VDES R-mode Stakeholder Requirements

# Summary

## Purpose of the document

This document provides a summary of the VDES R-mode stakeholder requirements and is intended as a basis for discussion and further development of the concept. These requirements are not complete and further collaborative work is required to develop a full set of stakeholder needs, stakeholder and system requirements.

## Related documents

See the ‘References’ section below.

# Background

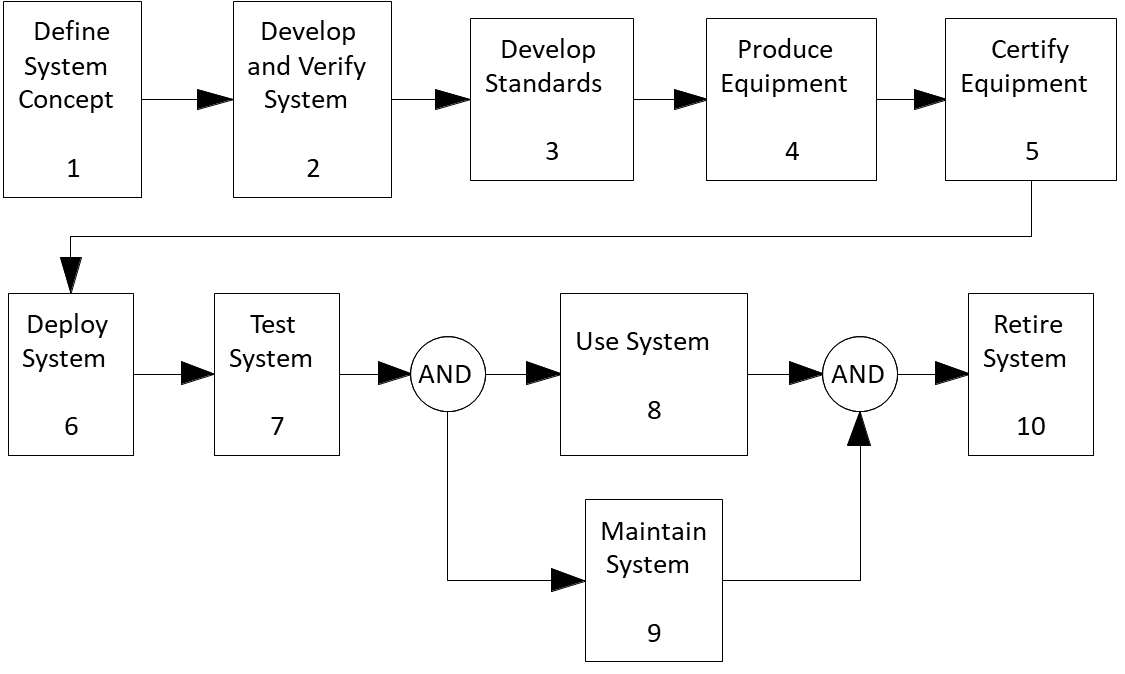
At recent meetings, the ENG and ENAV committees have discussed the possibility of using VDES for ranging (R‑mode). Several working documents and liaison notes have been produced on the topic, addressing various aspects of the concept. The authors of this paper have reviewed the available sources and compiled a list of stakeholder requirements for VDES R-mode. It is hoped the information contained here will help establish a common understanding of VDES R-mode among all stakeholders and serve as a basis for further development of the concept.

This document addresses the externally observable characteristics of the VDES R-mode system. Characteristics of the internal system components (i.e. the system requirements) will be captured in a separate document as the concept evolves.

# Discussion

## System Context

Figure 1 shows the anticipated stages of the VDES R-mode system “life cycle”. Each stage will likely see a different group of stakeholders interacting with the system, giving rise to different sets of requirements. This paper focuses mainly on stage 8 – ‘Use System’ as this is expected to provide the most valuable insights into the intended functionality and required performance of the system; however, it is important that further work consider the rest of the life cycle in more detail in order to obtain the complete picture.

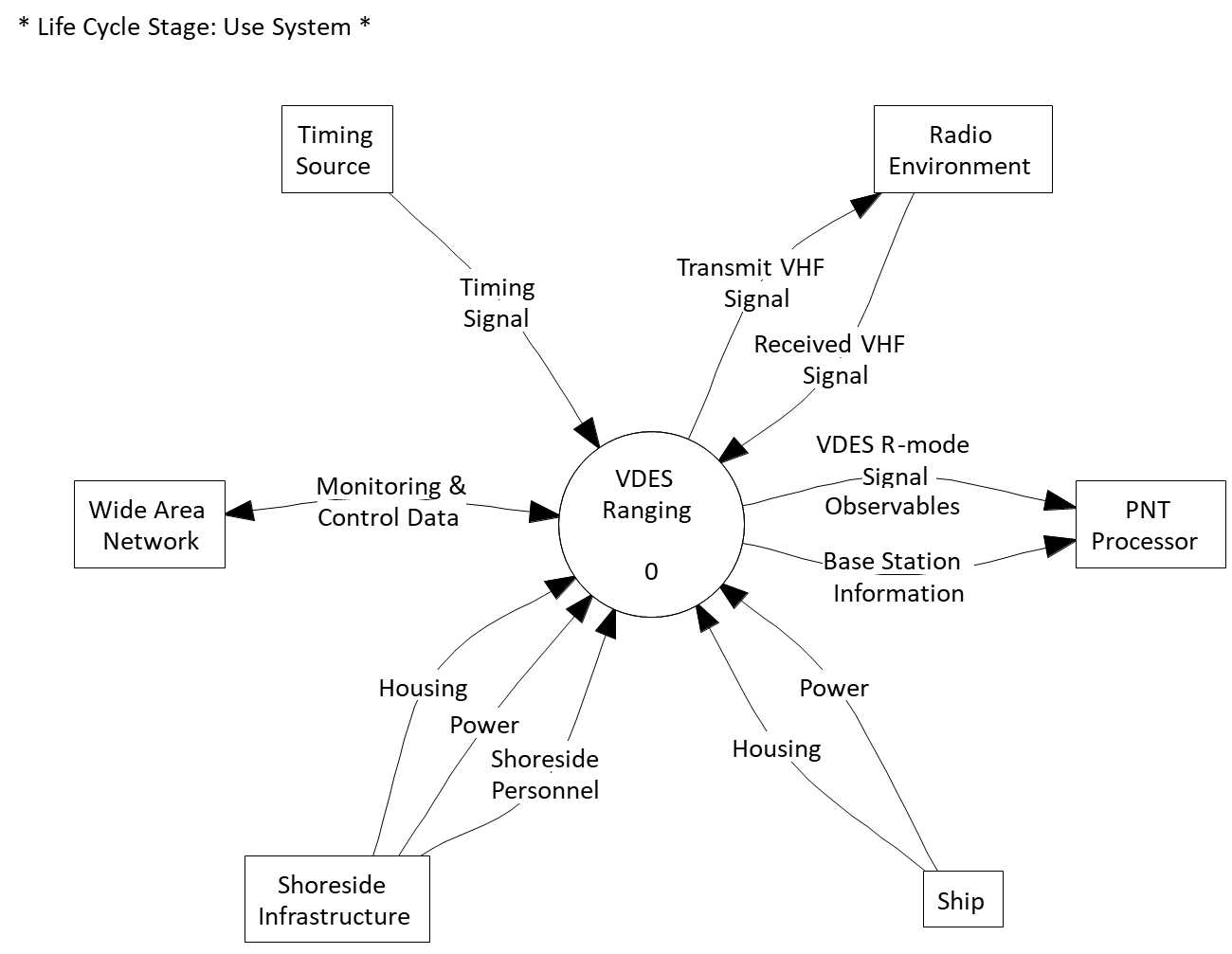


1. Anticipated stages of the VDES R-mode system “life cycle”.

Figure 2 then shows a preliminary context diagram for the ‘Use System’ life cycle stage. VDES R-mode sends accurately timed VHF transmissions and measures the timing (and possibly other) parameters of the received signals. The measured observables are output to an external Position, Navigation and Time (PNT) processor, which determines the user’s position, speed over ground and other navigation parameters.

VDES R-mode should, as far as possible, use pre-existing shoreside infrastructure, including shore stations and monitoring and control centres, and pre-existing AIS/VDES shipborne installations. Monitoring and control data is likely to be carried via pre-existing wide area networks.

VDES R-mode is synchronised to an external timing source traceable to a common time scale in order to facilitate interoperability with other PNT systems.



1. Preliminary VDES R-mode system context diagram.

## Stakeholder Identification

The following table lists the key stakeholders in the VDES R-mode system and their respective anticipated roles.

1. Key stakeholders in the VDES R-mode system.

| **Stakeholder** | **Role** |
| --- | --- |
| IMO | Provides performance standards for PNT systems |
| ITU | Provides the Radio Regulations and other related documents;  Produces the technical specification for VDES |
| IALA | Provides operational requirements for VDES R-mode;  Provides input to the technical specification for VDES |
| Shore Authorities | Provide operational requirements for VDES R-mode;  Provide shoreside infrastructure for VDES |
| Ship side | Provide operational requirements for the use of VDES R-mode;  Provide input into training requirements for the use of VDES R-mode |
| Ship owners (ICS) | Provide, a position in conjunction with IMO, on carriage requirements. |
| GNSS Operators | Provide technical expertise with respect to GNSS vulnerabilities and GNSS time transfer applications |
| CIRM / Equipment Manufacturers | Provide technical expertise with respect to VDES;  Conduct market research;  Produce VDES equipment;  Integrate VDES R-mode into a resilient PNT solution |
| IEC  ETSI  RTCM | Develop test standards for VDES equipment  Develop test standard for resilient PNT solution |
| Test Houses | Certify VDES equipment |
| R-mode Baltic Project | EU-funded project aiming to set up an R-mode test bed in the Baltic Sea region;  Provides technical expertise with respect to VDES R-mode;  Produces prototype VDES R-mode equipment;  Conducts tests of the VDES R-mode equipment / system |

## Stakeholder Requirements

Appendix 1 contains a list of stakeholder requirements extracted from the sources listed in the ‘References’ section. The requirements were categorised into several groups, such as functional, coverage, performance and a number of other non-functional requirements categories. Each requirement was assigned a priority as one of: Mandatory, High, Medium or Low.

Each requirement also has a status indicating the maturity of the requirement; permissible values are: New (the requirement has been captured from an external source), Ready (the requirement has been cleaned of any ambiguous statements and characterised), Checked (the requirement has been checked by the project team[[1]](#footnote-1)), Review (the requirement is being reviewed by stakeholders), Agreed (the requirement has been accepted by stakeholders), Rejected (the requirement has been rejected by stakeholders and is to be reworked) and Deleted (the requirement is no longer needed).

The functional requirements were largely derived from the IMO Resolution MSC.401(95), ‘Performance Standards for Multi-System Shipborne Radionavigation Receivers’ [1] and the draft ‘R-mode Baltic – Baseline and Priorities’ document [2].

The coverage and performance requirements are based on statements provided by the IALA ARM Committee in Liaison Note [3], the R-mode Baltic document [2] and the IALA Recommendation R-129, ‘GNSS Vulnerability and Mitigation Measures’ [4]. R-129 provides a useful categorisation of potential alternative PNT systems:

A redundant system provides the same functionality as the primary system, allowing a seamless transition with no change in procedures.

A backup system ensures continuation of the navigation application, but not necessarily with the full functionality of the primary system and may necessitate some change in procedures by the user.

A contingency system allows safe completion of a manoeuvre, but may not be adequate for long-term use.

The R-mode Baltic document [2]provides the following statements with respect to the above categories:

*‘The R-Mode project […] is intended as a backup system, or in between a contingency and backup system, to GNSS.*

*‘it is assumed that R-Mode should be available for at least 2 h after GNSS has failed within the R-Mode accuracy requirement.'*

*The 2h window is derived from a. finishing manoeuvres is expected to finish within 2 hours and b. Rubidium clocks are stable for 2-6 hours, therefore a minimum time of 2 hours was set*

In addition, ARM states that [3]:

*‘R-Mode (of any variety) should be considered as a “backup” to GNSS as defined in R-129 as the full functionality of GNSS is not required and R-Mode is therefore not considered as a fully “redundant” system.’*

Therefore, this specification considers VDES R-mode to be a contingency system with a holdover capability of at least 2 hours, with a design goal of being capable of operating as a backup.

ARM further provided the following statements with respect to the performance requirements of R-129 [3]:

*‘The backup requirements of R-129 are derived from IMO A.915(22) and as such would be difficult to revise in the timescale of this response. ARM considers that a further wider consideration of requirements for backup systems is needed (and also primary systems), but this is beyond the scope of ARM and indeed IALA and would require the considered debate within other bodies such as the IMO. In the timescales of this response however, ARM considers that the requirements remain valid’;*

Therefore, this specification adopts the performance requirements for a backup system stated in R-129.

R-129 specifies different requirements for different phases of voyage. These include ocean, coastal waters, port approaches and ports. With respect to the voyage phase, the R-mode Baltic document [2] states:

*‘A global coverage is not possible with R-Mode due to the selected carriers (AIS and MF), but a global harmonization, in line with the e-Navigation concept, is important. The highest risk for degradation of the signal due to intentional and unintentional jamming is expected to be in coastal waters. R-Mode, as a system, is designed for coverage in coastal waters.’*

*‘The system should support port approaches and navigation in restricted waters.’*

Therefore, this specification adopts the R-129 performance requirements applicable to navigation in coastal waters as well as port approaches, restricted waters and inland waterways (but not the requirements for navigation in ocean waters and ports).

Further non-functional requirements were extracted from documents prepared by ENAV WG3, the ITU Radio Regulations and the sources referenced previously.

# References

[1] IMO, ‘Performance Standards for Multi-system Shipborne Radionavigation Receivers’, Resolution MSC.401(95), Jun. 2015.

[2] M. Dziewicki, ‘R-mode Baltic - Baseline and Priorities’, Sep. 2018.

[3] IALA ARM, ‘VDES R-mode System Requirements’, Liaison Note to IALA ENG and ENAV, Oct. 2018.

[4] IALA, ‘GNSS Vulnerability and Mitigation Measures’, Recommendation No. 129, Dec. 2012.

[5] IMO, ‘Resolution A.1046(27), Worldwide Radionavigation System’, Dec. 2011.

[6] IALA ENG, ‘VDES R-mode Requirements’, Liaison Note to IALA ENAV and ARM, Oct. 2018.

[7] ITU, ‘Radio Regulations’, 2016.

[8] IALA ENAV, ‘VDES R-mode Development and Standardisation’, Liaison Note to IALA ENG, Oct. 2018.

# Action requested of the Committee

The ENAV and ENG committees are requested to review the stakeholder requirements listed in Appendix 1 and provide comments (and any additional requirements) to ENAV WG3 (Digital Communication Systems).

1. VDES R-MODE STAKEHOLDER REQUIREMENTS

| **Key** | **Name** | **Identity** | **Requirement Details** | **Comments** | **Priority** | **Status** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **Functional** | REQ-2 |  |  |  | Accepted |  |
| **1.1** | **Provide VDES R-mode Base Station Information** | REQ-42 |  |  |  | Accepted |  |
| **1.1.1** | **Base Station Almanac** | REQ-30 | The system shall provide to an external, shipborne PNT processor information on the identity and location of the VDES R-mode Base Stations. | Each station should transmit information at least for itself and neighbouring stations. | Mandatory | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **1.1.2** | **Base Station Health** | REQ-15 | The system shall provide to an external, shipborne PNT processor a "station safe to use"/"do not use" information for each Base Station within the system. |  | Mandatory | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **1.1.3** | **Base Station Signal Quality** | REQ-31 | The system shall provide to an external, shipborne PNT processor information on the quality of the VDES R-mode ranging signal such that the processor can obtain a measure of accuracy and integrity of the position solution derived from the VDES R-mode observables. | Should include estimated clock synchronisation error, BS position accuracy, etc. | Mandatory | Accepted | Internal GLA Discussions |
| **1.2** | **Provide VDES R-mode Observables** | REQ-41 |  |  |  | Accepted |  |
| **1.2.1** | **UTC** | REQ-11 | The system shall provide to an external, shipborne PNT processor VDES R-mode observables such that the processor could determine UTC to within one tenth of a second.  For the purpose of this specification, it is assumed that the external processor may also use inputs from other PNT systems (but not to the exclusion of VDES R-mode). |  | Mandatory | Accepted | IMO Resolution MSC.401(95) [1] |
|  | **System timing** | REQ-XX | The system shall provide a reference to its source of timing |  |  |  | ENG10 |
|  | **Timing offset** | REQ-XX | The system shall provide information on the timing offset between each R-Mode network and other nearby networks and GNSS to enable interoperability. |  |  |  | ENG10 |
| **1.2.2** | **Position** | REQ-8 | The system shall provide to an external, shipborne PNT processor VDES R-mode observables such that the processor can estimate the ship's geodetic horizontal position (latitude, longitude) in accordance with the World Geodetic System revision 1984 (WGS84).  For the purpose of this specification, it is assumed that the external processor may also use inputs from other PNT systems (but not to the exclusion of VDES R-mode). |  | Mandatory | Accepted | IMO Resolution MSC.401(95) [1] |
| **1.2.3** | **Course over Ground** | REQ-9 | The system shall provide to an external, shipborne PNT processor VDES R-mode observables such that the processor can estimate the ship's course over ground (COG).  For the purpose of this specification, it is assumed that the external processor may also use inputs from other PNT systems (but not to the exclusion of VDES R-mode). |  | Mandatory | Accepted | IMO Resolution MSC.401(95) [1] |
| **1.2.4** | **Speed over Ground** | REQ-10 | The system shall provide to an external, shipborne PNT processor VDES R-mode observables such that the processor can estimate the ship's speed over ground (SOG).  For the purpose of this specification, it is assumed that the external processor may also use inputs from other PNT systems (but not to the exclusion of VDES R-mode). |  | Mandatory | Accepted | IMO Resolution MSC.401(95) [1] |
| **2** | **Coverage** | REQ-3 |  |  |  | Accepted |  |
| **2.1** | **Coastal Waters** | REQ-43 | The system shall be capable of being used for navigation in coastal waters. |  | Mandatory | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **2.2** | **Port approaches, Restricted Waters, Inland Waterways - Goal** | REQ-44 | The system should, as a goal, be capable of being used for navigation in port approaches, restricted waters and inland waterways. | There is no common, accepted, definition of where the boundary is between coastal waters and port approach.  Search IMO SOLAS, Reg. V, and Circulars. | High | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **3** | **Performance** | REQ-4 |  |  |  | Accepted |  |
| **3.1** | **Position Accuracy - Coastal Waters** | REQ-12 | When the system is used for navigation in coastal waters, the Horizontal Position Accuracy of the externally estimated position solution shall be at most 100 m, 95%. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.2** | **Integrity - Coastal Waters** | REQ-13 | When the system is used for navigation in coastal waters, the Integrity Risk of the externally estimated horizontal position solution shall be at most 1e-4 over a period of 3 hours, with a Horizontal Alert Limit (HAL) of 250 m.  Note: The continuity requirement (REQ-20) uses a time interval of 15 minutes. For compatibility reasons, it would be beneficial to use the same time interval for both the integrity and continuity requirements. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.3** | **Time to Alarm - Coastal Waters** | REQ-14 | The Base Station Health information shall be provided in such a manner that mariners using the system for navigation in coastal waters can be warned of a system fault within 30 seconds of the fault occurring. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.4** | **Availability - Coastal Waters** | REQ-16 | When the system is used for navigation in coastal waters, the Availability of the externally estimated position solution shall be at least 99%. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.5** | **Fix Interval - Coastal Waters** | REQ-17 | When used for navigation in coastal waters, the system shall provide new signal observables to the external processor at least once every 15 seconds. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.6** | **Position Accuracy - Port Approach** | REQ-18 | When the system is used for navigation in port approaches, restricted waters or inland waterways, the Horizontal Position Accuracy of the externally estimated position solution shall be at most 10 m, 95%. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.7** | **Integrity - Port Approach** | REQ-19 | When the system is used for navigation in port approaches, restricted waters or inland waterways, the Integrity Risk of the externally estimated horizontal position shall be at most 1e-4 over a period of 3 hours, with a Horizontal Alert Limit (HAL) of 25 m.  Note: The continuity requirement (REQ-20) uses a time interval of 15 minutes. For compatibility reasons, it would be beneficial to use the same time interval for both the integrity and continuity requirements. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.8** | **Time to Alarm - Port Approach** | REQ-25 | The Base Station Health information shall be provided in such a manner that mariners using the system for navigation in port approaches, restricted waters and inland waterways can be warned of a system fault within 10 seconds of the fault occurring. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.9** | **Continuity - Port Approach** | REQ-20 | When the system is used for navigation in port approaches, restricted waters or inland waterways, the Continuity of the externally estimated horizontal position solution shall be at least 99.97% over a time interval of 15 minutes. |  | Mandatory | Accepted | IALA R-129 [4] |
| **3.10** | **Fix Interval - Port Approach** | REQ-21 | When used for navigation in port approaches, restricted waters or inland waterways, the system shall provide new observables to the external processor at least once every 2 seconds. |  | Mandatory | Accepted | IALA R-129 [4] |
| **4** | **Capacity - Goal** | REQ-22 | The system should, as a goal, be capable of being used by an unlimited number of ships.  Capacity may be limited if using active ranging. |  | High | Accepted | IMO Resolution A.1046(27) [5] |
| R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **5** | **Interface - Goal** | REQ-5 | The system should use standardized and approved communication protocols for interfacing. |  | High | Accepted | IMO Resolution MSC.401(95) [1] |
| **6** | **Security** | REQ-6 | The system shall be designed to consider cyber-attacks (including jamming and spoofing) so that such events can be detected and their effects mitigated. |  | Mandatory | Accepted | VDES R-Mode Requirements [6] |
| **7** | **Regulatory** | REQ-7 |  |  |  | Accepted |  |
| **7.1** | **ITU Radio Regulations** | REQ-23 | The system shall be designed and operated in accordance with ITU Radio Regulations, Article 28. | This may mean that additional (radiodetermination service) allocations will need to be made for the VDES frequencies under Radio Regulations Chapter II, Article 5 and a designation under Appendix 18. | Mandatory | Accepted | ITU Radio Regulations [7] |
| **8** | **Environmental** | REQ-27 |  |  |  | Accepted |  |
| **8.1** | **GNSS Disruption at Ship** | REQ-26 | Following a disruption to GNSS services (due to jamming/spoofing/interference/satellite failures, etc.) local to the ship, the system shall continue to meet the Functional, Coverage and Performance Requirements set out in this specification for an unlimited period of time.  For the purpose of this requirement, it is assumed that GNSS reception at the locations of the VDES R-mode Base Station Infrastructure is nominal. |  | Mandatory | Accepted |  |
| **8.2** | **GNSS Disruption at Infrastructure** | REQ-28 | Following a disruption to GNSS services (due to jamming/spoofing/interference/satellite failures, etc.) at one or more locations of the VDES R-mode Base Station Infrastructure, and regardless of GNSS service availability and performance at the ship's location, the system shall continue to meet the Functional, Coverage and Performance Requirements set out in this specification for a minimum duration of 2 hours. | This means the BS will need to be able to detect GNSS disruptions. | Mandatory | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **8.3** | **GNSS Disruption at Infrastructure - Goal** | REQ-29 | Following a disruption to GNSS services (due to jamming/spoofing/interference/satellite failures, etc.) at one or more locations of the VDES R-mode Base Station Infrastructure, and regardless of GNSS service availability and performance at the ship's location, the system should, as a goal, continue to meet the Functional, Coverage and Performance Requirements set out in this specification for an unlimited period of time. |  | Medium | Accepted | VDES R-Mode System Requirements [3] |
| **8.4** | **Ship Dynamics** | REQ-32 | The system shall meet the requirements set out in this specification during static and dynamic ship operations. | One critical issue with this respect is the measurement update rate. | Mandatory | Accepted | IMO Resolution MSC.401(95) [1] |
| **9** | **Resource** | REQ-33 |  |  |  | Accepted |  |
| **9.1** | **VDES Channels** | REQ-35 | The system should operate on the VDE-TER or ASM channels. | It is acknowledged that VDE will provide better performance than AIS R-mode but implementing R-mode using AIS could be a start. | Medium | Accepted | VDES R-mode Development and Standardisation [8] |
|  | **Radio Freuency** | REQ-XX | The system shall be designed to operate within the frequency band 283.5-315 kHz in region 1 and 285-325 kHz in region 2 and 3, if the MF variant is used. |  |  |  | ENG10 |
| **9.2** | **VHF Data Link Loading - Goal** | REQ-34 | The system should impose a maximum additional VDES Data Link loading of 7% of the total link capacity. | 7% may not be sufficient due to slot use coordination requirements. The coordination distance between two AIS BS is probably 120 NM. | High | Accepted | VDES R-mode Development and Standardisation [8] |
| **10** | **Testability** | REQ-36 |  |  |  | Accepted |  |
| **10.1** | **Self-testability** | REQ-37 | The system shall be designed to support self-testability. |  | High | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **10.2** | **Remote Monitoring** | REQ-38 | The system shall be designed to support remote infrastructure monitoring. |  | High | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |
| **11** | **Interoperability** | REQ-40 | The system shall be interoperable with other VDES R-Mode networks (using a different time source), Medium Frequency R-mode, eLoran and other similar PNT systems. | If possible, using the same time base, geodetical coordinate systems, etc. | Mandatory | Accepted | R-mode Baltic - Baseline and Priorities (Draft) [2] |

1. ‘Project team’ in this context is internal GLA, but all aspects are open to wider international discussion and collaboration. [↑](#footnote-ref-1)