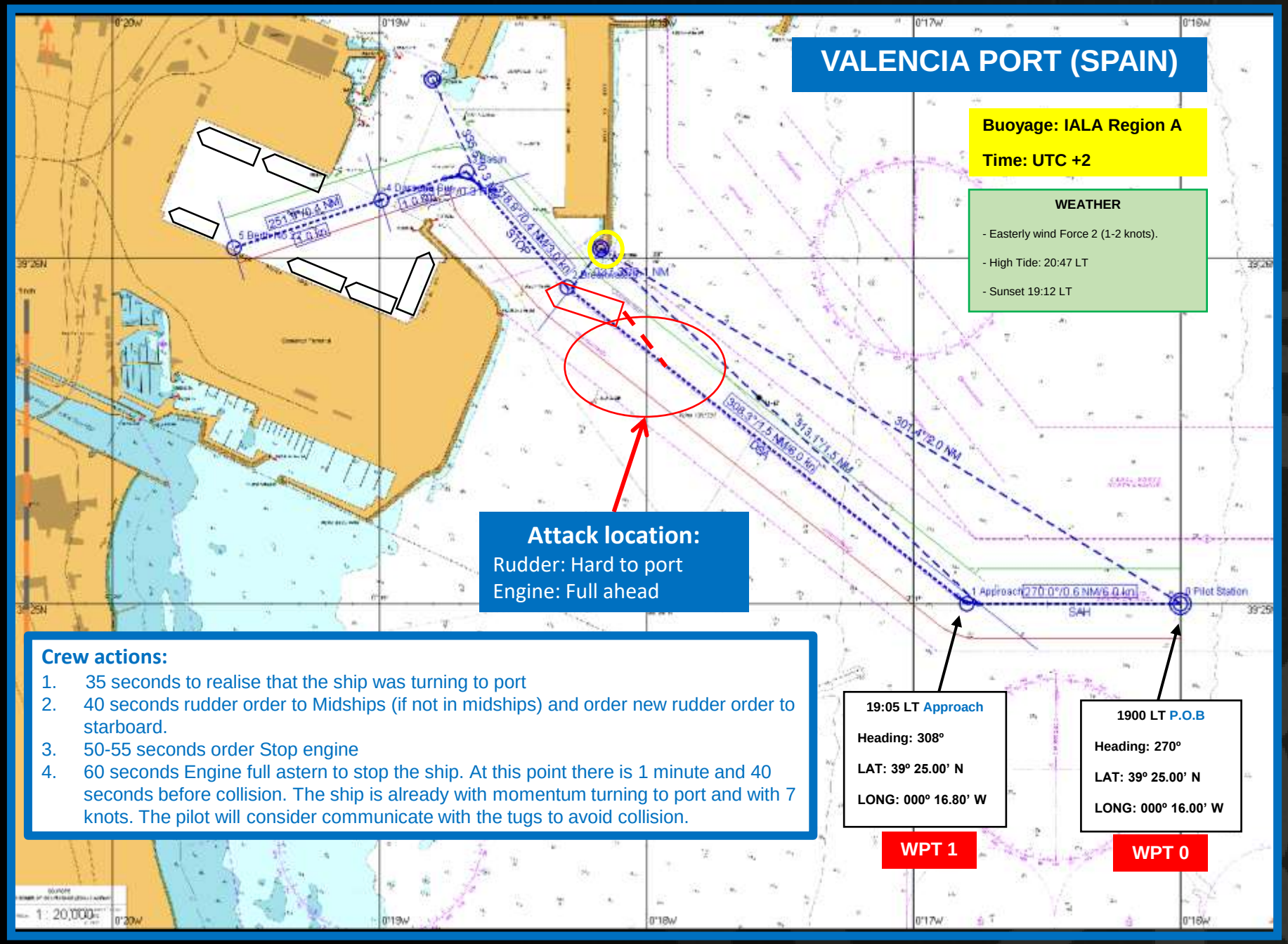
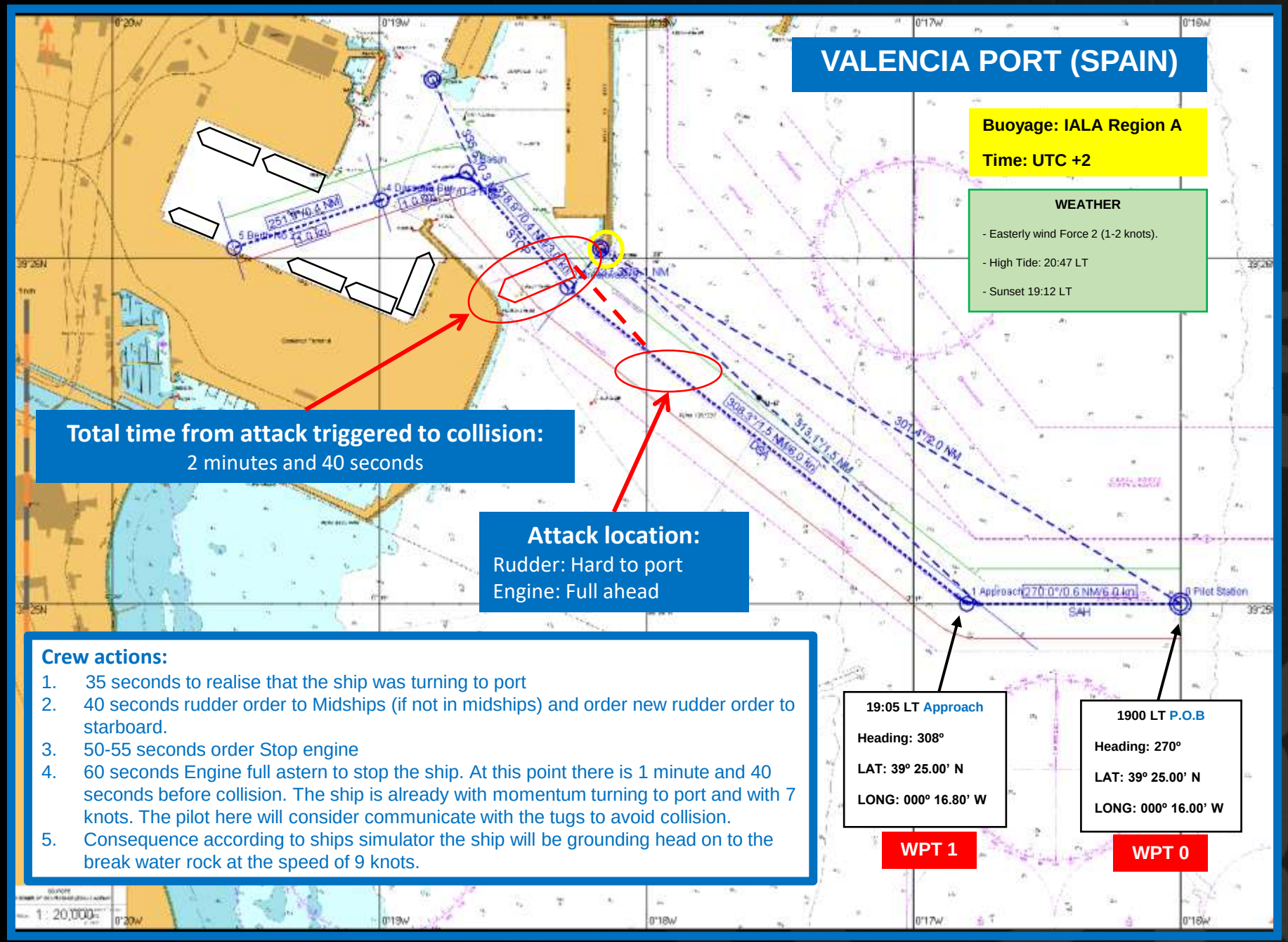
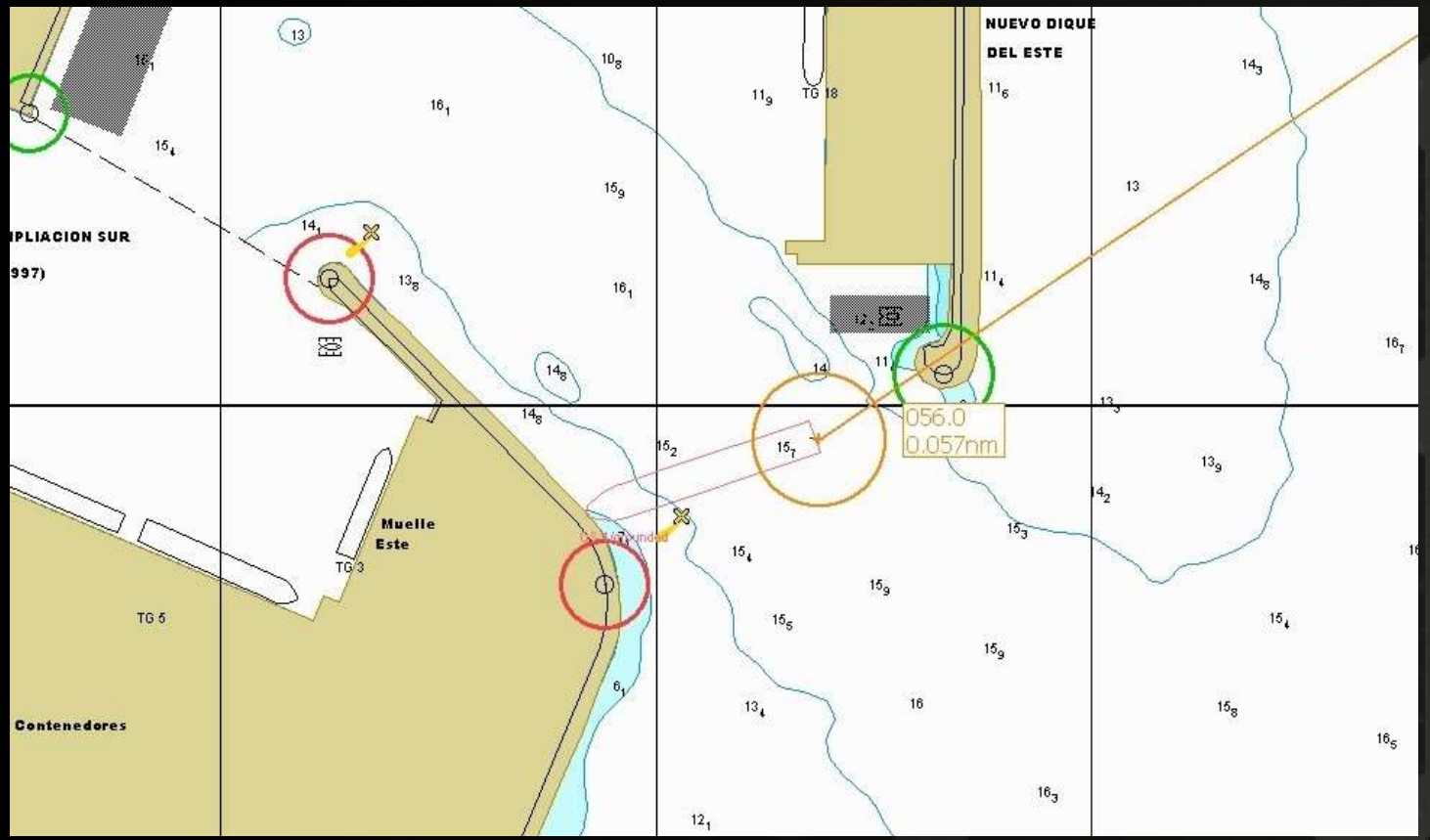

VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
Attack location:
Rudder: Hard to port
Engine: Full ahead
Crew actions:
1. 35 seconds to realise that the ship was turning to port
2. 40 seconds rudder order to Midships (if not in midships) and order new rudder order to starboard.
3. 50-55 seconds order Stop engine
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0

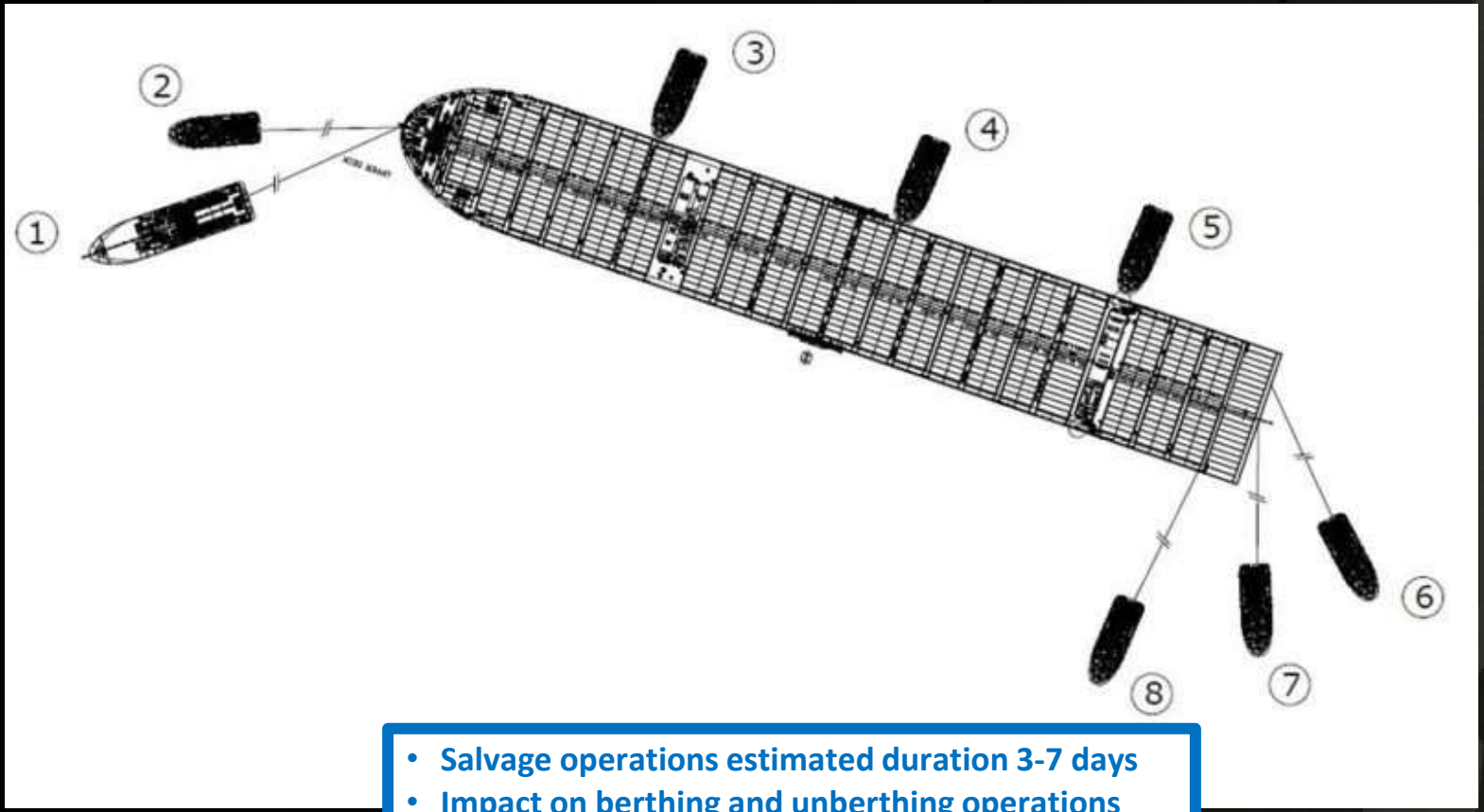

VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
Attack location:
Rudder: Hard to port
Engine: Full ahead
Crew actions:
1. 35 seconds to realise that the ship was turning to port
2. 40 seconds rudder order to Midships (if not in midships) and order new rudder order to starboard.
3. 50-55 seconds order Stop engine
4. 60 seconds Engine full astern to stop the ship. At this point there is 1 minute and 40 seconds before collision. The ship is already with momentum turning to port and with 7 knots. The pilot will consider communicate with the tugs to avoid collision.
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0


VALENCIA PORT (SPAIN)
Buoyage: IALA Region A
Time: UTC +2
WEATHER
- Easterly wind Force 2 (1-2 knots).
- High Tide: 20:47 LT
- Sunset 19:12 LT
Total time from attack triggered to collision:
2 minutes and 40 seconds
Attack location:
Rudder: Hard to port
Engine: Full ahead
Crew actions:
1. 35 seconds to realise that the ship was turning to port
2. 40 seconds rudder order to Midships (if not in midships) and order new rudder order to starboard.
3. 50-55 seconds order Stop engine
4. 60 seconds Engine full astern to stop the ship. At this point there is 1 minute and 40 seconds before collision. The ship is already with momentum turning to port and with 7 knots. The pilot here will consider communicate with the tugs to avoid collision.
5. Consequence according to ships simulator the ship will be grounding head on to the break water rock at the speed of 9 knots.
19:05 LT Approach
Heading: 308º
LAT: 39º 25.00' N
LONG: 000º 16.80' W
WPT 1
1900 LT P.O.B
Heading: 270º
LAT: 39º 25.00' N
LONG: 000º 16.00' W
WPT 0



- What tugs could do to avoid collision with break water?
- Vessel blocking the Port of Valencia entrance (100 metres gap)

Vessel with tug operations to recover a ship that run's aground *"Mumbai ... and outside Bremerhaven, Germany on 2 February, 2022"*



- **Salvage operations estimated duration 3-7 days**
- **Impact on berthing and unberthing operations**