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| IALA Guideline |

Stakeholder Requirements for R-Mode

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# INTRODUCTION

## Identification

This document presents the stakeholder requirements for an R-Mode System to be developed by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). It is intended to help establish a common understanding of R‑Mode among key stakeholders and serve as a basis for further development of the concept. These requirements are not complete and further collaborative work is required to develop a full set of stakeholder needs and requirements.

Once agreed by the IALA community, the requirements contained herein will be developed into a set of system requirements, providing a basis for design, development, verification and acceptance of the system.

## System Purpose

The R-Mode System will provide regional ranging services to a dedicated R-Mode processor or multi-system radionavigation equipment installed on-board maritime and inland waterway vessels, enhancing the integrity of the Position, Navigation and Timing (PNT) data available on-board, and mitigating the impact of disruptions to Global Navigation Satellite System (GNSS) services.

Two concepts for R-Mode are currently being studied by the international maritime community, based on the Medium-Frequency (MF) signals of the IALA Marine Beacon DGPS system, and the use of base station networks of the Automatic Identification System (AIS) and its planned successor, the VHF Data Exchange System (VDES).

## Document Structure

The following two sections list the references, definitions and acronyms used throughout this document. Section 4 describes the anticipated R-Mode System life cycle. Section 5 identifies the key stakeholders in the R-Mode System and their anticipated roles at different phases of the life cycle. A review of existing source documents related to R-Mode requirements is provided in Section 6. Section 7 (along with ANNEX A) outlines the operational concept for the R-Mode System, including proposed use cases and scenarios. Section 8 identifies the external systems that the R-Mode System is expected to interface with and the inputs, controls and outputs flowing between these systems and R-Mode. Section 9 presents a suggested objectives hierarchy for R-Mode intended to capture the stakeholders’ preferences with respect to the system’s performance and other characteristics, and to inform trade-off analyses to be performed during the system development phase. Finally, a consolidated set of stakeholder requirements for R-Mode is presented in Section 10. Some general systems engineering advise is also provided in the document, based largely on reference (Buede and Miller, 2016).

# References

The following sources are referred to in this document:

|  |  |
| --- | --- |
| Buede and Miller, 2016 | The Engineering Design of Systems, 3rd Ed., John Wiley & Sons, Inc. |
| GLA, 2019 | Internal GLA Discussions |
| IALA ARM, 2018 | VDES R-Mode System Requirements, Liaison Note from IALA ARM to ENG/ENAV. |
| IALA ENAV WG3, 2018 | Results of Discussion on VDES R-mode, Output Document from IALA ENAV WG3 meeting in Yiwu, China. |
| IALA ENAV, 2018 | VDES R-mode Development and Standardisation, Liaison Note IALA ENAV to ENG. |
| IALA ENAV, 2019 | VDES R-Mode Stakeholder Requirements, IALA ENAV, April 2019 |
| IALA ENG, 2018 | VDES R-Mode Requirements, Liaison Note from IALA ENG to ENAV |
| IALA R-129, 2012 | IALA R-129, Recommendation R-129 on GNSS Vulnerability and Mitigation Measures |
| IMO A.1046(27) | IMO Resolution A.1046(27) |
| IMO MSC.1/Circ.1575 | Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing |
| IMO MSC.401(95) | IMO Resolution MSC.401(95), Performance Standards for Multi-system Shipborne Radionavigation Receivers |
| IMO NCSR 1/28 | Report to the Maritime Safety Committee, NCSR 1/28 |
| ITU RR, 2016 | ITU Radio Regulations |
| ITU RR, 2016a | ITU Radio Regulations, Article 28 |
| R-Mode Baltic, 2019 | R-Mode Baltic - Baseline and Priorities, Issue 1.0, March 2019 |
| R-Mode Baltic, 2019a | Time Source for R-Mode VDES Base Stations, Input document to IALA ENAV WG3 meeting, St-Germain-en-Laye, August 2019. |

# Definitions and Acronyms

## Definitions

The definitions of terms used in this IALA document can be found in the International Dictionary of Marine Aids to Navigation (IALA Dictionary) at <http://www.iala-aism.org/wiki/dictionary> and were checked as correct at the time of going to print. In addition, the terms below are defined. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

*Accuracy* means the degree of conformance between the estimated value of a parameter at a given time and its true value at that time.

*Availability* means the percentage of time that a system (or a system element) is performing a required function under stated conditions. Non-availability can be caused by scheduled or unscheduled interruptions.

*Beacon Site* means a facility in which an R-Mode Beacon is installed.

*Continuity* means the probability that a system (or a system element) remains available over a specified Continuity Time Interval, assuming it was available at the beginning of the interval.

*Continuity Risk* is calculated as one minus the Continuity requirement; for example, the Continuity requirement of 99.97% per 15 minutes is equivalent to a Continuity Risk of 3e-4 per 15 minutes.

*Continuity Time Interval* means the time-period required to complete an operation during which continuous availability of a system (or a system component) is required.

*Coordinated Universal Time / Temps Universel Coordonné / UTC* is a post-processed virtual time scale computed and maintained by the BIPM. The time scale is not directly accessible; however, it is common practice to use a contributing UTC(k) as a physical realization of UTC.

*DRMS Accuracy* means the Root Mean Square value of the Horizontal Position Error.

*GNSS-disrupted Environment* refers to an environment in which one or more GNSS are not available or do not meet their respective performance standards.

*GNSS-nominal Environment* refers to the environment in which all GNSS meet their respective performance standards.

*Global Navigation Satellite System(s)* means any combination of one or more of the following systems: GPS; GLONASS; BeiDou; Galileo.

*Hazardously Misleading Information* means the occurrence of a position fix with Horizontal Position Error larger than the Horizontal Alert Limit without an alarm being raised within the Time to Alarm.

*Horizontal Alert Limit* means the maximum tolerable Horizontal Position Error for a given application / phase of voyage. Typically, this is set as 2.5 times the corresponding R95 Accuracy requirement for the application.

*Horizontal Position Error* means the distance between the true position of a sensor at a given time and the projection of the estimated position onto the local tangent plane containing the true position at that time.

*May* expresses permissive guidance.

*Multisystem Shipborne Radionavigation Unit* means a multisystem shipborne radionavigation receiver or transceiver (including PNT data processing capability).

*Passive Ranging Service* means the provision of VDES R-Mode navigation data and passive ranging observables.

*Positioning Availability* means the percentage of all positioning epochs in any given time period for which an external PNT processor has a position fix and can guarantee its integrity. Non-availability can be caused by a range of factors such as: loss of navigation data; insufficient number of visible ranging signals; receiver fault; inability to perform integrity monitoring (due to insufficient number of visible ranging signals or poor HDOP); fixes which are determined by the integrity monitor to represent a risk; and fixes for which the determined level of integrity is not sufficient to meet the requirements.

*Positioning Continuity* means the probability that a user will be able to determine position with specified Accuracy and is able to monitor the Integrity of the determined position over a specified Continuity Time Interval applicable for a particular operation. It is assumed that, at the beginning of the operation, the user equipment is fault-free and the system is available. Events which cause loss of Continuity are the same ones which cause loss of Positioning Availability with the exception of events which can be forecast, such as poor HDOP or announced down-time of some part of the system.

*Positioning Integrity* means the ability of a system to provide timely warnings to users when the system should not be used for navigation. It is usually specified in terms of an Integrity Risk, a Horizontal Alert Limit and a Time to Alarm.

*Positioning Integrity Risk* means the probability of the user being presented with Hazardously Misleading Information at any time during a stated operation window.

*R-Mode Beacon (also Beacon)* means a Radio Station installed at a fixed, known location, capable of being used by an R-Mode Sensor as a reference object for ranging or pseudoranging. This includes R-Mode capable MF radio beacons and VDES Base Stations.

*R-Mode Navigation Data (also Navigation Data)* means the following data items, as defined in this document:

(i) Beacon Static Data;

(ii) Beacon Health;

(iii) Beacon Signal Quality;

(iv) UTC Synchronization Data; and

(v) Downtime Notifications.

*R-Mode Reference Time* is a time scale defined for a certain area of R-Mode operation. It shall be traceable to UTC. It could be constituted by a single UTC(k), a combination of several UTC(k), a GNSS system time or an arbitrary timescale implementation. RMRT shall be maintained within 100 ns of UTC.

*R-Mode Sensor (also Shipborne Equipment)* means a Radio Station, typically installed on a ship, capable of using radio transmissions from R-Mode Beacons to obtain signal time of arrival / range / pseudorange (TBD) measurements and R-Mode navigation data.

*R95 Accuracy* means the Horizontal Position Error not exceeded with a probability of 95%.

*Radio Station* means one or more transmitters or receivers or a combination of transmitters and receivers, including the accessory equipment, necessary at one location for carrying on communication via radio waves.

*Radio Station Site (also Site)* means a facility in which one or more Radio Stations are installed.

*Ranging Service* means the provision of R-Mode navigation data and ranging observables. This may include the MF R-Mode ranging service and VDES R-Mode passive and active ranging services.

*Service Area* means a geographical area designated by the R-Mode System operator within which the system is expected to meet all requirements applicable to the Navigation Data and Observables Function as specified in this document.

*Service Availability* means the percentage of time a given service meets all requirements applicable to that service stated herein.

*Shall* expresses a characteristic which is to be present in the item which is the subject of the specification, i.e. 'shall' expresses a binding requirement.

*Should* expresses a target or goal to be pursued, but not necessarily achieved.

*Time of Arrival* means the time (measured relative to a stated time scale) the R-Mode ranging signal reaches the R-Mode Sensor's or R-Mode Beacon's RF interface.

*Time of Transmission* means the time (measured relative to a stated time scale) the R-Mode ranging signal is transmitted via the R-Mode Beacon's or R-Mode Sensor's (for two-way ranging) RF interface.

*UTC(k)* means a realization of UTC maintained by a National Metrology Institute. Such a realization is per convention required to be within 100 ns of UTC. Values and uncertainties of UTC-UTC(k) are published by the BIPM as the Circular-T, monthly for the previous month.

*User Range Accuracy* means an estimate of the one-sigma range error to a Beacon due to the intrinsic Beacon and Time Source errors.

*Will* expresses a declaration of intent on the part of IALA. 'Will' does not express a binding requirement. 'Will' may also be used to express simple futurity.

## Acronyms

*1PPS* One Pulse Per Second

*ARAIM* Advanced Receiver Autonomous Integrity Monitoring

*BIPM* Bureau International de Poids et Mesure

*CIRM* Comité International Radio-Maritime

*CRC* Cyclic Redundancy Check

*CTI* Continuity Time Interval

*EIRP* Effective Isotropic Radiated Power

*ETSI* European Telecommunications Standards Institute

*FMS* Far-field Monitoring Station

*GNSS* Global Navigation Satellite System(s)

*HAL* Horizontal Alert Limit

*HMI* Hazardously Misleading Information

*HPE* Horizontal Position Error

*IALA* International Association of Marine Aids to Navigation and Lighthouse Authorities

*ICS* International Chamber of Shipping

*IEC* International Electrotechnical Commission

*IR* Integrity Risk

*MCC* Monitoring and Control Centre

*MCS* Monitoring and Control Station

*MRAIM* Maritime RAIM

*MSR* Multisystem Shipborne Radionavigation Receiver

*MSRU* Multisystem Shipborne Radionavigation Unit

*PKI* Public Key Infrastructure

*PNT* Positioning, Navigation and Timing

*RF* Radio Frequency

*RMB* R-Mode Beacon (also Beacon)

*RMRT* R-Mode Reference Time

*RMS* Root Mean Square

*RMSens* R-Mode Sensor (also Shipborne Equipment)

*RTCM* Radio Technical Commission for Maritime Services

*SA* Service Area

*SINR* Signal-to-Interference-and-Noise Ratio

*TBC* To Be Confirmed

*TBD* To Be Defined / Determined

*TOA* Time of Arrival

*TOT* Time of Transmission

*TTA* Time to Alarm

*URA* User Range Accuracy

*UTC* Coordinated Universal Time / Temps Universel Coordonné / UTC

*VDES* VHF Data Exchange System

*VHF* Very High Frequency

*VRM* VDES R-Mode

*VRMS* VDES R-Mode Sensor

*WAN* Wide Area Network

# Anticipated System Life Cycle

A system’s life cycle describes the staged development and utilization of the system from initial concept through to retirement. The diagram overleaf illustrates the anticipated phases of the R-Mode System life cycle, using the IDEF0 modelling language (see Section B 1 in ANNEX B for an introduction to IDEF0). These phases are not necessarily distinct in time as some concurrency is often inevitable.

The System Concept phase defines consistent and agreed stakeholder and system requirements. It includes capturing, analysing and managing the requirements, the identification of potential system architectures, and architecture trade-off studies. At the end of this phase, clearly delineated units will define the system architecture, each with allocated system requirements and interfaces between other units and at the system boundary specified. This stage should also identify any business and technical risks.

The Development and Standardization Phase adds detail to the architecture units, transforming them into complete and consistent detailed designs. Development and standardization, Manufacturing, Certification, Deployment and Training Phase activities are often pursued concurrently. Specifications, guidelines and standards flow from Development to the other four processes. Manufactured, training and deployed elements flow to Development for testing. Interaction continues with the stakeholders as testing occurs.

The Utilization Phase begins when users receive the first operational system elements. This phase usually runs concurrently with manufacturing, certification as well as deployment and training of the system’s operators and maintainers (O/M). Manufactured and certified elements are sent to the deployment system, which delivers them to users. One of the problems faced at this stage is how to deploy upgraded elements while the existing ones are being phased out. Users and maintainers provide feedback about the system, which is used during the Refinement Phase to make changes to the system design, leading to upgrades.

When the operational life of the system is over, the Retirement Phase is initiated.

The current edition of this document focuses mainly on the Utilization Phase of the R-Mode System as this is expected to provide the most valuable insights into the required functionality and performance of the system. However, it is recommended that further work consider the rest of the system life cycle in more detail to ensure that important requirements have not been missed.

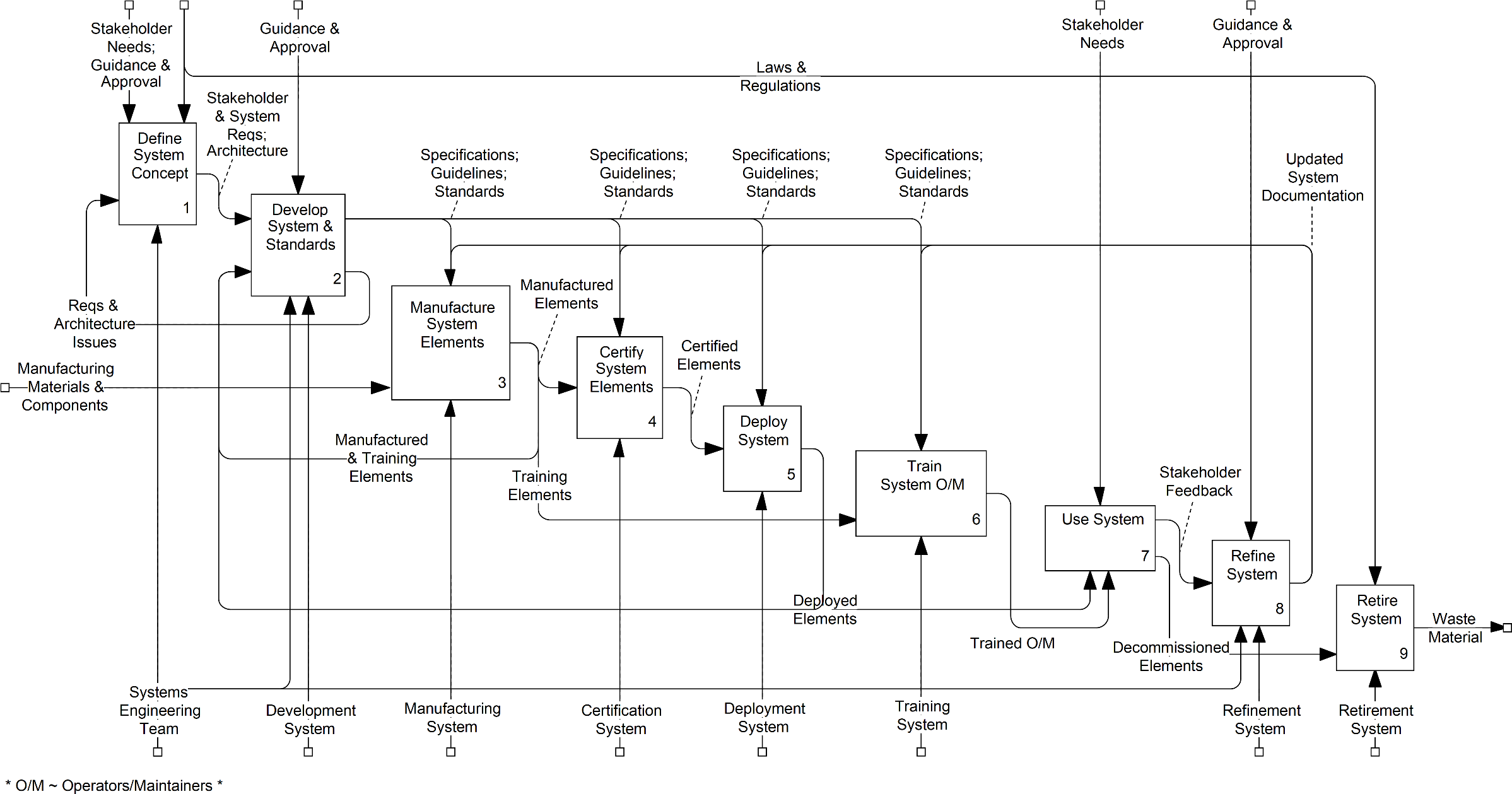


Figure 1 - Anticipated phases of the R-Mode System life cycle

# Stakeholder Identification

The following table lists the key stakeholders in the R-Mode System and their anticipated roles during the different phases of the system’s life cycle.

1. Key stakeholders in the R-Mode System.

| Stakeholder | Role | System Life Cycle Phase | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Concept Definition | Development & Standardization | Manufacturing | Certification | Deployment | Training | Utilization | Refinement | Retirement |
| **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 R-Mode;  Provides input to the technical specification for VDES | ✓ | ✓ |  |  |  |  |  | ✓ |  |
| **Operators / Competent Authorities** | Provide operational requirements for R-Mode;  Provide MF Beacon and VDES shoreside infrastructure | ✓ | ✓ |  |  | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Seafarers / Users / The Nautical Institute** | Provide operational requirements for the use of R‑Mode;  Provide training requirements for the use of 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;  Provide time transfer services (potentially) | ✓ | ✓ |  |  |  |  | ✓ | ✓ |  |
| **Equipment Manufacturers / CIRM** | Provide technical expertise with respect to MF Beacon and VDES technology;  Conduct market research;  Manufacture R-Mode equipment;  Integrate R-Mode into a resilient PNT solution | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  | ✓ |  |
| **Standardization Bodies / IEC;**  **ETSI;**  **RTCM** | Develop test standards for R-Mode equipment  Develop test standard for resilient PNT solution |  | ✓ |  |  |  |  |  | ✓ |  |
| **Test Houses** | Certify R-Mode equipment |  |  |  | ✓ |  |  |  |  |  |
| **Testbeds / 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 R-Mode;  Produces prototype R-Mode equipment;  Conducts tests of R‑Mode equipment / system | ✓ | ✓ | ✓ |  | ✓ | ✓ | ✓ | ✓ | ✓ |

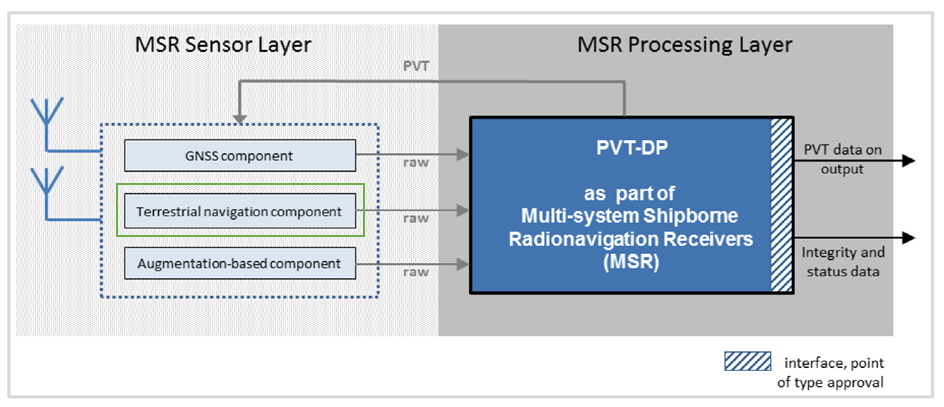
# Review of Existing Source Documents

This section identifies the documents that were used as sources of the stakeholder needs considered in this document and the stakeholder requirements listed in Section 10.

The need for resilient PNT in maritime shipping is well recognised by IMO (see, for example, Risk Control Option 5 in the e‑Navigation Strategy Implementation Plan (IMO NCSR 1/28)) and the combined use of various radionavigation and augmentation systems (including, potentially, R-Mode) on-board maritime vessels is enabled by IMO Resolution MSC.401(95): ‘Performance Standards for Multi-system Shipborne Radionavigation Receivers’. Resolution (IMO MSC.401(95)) identifies a number of functional requirements for the Multi-system Shipborne Radionavigation Receiver (MSR) (and by extension R-Mode), as well as some performance requirements, largely specified by reference to IMO Resolution A.1046(27): ‘Worldwide Radionavigation System’ (IMO A.1046(27)).

The concept of the MSR is further developed in IMO document MSC.1/Circ.1575: ‘Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing’ (IMO MSC.1/Circ.1575). R-Mode is listed as one of the potential sources of data for the MSR in MSC.1/Circ.1575, within the ‘Regional Terrestrial Navigation Systems’ category. VDES is also listed as a potential source of ‘Additional Input Data’, which may be provided to ‘increase redundancy or to evaluate plausibility and consistency of data input (ship sensed position, e.g. by position reference systems)’.

Figure 1 shows the top-level functional architecture for the MSR (extracted from (IMO MSC.1/Circ.1575)), which is reproduced here in order to provide context for the shipborne R-Mode System elements (which are assumed to be part of the ‘Terrestrial navigation component’ shown in green in Figure 1). From the diagram it can be seen that, as a minimum, the shipborne R-Mode Sensor will need to have an RF signal input and a raw observables (e.g. signal time of arrival) output feeding into the Position, Velocity and Time Data Processing (PVT-DP) module of the MSR. The diagram further suggests that the sensor may also need to have a PVT input.



1. Suggested functional architecture of the MSR as per MSC.1/Circ.1575.

With respect to the input/output data formats, MSC.1/Circ.1575 states that ‘Where possible, standardized and approved communication protocols for interfacing should be used’ (referencing IEC 61162).

MSC.1/Circ.1575 also defines a number of performance requirements for the data being output by the MSR (four levels of positioning accuracy and four levels of integrity performance are defined). However, no performance requirements are specified for the individual data sources (such as R-Mode).

The coverage and performance requirements for R-Mode eventually used in this document are based on statements provided by the IALA ARM Committee in Liaison Note (IALA ARM, 2018), by the R-Mode Baltic project in report (R-Mode Baltic, 2019) and the IALA Recommendation R-129, ‘GNSS Vulnerability and Mitigation Measures’ (IALA R-129, 2012). 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 report (R-Mode Baltic, 2019) 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 (IALA ARM, 2018):

‘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.’

To be consistent with both the R-Mode Baltic project and the statements provided by ARM, this document considers R-Mode as a contingency PNT system with a holdover capability of at least 2 hours, with a design goal of being capable of operating as a full backup to GNSS. Whether R-Mode is configured as a contingency or a backup system will depend on the design chosen and budget available.

ARM further provided the following statements with respect to the performance requirements of R-129 (IALA ARM, 2018):

‘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 document adopts the positioning 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, report (R-Mode Baltic, 2019) 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 document 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).

Some regulatory requirements were extracted from ITU publications. R‑Mode appears to fall within the ITU’s definition of a radiodetermination service. Radiodetermination services are subject to policies set forth in ITU Radio Regulations (RR) Article 28 (ITU RR, 2016a). These include the following general provisions:

‘28.3 § 3 Administrations shall notify to the Bureau the characteristics of each radiodetermination station providing an international service of value to the maritime mobile service and, if considered necessary, for each station or group of stations, the sectors in which the information furnished is normally reliable. This information is published in the List of Coast Stations and Special Service Stations (List IV), and the Bureau shall be notified of any change of a permanent nature.

28.4 § 4 The method of identification of radiodetermination stations shall be so chosen as to avoid any doubt as to their identity.

28.5 § 5 Signals sent by radiodetermination stations shall be such as to permit accurate and precise measurements.

28.6 § 6 Any information concerning modification or irregularity of working of a radiodetermination station shall be notified without delay in the following manner:

28.7 a) land stations of countries operating a radiodetermination service shall send out daily, if necessary, notices of modifications or irregularities in working until such time as normal working is restored or, if a permanent alteration has been made, until such time as it can reasonably be taken that all navigators interested have been warned;

b) permanent alterations or irregularities of long duration shall be published as soon as possible in the relevant notices to navigators.’

Article 28 further contains provisions specific to the radiodetermination-satellite service, radio direction-finding stations and radiobeacon stations. The radiobeacon category appears to be the most relevant for R-Mode. With respect to radiobeacon stations, Article 28 states:

‘28.18 § 11 When an administration thinks it desirable in the interests of navigation to organize a service of radiobeacon stations, it may use for this purpose:

28.19 a) radiobeacons properly so-called, established on land or on ships permanently moored or, exceptionally, on ships navigating in a restricted area, the limits of which are known and published. The emissions of these radiobeacons may have either directional or non-directional patterns;

28.20 b) fixed stations, coast stations or aeronautical stations designated to function as radiobeacons, at the request of mobile stations.

28.21 § 12 1) Radiobeacons properly so-called shall use the frequency bands which are available to them under Chapter II.

28.22 2) Other stations notified as radiobeacons shall use for this purpose their normal working frequency and their normal class of emission.

28.23 3) The power radiated by each radiobeacon properly so-called shall be adjusted to the value necessary to produce the stipulated field strength at the limit of the range required (see Appendix 12).’

It is understood that the frequency band used by the IALA MF DGPS system has the appropriate allocation in the RR to allow an MF R-Mode service. However, this may not be the case with VDES R-Mode as the VDES channels currently only have a radiocommunication service allocation. It is unclear at this stage whether VDES R-Mode stations would be considered by ITU as ‘radiobeacons properly so-called’, or as stations ‘designated to function as radiobeacons’. It appears from the above that the former would require additional (radiodetermination service) allocations to be made under RR Chapter II, Article 5 for the VDES frequencies. Conversely, paragraphs 28.20 and 28.22 above seem to suggest that this may not be necessary if the VDES stations are merely ‘designated to function as radiobeacons’.

A number of additional requirements were extracted from documents prepared by the IALA e-Navigation Committee (IALA ENAV WG3, 2018; IALA ENAV, 2018; IALA ENAV, 2019), IALA Engineering and Sustainability Committee (IALA ENG, 2018) and in discussions held within the General Lighthouse Authorities of the UK & Ireland (GLA, 2019). In particular, the GLA would like to emphasise the need to ensure that the R-Mode signals are cryptographically secured against spoofing attacks. This is considered especially important for VDES R-Mode as VHF radio signals are relatively easy to generate using low-cost, compact radio equipment and antennas (unlike MF or LF signals which require large antenna masts for effective transmission).

# Operational Concept

An operational concept is a description of how a system will be used. It is intended to create a shared vision among all of the stakeholders for the major interactions of the key actors (such as users, operators and various other external systems) with the system of interest (the term ‘actor’ is often used as an abstraction representing a particular type of stakeholder or an external system).

The operational concept includes a collection of use cases as described in a use case diagram (see Section 7.1.2). Each use case addresses one way that a particular actor will interact with the system. The use case diagram provides a depiction of how the individual use cases relate to each other.

Each use case contains one or more scenario(s). A scenario defines how the system will respond to inputs from the actors in order to produce the desired outputs. The scenario does not describe how the system should process inputs to produce outputs; rather, the focus is on the exchange of inputs and outputs between the system and the actors.

The operational concept provides the first hints as to the system boundary. The inputs and outputs cross this boundary, defining the input/output functional requirements and, to some extent, the external interface requirements for the system of interest. The operational concept also suggests the top-level functional decomposition of the system.

In general, there is a system for each phase of the system’s life cycle and an operational concept should be developed for each of those systems. The current edition of this document addresses only the operational concept for the Utilization Phase (other phases may be addresses in a later edition).

## Operational Concept for the Utilization Phase

### Actors

The intended actors in the R-Mode System, in the Utilization Phase, are:

1. Multisystem Shipborne Radionavigation Unit
2. Operator - Field Engineer
3. Operator - Monitoring & Control
4. Operator - System Administrator
5. e-Navigation Client

### Use Cases

The intended uses of the R-Mode System in the Utilization phase are shown in the use case diagram below. Example scenarios for each use case shown here are then provided in  ANNEX A.

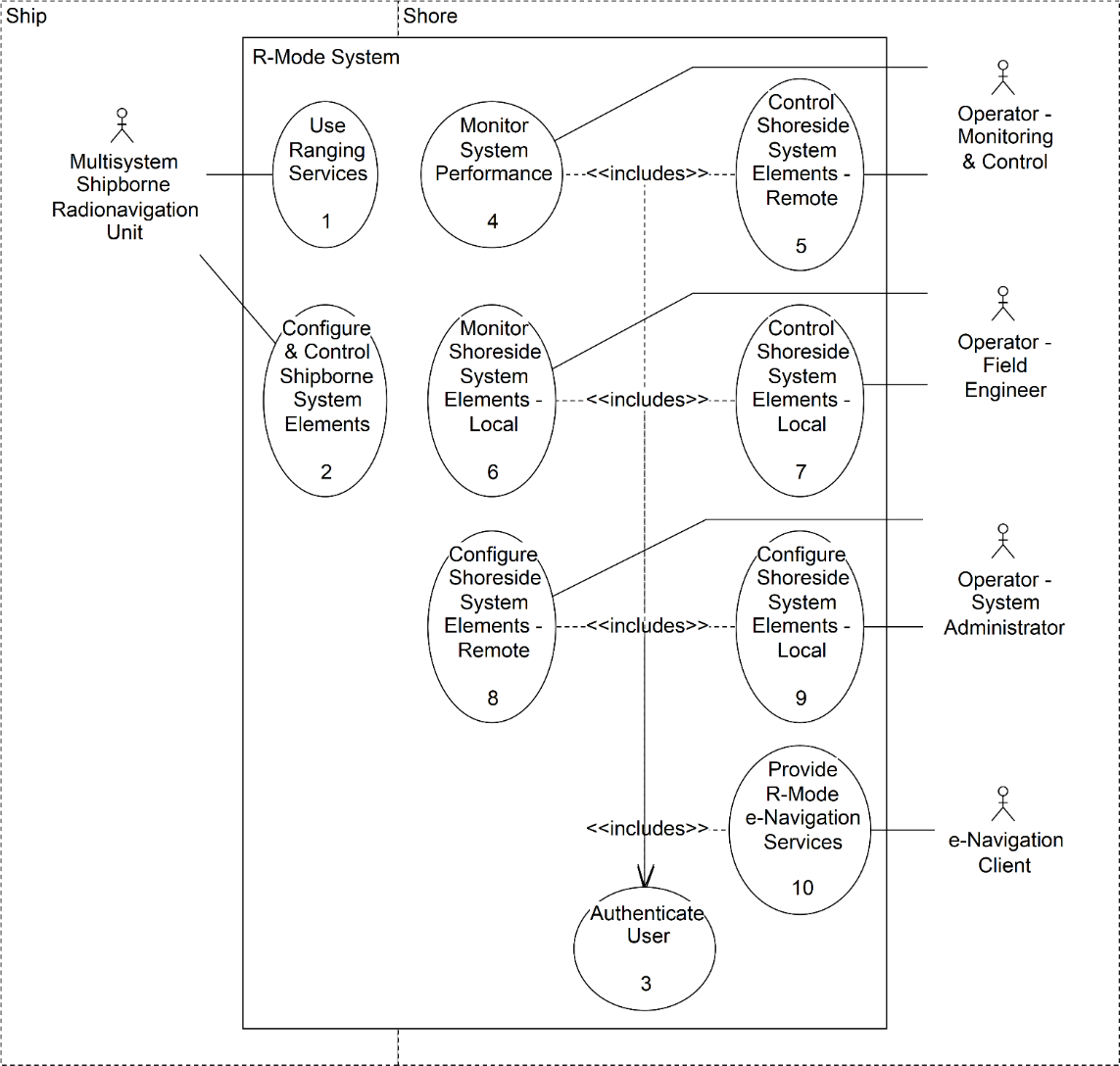


Figure 2 - R-Mode System Use Cases for the Utilization Phase

# External Systems Diagrams

One of the key questions in defining a new system is where to draw the system’s boundary. Everything within the system boundary is open to change, and nothing outside the boundary can be changed. An External Systems Diagram (ESD) is a model of the interaction between the system, the actors (as defined by the operational concept) and, possibly, other external systems not yet identified.

An external system is defined here as a system that interacts with the system of interest via the system’s external interfaces. An external system can impact the system of interest and vice versa. In addition, the term context is defined here as a set of entities that can impact the system of interest but cannot be impacted by the system.

An ESD provides a definition of the system’s boundary in terms of the system’s inputs and outputs (some of which would have been identified in the use case scenarios developed as part of the operational concept), and helps identify the required external interfaces. Where relevant, the ESD may also show inputs from the system’s context.

Different modelling conventions can be used to create ESDs; this document uses the IDEF0 approach, described in Section B 1 in ANNEX B.

ESDs should be developed for every life cycle phase of the system. However, as in the preceding sections, the focus here will be on the Utilization Phase.

## External Systems Diagrams for the Utilization Phase

A set of ESDs for the Utilization Phase of the R-Mode System is provided below. For clarity, separate diagrams are provided, each representing the viewpoint of one of the actors identified in the operational concept.

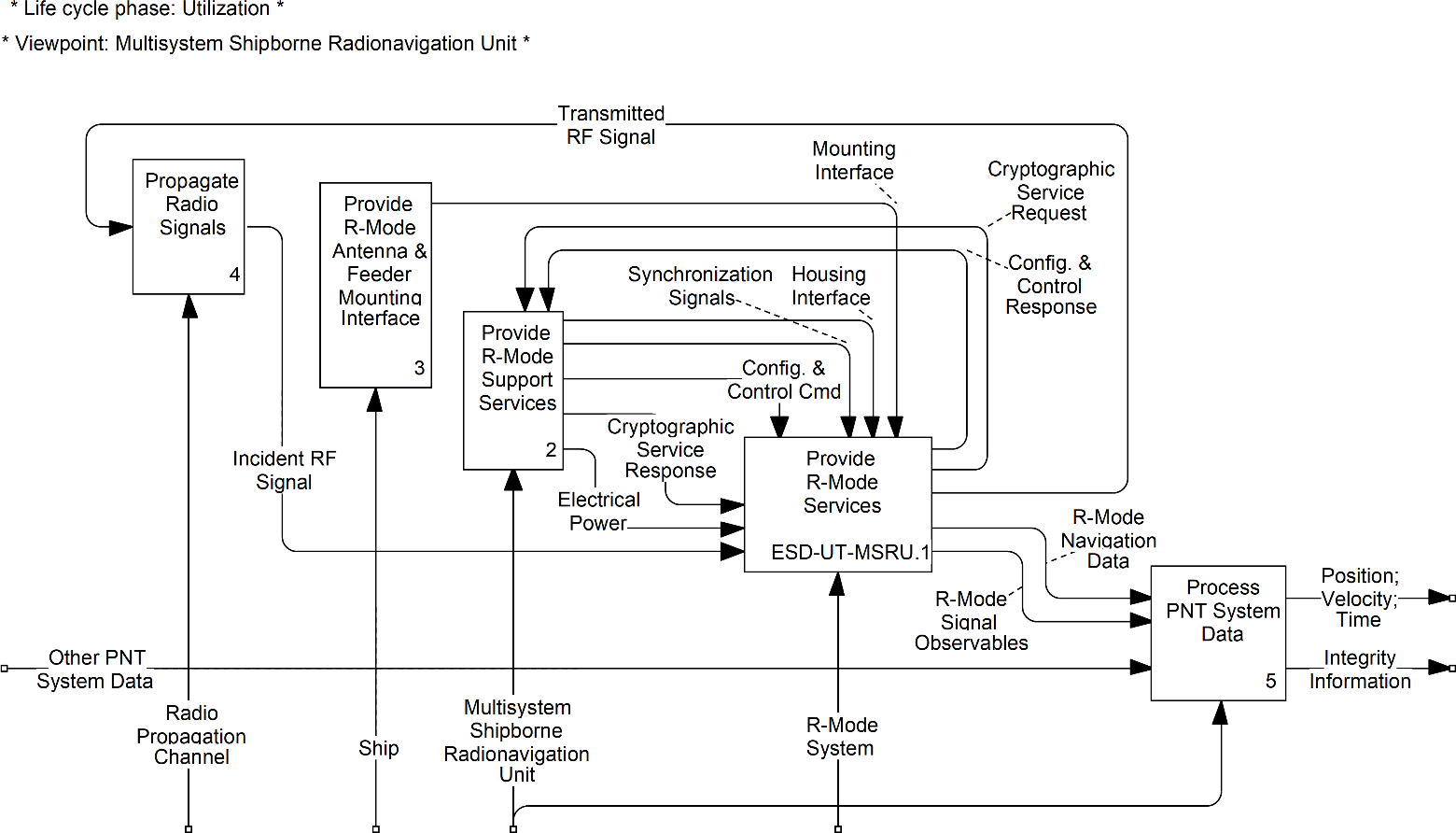


Figure 3 - External Systems Diagram for the Utilization Phase from the viewpoint of the Multisystem Shipborne Radionavigation Unit

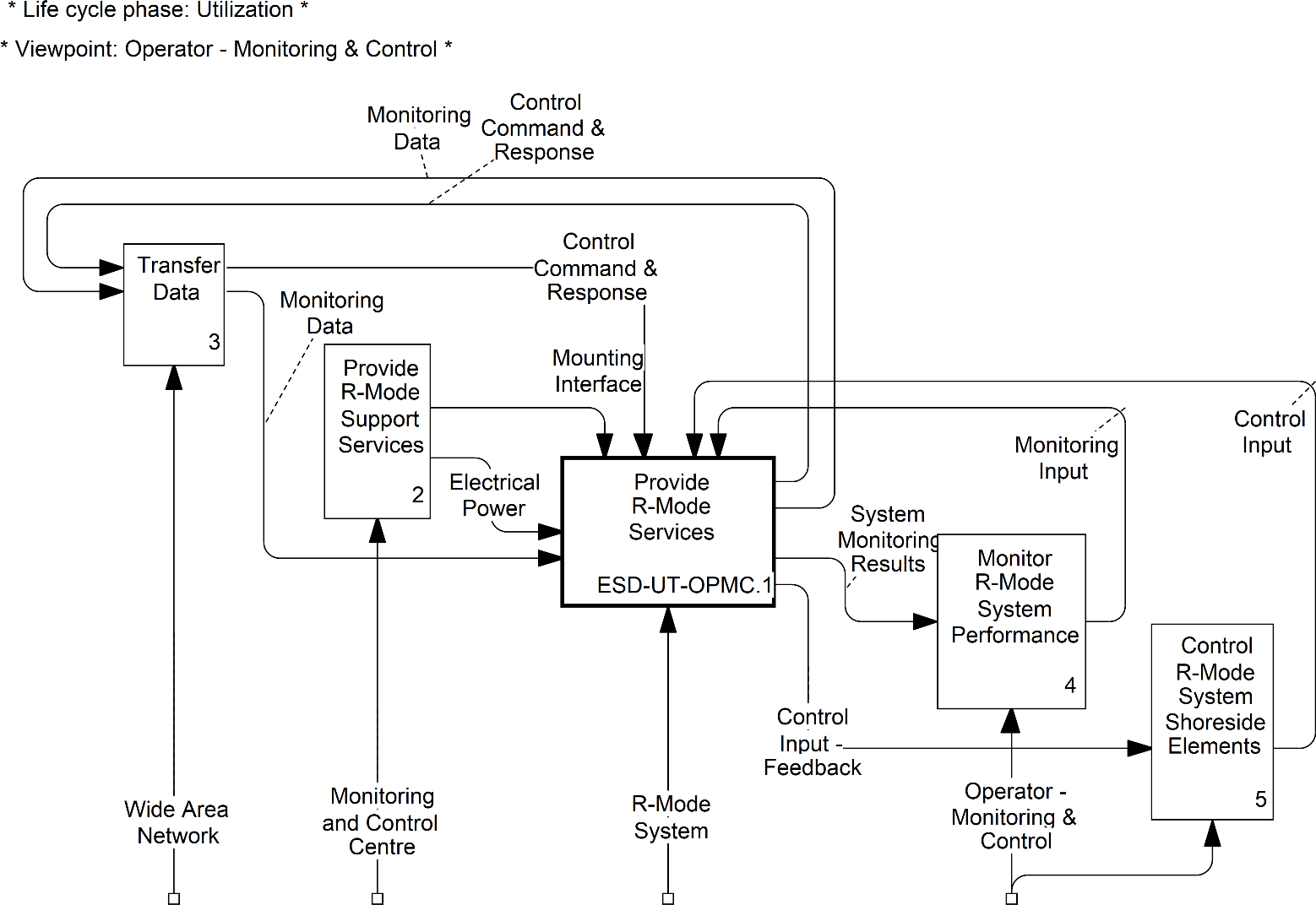


Figure 4 - External Systems Diagram for the Utilization Phase from the viewpoint of Operator - Monitoring & Control

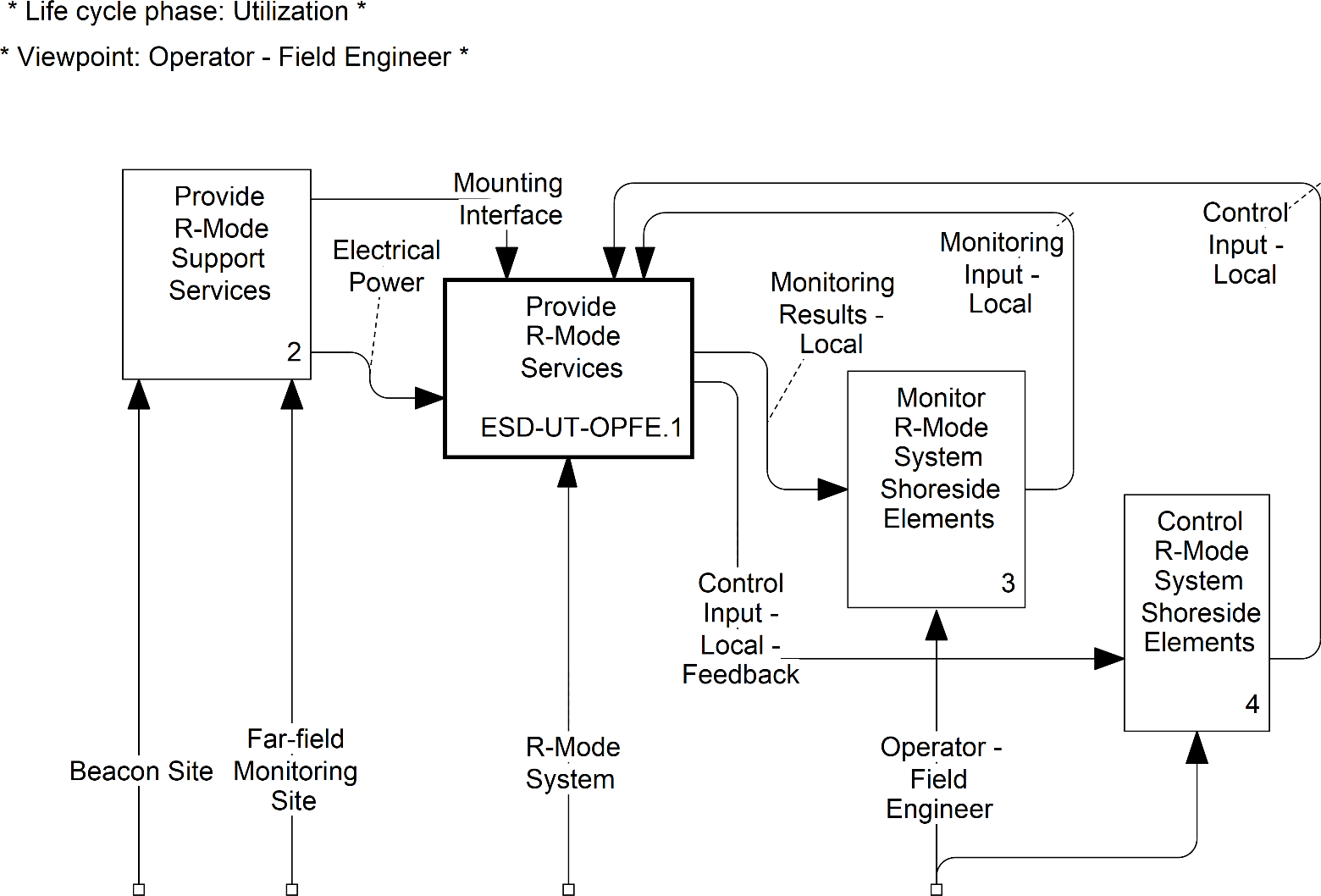


Figure 5 - External Systems Diagram for the Utilization Phase from the viewpoint of Operator - Field Engineer

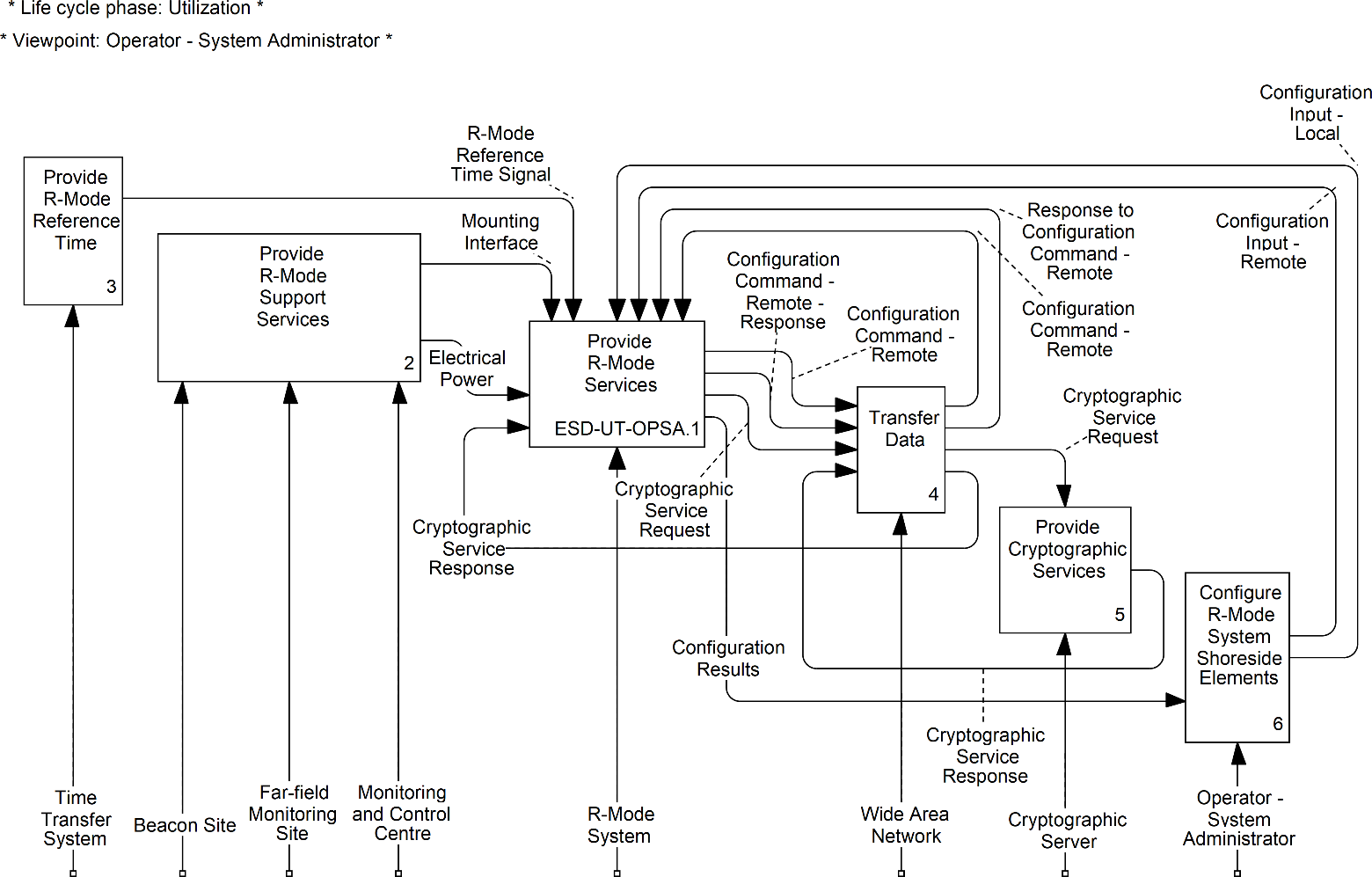


Figure 6 - External Systems Diagram for the Utilization Phase from the viewpoint of Operator - System Administrator

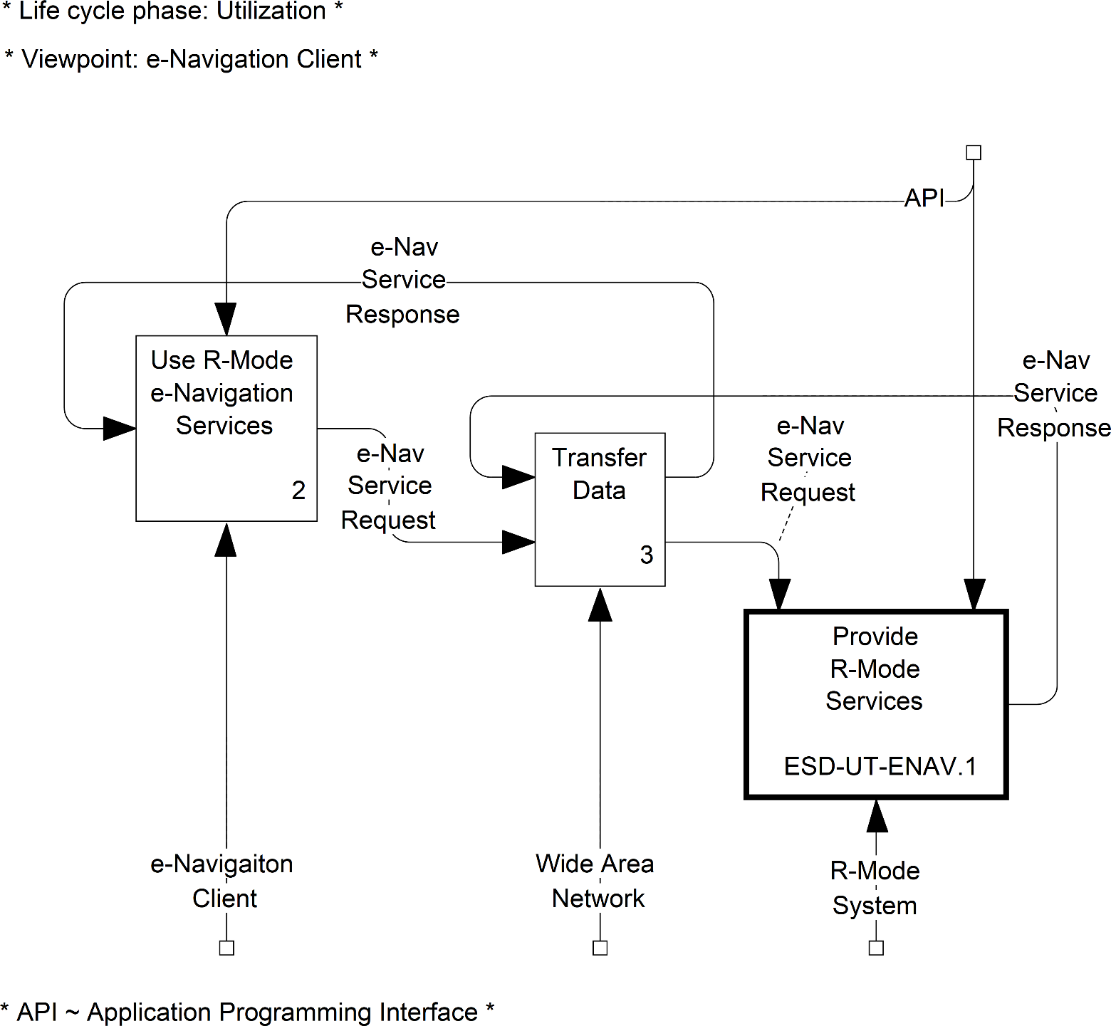


Figure 7 - External Systems Diagram for the Utilization Phase from the viewpoint of an e-Navigation Client

# Objectives Hierarchy

## Use of the Objectives Hierarchy in Trade-off Studies

Since the systems engineering design process is decision rich, it is beneficial to introduce some concepts from decision analysis. Decision analysis supports trade-off decisions through the use of value curves, weighting algorithms and objectives hierarchies. These must be developed in consultation with the stakeholders, as the design decisions must reflect the values of the stakeholders rather than those of the systems engineers.

The objectives hierarchy of a system comprises a hierarchical breakdown of those attributes of the system that are of particular importance to the stakeholders and which are/will be associated with design goals. Typically, these attributes (also termed measures of performance or figures of merit) include various aspects of the system’s performance, cost and schedule.

Once the attributes of interest are determined, a scale is defined for each attribute at the bottom of the hierarchy by defining the minimum acceptable level of performance (or cost/schedule, as applicable) for that attribute (referred to as the minimum requirement or threshold) and the most desired level of performance (the design goal).

Then, value curves are developed for each bottom-level attribute, describing how the subjective value of the attribute (as perceived by the stakeholders) changes as the level of performance for that attribute improves from the threshold to the design goal. These value curves take four general forms: (i) decreasing returns to scale; (ii) linear returns to scale; (iii) increasing returns to scale and (iv) an S-curve.

After value curves are defined for each bottom-level attribute, value weights (also termed swing weights) that address the relative value associated with improving from the threshold of acceptability to the design goal are set by the stakeholders for all bottom-level attributes, as well as the intermediate, aggregate attributes in the hierarchy.

Rather than trying to elicit the value weights directly from the stakeholders, the system engineers can ask the stakeholders to prioritize the attributes at each level of the objective hierarchy and use a suitable mathematical transformation to translate the priority rank orders into weights. Several such transformations have been described in the literature (Buede and Miller, 2016). It is proposed here that the Rank-Order Centroid (ROC) technique be used to determine the weights for the R-Mode objectives hierarchy:

1. Value weights.

Where:

is the priority rank of the th attribute of interest (obtained from the stakeholders);

is the total number of attributes at a given level in the objectives hierarchy; and

is the proposed value weight for the th attribute.

When performing a trade-off study, the value curves and weights provided by the stakeholders can be used to determine the overall value of a particular system design by aggregating across all attributes in the hierarchy using a weighting algorithm, such as the following:

1. Value aggregation algorithm.

Where:

represents the performance level for each attribute at a given level of the objectives hierarchy achieved by the given system design alternative;

represents the value associated with –this is obtained either from the value curves (when aggregating values at the bottom level of the objectives hierarchy) or as a result of aggregations one level below (when aggregating at an intermediate or the top level of the hierarchy); and

represents the value weights, as discussed previously.

The aim of the systems engineering process is to select that system design alternative which maximizes the overall value of the system to the stakeholders.

## Suggested Objectives Hierarchy for R-Mode

The diagrams below represent a suggested objectives hierarchy for the R-Mode System. The format follows that shown in Table 2.

The hierarchy is not complete at this stage and will need to be reviewed and finalized in consultation with the IALA community. Currently, the hierarchy only covers aspects of operational performance and the length of operational life. It would seem desirable to also include some cost objectives (in particular various aspects of deployment and operating costs).

The value curves for the bottom-level objectives are to be defined.

For each bottom-level objective in the hierarchy there should be a corresponding performance (or cost/schedule) requirement and design goal listed in Section 10.

1. A bottom-level objective (left) and an intermediate/top-level aggregate objective (right).

|  |  |  |
| --- | --- | --- |
| Objective |  | Aggregate Objective |
| Design Goal  Minimum Requirement |  |  |
| Priority Rank |  | Priority Rank |

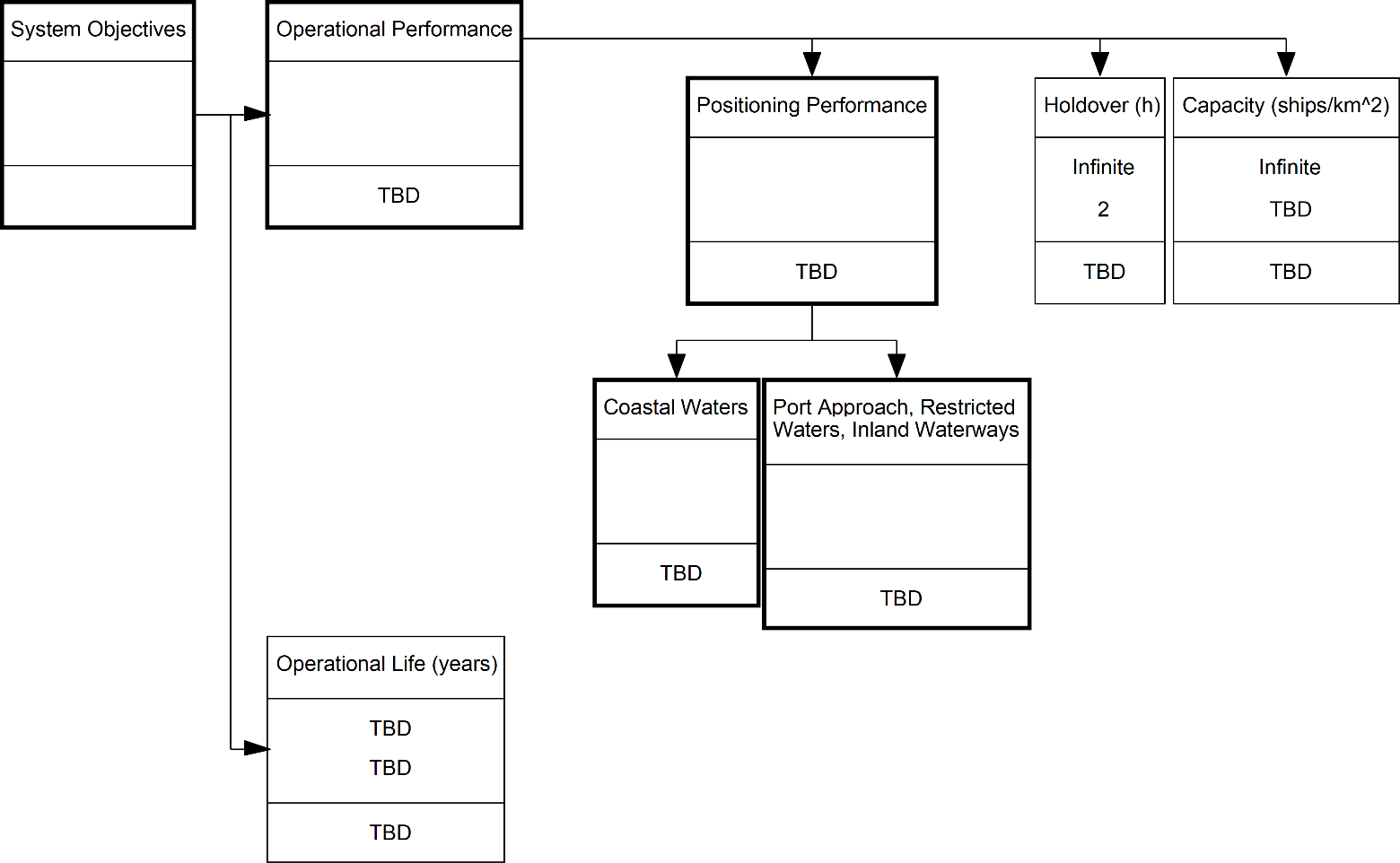


Figure 8 - System Objectives Hierarchy

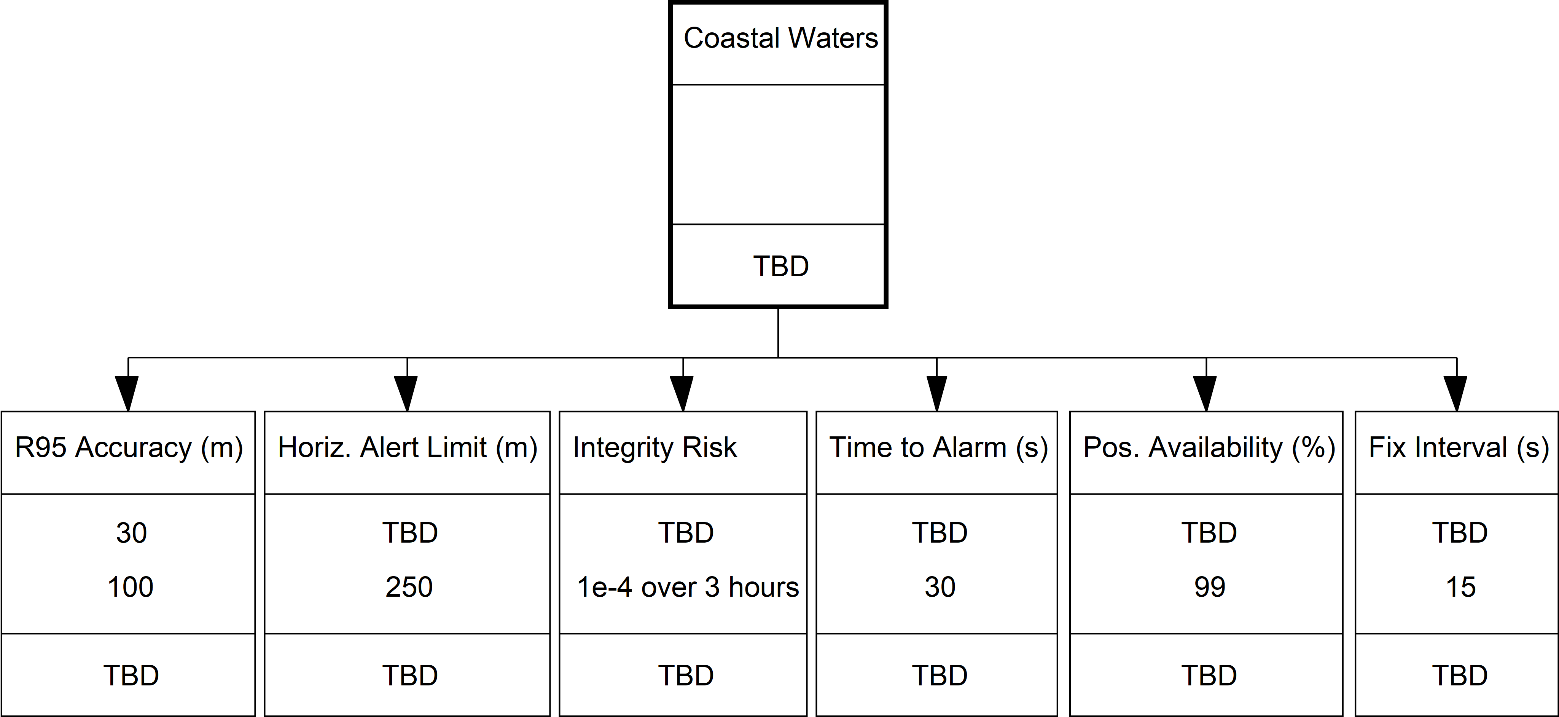


Figure 9 - Positioning Performance Objectives Hierarchy for Coastal Waters

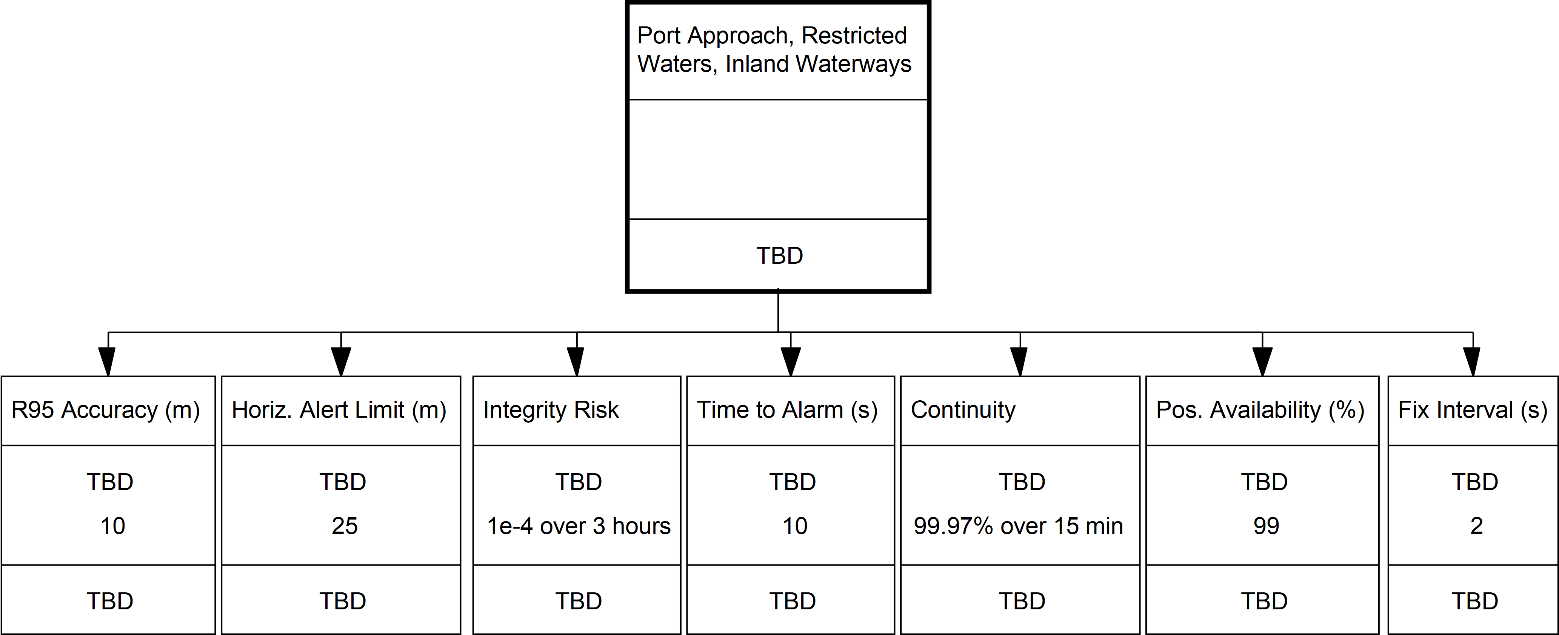


Figure 10 - Positioning Performance Objectives Hierarchy for Port Approach, Restricted Waters and Inland Waterways

# Requirements

This section contains a proposed list of stakeholder requirements for the R-Mode System extracted from the source documents reviewed in Section 6 and discussions in Section 7 to 9. A separate set of requirements is provided for each phase of the system life cycle (currently focusing on the Utilization Phase). Within each phase, the requirements are categorised into several groups, such as functional, coverage, performance and a number of other non-functional requirements categories. Each requirement is assigned a priority as one of: Mandatory, High, Medium or Low. The non-mandatory requirements are considered as design goals and can be traded off according to the objectives hierarchy defined in Section 9.

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 systems engineering team), 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).

## Development and Standardization Phase

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Title:** | **Applicability of Utilization Phase Requirements in the Development and Standardization Phase** | | | | |
| **Identity:** | REQ-DS-1 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | During the Development and Standardization Phase, the R-Mode System shall meet all requirements specified in the Utilization Phase section of this document, unless otherwise stated in this section. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

## Manufacturing Phase

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Title:** | **Applicability of Utilization Phase Requirements in the Manufacturing Phase** | | | | |
| **Identity:** | REQ-MA-1 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | During the Manufacturing Phase, the R-Mode System shall meet all requirements specified in the Utilization Phase section of this document, unless otherwise stated in this section. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

## Certification Phase

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Title:** | **Applicability of Utilization Phase Requirements in the Certification Phase** | | | | |
| **Identity:** | REQ-CE-1 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | During the Certification Phase, the R-Mode System shall meet all requirements specified in the Utilization Phase section of this document, unless otherwise stated in this section. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

## Deployment Phase

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Title:** | **Applicability of Utilization Phase Requirements in the Deployment Phase** | | | | |
| **Identity:** | REQ-DE-1 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | During the Deployment Phase, the R-Mode System shall meet all requirements specified in the Utilization Phase section of this document, unless otherwise stated in this section. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

## Training Phase

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Title:** | **Applicability of Utilization Phase Requirements in the Training Phase** | | | | |
| **Identity:** | REQ-TR-1 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | During the Training Phase, the R-Mode System shall meet all requirements specified in the Utilization Phase section of this document, unless otherwise stated in this section. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

## Utilization Phase

### Functional Requirements

#### Output Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Title:** | **Beacon Static Data ("Almanac")** | | | | |
| **Identity:** | REQ-UT-1 | **Status:** | Agreed | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide to the Multi-system Shipborne Radionavigation Unit data on the identity, location and other static characteristics of R-Mode Beacons required for positioning (collectively referred to herein as 'Beacon Static Data') for each R-Mode Beacon in the Ship's view. | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** | IALA ENAV WG3: Each Beacon should transmit information at least for itself and neighbouring Beacons.  S. Gewies (R-Mode Baltic): There is no need for a Beacon to transmit position / identity data for other Beacons. | | | | |

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| **Title:** | **Beacon Health** | | | | |
| **Identity:** | REQ-UT-2 | **Status:** | Agreed | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide to the Multi-system Shipborne Radionavigation Unit an indication of whether each R-Mode Station is being synchronized to the R-Mode Reference Time and is performing within specified thresholds. | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** | IALA R-Mode Workshop: Requirement should be disaggregated into two (or more) system requirements. | | | | |

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| **Title:** | **Beacon Signal Quality** | | | | |
| **Identity:** | REQ-UT-3 | **Status:** | Agreed | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide to the Multi-system Shipborne Radionavigation Unit (MSRU) statistical data on the quality of the R-Mode Transmitted RF Signal and the data it carries such that the MSRU can obtain a measure of accuracy and integrity of the position solution derived using R-Mode. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** | IALA ENAV WG3: This may include the estimated Beacon clock synchronization error and accuracy of the surveyed Beacon position projected into the range domain, fault probabilities to support RAIM, etc. | | | | |

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| **Title:** | **UTC Synchronization Data** | | | | |
| **Identity:** | REQ-UT-4 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide to the Multi-system Shipborne Radionavigation Unit (MSRU) supporting data (referred to herein as 'UTC Synchronization Data') to enable the MSRU to relate measurements made with respect to the R-Mode Reference Time to UTC. | | | | |
| **Source(s):** | IMO MSC.401(95) | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Downtime Notification** | | | | |
| **Identity:** | REQ-UT-6 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide to the Multi-system Shipborne Radionavigation Unit (MSRU) timely notifications of any planned service outages such that the MSRU can determine the likely impact of the outage on the continuity of the position solution. | | | | |
| **Source(s):** | ITU RR, 2016a | | | | |
| **Comments:** | GLA: Is there a need for other types of notification? | | | | |

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| **Title:** | **R-Mode Observables** | | | | |
| **Identity:** | REQ-UT-5 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide to the Multi-system Shipborne Radionavigation Unit (MSRU) R-Mode Observables such that the MSRU can estimate:  (i) the Ship's horizontal position (latitude, longitude) in accordance with the World Geodetic System revision 1984 (WGS84);  (ii) course over ground;  (iii) speed over ground; and  (iv) time, referenced to UTC, of the position solution.  For the purpose of this specification, it is assumed that R-Mode is the only source of ranging observables used by the MSRU. However, it is noted that in an actual deployment scenario, the R-Mode observables may be replaced, or complemented by, observables provided by other PNT systems, which may result in less (or more) stringent requirements on the R-Mode System than implied by this specification. | | | | |
| **Source(s):** | IMO MSC.401(95) | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Transmitted RF Signal** | | | | |
| **Identity:** | REQ-UT-7 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide a Transmitted RF Signal capable of being used for ranging and R-Mode Navigation Data transmission. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Cryptographic Service Request - Ship** | | | | |
| **Identity:** | REQ-UT-8 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall be capable of sending requests to the Multi-system Shipborne Radionavigation Unit for cryptographic material (such as public keys and certificates) required for the authentication of the R-Mode RF signal received at the ship. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Configuration and Control Command - Response** | | | | |
| **Identity:** | REQ-UT-9 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, upon receipt of a Configuration and Control Command from the Multi-system Shipborne Radionavigation Unit (MSRU), shall send a command response to the MSRU. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Monitoring Data** | | | | |
| **Identity:** | REQ-UT-10 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall send Monitoring Data generated by the shoreside system elements via the Wide Area Network to an R-Mode Monitoring and Control Station (MCS) located in the Monitoring and Control Centre.  The system may use several redundant MCS' installed at different locations. | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **System Monitoring Results** | | | | |
| **Identity:** | REQ-UT-11 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall display real-time System Monitoring Results to Operator - Monitoring & Control located in the Monitoring and Control Centre. | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Control Command (Output)** | | | | |
| **Identity:** | REQ-UT-12 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall be capable of sending Control Commands from a Monitoring and Control Station located in the Monitoring and Control Centre to other shoreside system elements via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Control Command - Response (Output)** | | | | |
| **Identity:** | REQ-UT-13 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, upon receipt of a Control Command via the Wide Area Network (WAN), shall send a command response to the issuer via the WAN. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Control Input - Feedback** | | | | |
| **Identity:** | REQ-UT-14 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, upon receipt of Control Input from Operator - Monitoring and Control, shall provide feedback to the operator on whether the requested control operation has been successfully completed. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Monitoring Results - Local** | | | | |
| **Identity:** | REQ-UT-15 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall display real-time monitoring results for a shoreside system element to Operator - Field Engineer (co-located with the system element being monitored). | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Control Input - Local - Feedback** | | | | |
| **Identity:** | REQ-UT-16 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, upon receipt of Control Input - Local from Operator - Field Engineer, shall provide feedback to the operator (co-located with the system element being controlled) on whether the requested control operation has been successfully completed. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Configuration Command - Remote (Output)** | | | | |
| **Identity:** | REQ-UT-17 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall be capable of sending remote configuration commands to the shoreside system elements via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Configuration Command - Remote - Response (Output)** | | | | |
| **Identity:** | REQ-UT-18 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, upon receipt of a configuration command via the Wide Area Network (WAN), shall send a command response to the issuer via the WAN. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Cryptographic Service Request** | | | | |
| **Identity:** | REQ-UT-19 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall be capable of sending requests, via the Wide Area Network, to the Cryptographic Server for cryptographic material (such as private/public keys and certificates) required for signing the Transmitted RF Signal and verifying the authenticity of the received R-Mode RF signal. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Configuration Input - Local - Feedback** | | | | |
| **Identity:** | REQ-UT-20 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, upon receipt of Configuration Input - Local from Operator - System Administrator, shall provide feedback to the operator (collocated with the system element being controlled) on whether the requested configuration operation has been successfully completed. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Title:** | **Configuration Input - Remote - Feedback** | | | | |
| **Identity:** | REQ-UT-21 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, upon receipt of Configuration Input - Remote from Operator - System Administrator, shall provide feedback to the operator on whether the requested control operation has been successfully completed. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** | GLA: Consider whether the System Administrator needs to be able to perform the remote configuration operations from any system element or only from certain location(s). | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **e-Navigation Service Response** | | | | |
| **Identity:** | REQ-UT-22 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, on receipt of an e-Navigation Service Request from the e-Navigation Service Client, shall provide an e-Navigation Service Response to the client via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

#### Input Requirements

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| **Title:** | **Synchronization Reference Signals** | | | | |
| **Identity:** | REQ-UT-23 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept reference signals from the Multi-system Shipborne Radionavigation Unit (MSRU) allowing it to synchronize the shipborne system elements to the MSRU clock. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Configuration & Control Commands** | | | | |
| **Identity:** | REQ-UT-24 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept Configuration & Control Commands from the Multi-system Shipborne Radionavigation Unit. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Incident RF Signal - Ship** | | | | |
| **Identity:** | REQ-UT-25 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall receive R-Mode RF signals incident on the Ship. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Electrical Power - Ship** | | | | |
| **Identity:** | REQ-UT-26 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept electrical power from the Multi-system Shipborne Radionavigation Unit. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Cryptographic Service Response - Ship** | | | | |
| **Identity:** | REQ-UT-27 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept responses from the Multi-system Shipborne Radionavigation Unit to cryptographic service requests. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Monitoring Input - Monitoring and Control Centre** | | | | |
| **Identity:** | REQ-UT-28 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept inputs from Operator - Monitoring & Control, allowing the operator to perform monitoring functions (such as selecting monitoring results to be displayed and acknowledging alarms). | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Control Input - Monitoring and Control Centre** | | | | |
| **Identity:** | REQ-UT-29 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept inputs from Operator - Monitoring & Control, allowing the operator to control the operation of the shoreside system elements. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Control Command (Input)** | | | | |
| **Identity:** | REQ-UT-30 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept control commands sent via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Control Command - Response (Input)** | | | | |
| **Identity:** | REQ-UT-31 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept responses to control commands sent via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Monitoring Data** | | | | |
| **Identity:** | REQ-UT-32 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept monitoring data from the shoreside system elements sent via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Electrical Power - Shore** | | | | |
| **Identity:** | REQ-UT-33 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept electrical power from the facilities in which the shoreside system elements are installed. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Incident RF Signal - Beacon Site** | | | | |
| **Identity:** | REQ-UT-34 | **Status:** | Ready | **Priority:** | Low |
| **Text:** | The R-Mode System may receive RF signals within the R-Mode frequency band(s) incident on the R-Mode Beacon. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Incident RF Signal - Monitoring Site** | | | | |
| **Identity:** | REQ-UT-35 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall receive RF signals within the R-Mode frequency band(s) incident on the Far-field Monitoring Site. | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Monitoring Input - Local** | | | | |
| **Identity:** | REQ-UT-36 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept inputs from Operator - Field Engineer allowing the operator to perform monitoring functions on the shoreside system elements co-located with the operator. | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Control Input - Local** | | | | |
| **Identity:** | REQ-UT-37 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept inputs from Operator - Field Engineer allowing the operator to control the operation of the shoreside system elements co-located with the operator. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Configuration Input - Local** | | | | |
| **Identity:** | REQ-UT-38 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept inputs from Operator - System Administrator allowing the operator to configure the shoreside system elements co-located with the operator. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Configuration Input - Remote** | | | | |
| **Identity:** | REQ-UT-39 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept inputs from Operator - System Administrator allowing the operator to configure the shoreside system elements using commands sent via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** | GLA: Consider whether the System Administrator needs to be able to perform the remote configuration operations from any system element or only from certain location(s). | | | | |

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| **Title:** | **Configuration Command - Remote (Input)** | | | | |
| **Identity:** | REQ-UT-40 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept configuration commands sent via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Configuration Command - Remote - Response (Input)** | | | | |
| **Identity:** | REQ-UT-41 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept responses to configuration commands sent via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **R-Mode Reference Time Signal** | | | | |
| **Identity:** | REQ-UT-42 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept a reference signal from the Time Transfer System allowing it to synchronize the shoreside system elements to the R-Mode Reference Time. | | | | |
| **Source(s):** | R-Mode Baltic, 2019a | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Cryptographic Service Response - Shore** | | | | |
| **Identity:** | REQ-UT-43 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept responses to cryptographic service requests sent by the Cryptographic Server via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **e-Navigation Service Request** | | | | |
| **Identity:** | REQ-UT-44 | **Status:** | Ready | **Priority:** | Low |
| **Text:** | The R-Mode System should, as a goal, accept e-Navigation Service Requests sent from the e-Navigation Service Client via the Wide Area Network. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

#### System Functions

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| **Title:** | **Transmitted RF Signal Function** | | | | |
| **Identity:** | REQ-UT-45 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept the following inputs:  (i) Electrical Power - Shore; and  (ii) R-Mode Reference Time Signal,  and produce the following output:  (i) Transmitted RF Signal.  The R-Mode System may also accept:  (i) Incident RF Signal - Beacon. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Navigation Data and Observables Function** | | | | |
| **Identity:** | REQ-UT-46 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept the following inputs:  (i) Electric Power - Ship;  (ii) Synchronization Reference Signals;  (iii) Configuration & Control Commands;  (iv) Incident RF Signals - Ship;  (v) Cryptographic Service Response - Ship,  and produce the following outputs:  (i) Configuration & Control Command - Response;  (ii) R-Mode Navigation Data (i.e. Beacon Static Data; Beacon Health; Beacon Signal Quality; UTC Synchronization Data; Downtime Notifications);  (iii) R-Mode signal observables; and  (iv) Cryptographic Service Request - Ship. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **System Monitoring and Control Function** | | | | |
| **Identity:** | REQ-UT-47 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept the following inputs:  (i) Electrical Power - Shore;  (ii) Incident RF Signal - Monitoring Site;  (iii) Monitoring Data;  (iv) Monitoring Input - Monitoring and Control Centre;  (v) Monitoring Input - Local;  (vi) Control Input - Monitoring and Centrol Centre;  (vii) Control Input - Local  (viii) Control Command (Input);  (ix) Control Command - Response (Input),  and produce the following outputs:  (i) Monitoring Data;  (ii) Monitoring Results;  (iii) Monitoring Results - Local;  (iv) Control Command (Output);  (v) Control Command - Response (Output);  (vi) Control Input - Feedback; and  (vii) Control Input - Local - Feedback;  The R-Mode System may also accept the following inputs:  (i) Incident RF Signal - Beacon Site;  (ii) R-Mode Reference Time Signal. | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **System Configuration Function** | | | | |
| **Identity:** | REQ-UT-48 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall accept the following inputs:  (i) Electrical Power - Shore;  (ii) Configuration Input - Local;  (iii) Configuration Input - Remote;  (iv) Configuration Command - Remote (Input);  (v) Configuration Command - Remote - Response (Input);  (vi) Cryptographic Service Response - Shore,  and produce the following outputs:  (i) Configuration Input - Local - Feedback;  (ii) Configuration Input - Remote - Feedback;  (iii) Configuration Command - Remote (Output);  (iv) Configuration Command - Remote - Response (Output);  (v) Cryptographic Service Request. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **e-Navigation Service Function** | | | | |
| **Identity:** | REQ-UT-49 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System, on receipt of the following inputs:  (i) Electrial Power - Shore; and  (ii) e-Navigation Service Request,  shall output:  (i) e-Navigation Service Response. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

### Coverage Requirements

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| **Title:** | **Coverage - Coastal Waters** | | | | |
| **Identity:** | REQ-UT-50 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall support navigation in coastal waters. | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Coverage - Port Approach** | | | | |
| **Identity:** | REQ-UT-51 | **Status:** | Ready | **Priority:** | High |
| **Text:** | The R-Mode System should, as a goal, support navigation in port approaches, restricted waters and inland waterways. | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** | IALA ENAV WG3: There is no common, accepted, definition of where the boundary is between coastal waters and port approach.  Search IMO SOLAS, Reg. V, and Circulars. | | | | |

### Performance Requirements

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| **Title:** | **Positioning Accuracy - Coastal Waters** | | | | |
| **Identity:** | REQ-UT-52 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in coastal waters within the Service Area, the R-Mode System shall provide Navigation Data and signal observables such that the R95 Accuracy of the position solution estimated by the Multi-system Shipborne Radionavigation Unit is at most 100 m. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Positioning Integrity - Coastal Waters** | | | | |
| **Identity:** | REQ-UT-53 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in coastal waters within the Service Area, the R-Mode System shall provide Navigation Data and signal observables such that the Integrity Risk of the position solution estimated by the Multi-system Radionavigation Shipborne Unit is at most 1e-4 over a period of 3 hours, with a Horizontal Alert Limit (HAL) of 250 m. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** | GLA: The continuity requirement uses a time interval of 15 minutes. For compatibility reasons, it may be beneficial to use the same time interval for both the integrity and continuity requirements. | | | | |

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| **Title:** | **Time to Alarm - Coastal Waters** | | | | |
| **Identity:** | REQ-UT-54 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in coastal waters within the Service Area, the R-Mode System shall provide Beacon Health data in such a manner that the Multi-system Shipborne Radionavigation Unit can warn the Ship's crew of a system fault within 30 seconds of the fault occurring. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** | GLA: IMO A.1046 requires 10 sec time to alarm in coastal waters. | | | | |

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| **Title:** | **Positioning Availability** | | | | |
| **Identity:** | REQ-UT-55 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used within the Service Area, the R-Mode System shall provide Navigation Data and Observables such that the Positioning Availability of the position solution estimated by the Multi-system Shipborne Radionavigation Unit is at least 99%. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Position Fix Interval - Coastal Waters** | | | | |
| **Identity:** | REQ-UT-56 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in coastal waters within the Service Area, the R-Mode System shall provide fresh R-Mode signal observables to the Multi-system Shipborne Radionavigation Unit at least once every 15 seconds. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** | GLA: Note also that IMO MSC.401(95) states that the MSR should:  ‘Be capable of generating a new PVT solution at least once every 0.5 s for high-speed craft (HSC) […] and at least once every 1 s for conventional vessels;  ’Provide a caution if after 2 s for HSC or 3 s for conventional vessels, equipment is unable to assess the current achieved performance (e.g. accuracy and integrity) with respect to each navigation phase; and  ‘Provide a warning, if after 5 s for HSC or 7 s for conventional vessels, new PVT data has not been calculated.’  This specification adopts the less stringent requirement of IALA R-129. | | | | |

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| **Title:** | **Positioning Accuracy - Port Approach** | | | | |
| **Identity:** | REQ-UT-57 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in port approaches, restricted waters and inland waterways within the Service Area, the R-Mode System shall provide Navigation Data and signal observables such that the R95 Accuracy of the position solution estimated by the Multi-system Shipborne Radionavigation Unit is at most 10 m. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Positioning Integrity - Port Approach** | | | | |
| **Identity:** | REQ-UT-58 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in port approaches, restricted waters or inland waterways within the Service Area, the R-Mode System shall provide Navigation Data and signal observables such that the Integrity Risk of the position solution estimated by the Multi-system Radionavigation Shipborne Unit is at most 1e-4 over a period of 3 hours, with a Horizontal Alert Limit (HAL) of 25 m. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** | GLA: The continuity requirement 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. | | | | |

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| **Title:** | **Time to Alarm - Port Approach** | | | | |
| **Identity:** | REQ-UT-59 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in port approaches, restricted waters or inland waterways within the Service Area, the R-Mode System shall provide Beacon Health data in such a manner that the Multi-system Shipborne Radionavigation Unit can warn the Ship's crew of a system fault within 10 seconds of the fault occurring. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Positioning Continuity - Port Approach** | | | | |
| **Identity:** | REQ-UT-60 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in port approaches, restricted waters or inland waterways within the Service Area, the R-Mode System shall provide Navigation Data and signal observables such that the Positioning Continuity of the position solution estimated by the Multi-system Shipborne Radionavigation Unit is at least 99.97% over a time interval of 15 minutes. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Position Fix Interval - Port Approach** | | | | |
| **Identity:** | REQ-UT-61 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used for navigation in port approaches, restricted waters or inland waterways within the Service Area, the R-Mode System shall provide fresh R-Mode signal observables to the Multi-system Shipborne Radionavigation Unit at least once every 2 seconds. | | | | |
| **Source(s):** | IALA R-129, 2012 | | | | |
| **Comments:** | GLA: Note also that IMO MSC.401(95) states that the MSR should:  ‘Be capable of generating a new PVT solution at least once every 0.5 s for high-speed craft (HSC) […] and at least once every 1 s for conventional vessels;  ’Provide a caution if after 2 s for HSC or 3 s for conventional vessels, equipment is unable to assess the current achieved performance (e.g. accuracy and integrity) with respect to each navigation phase; and  ‘Provide a warning, if after 5 s for HSC or 7 s for conventional vessels, new PVT data has not been calculated.’  This specification adopts the less stringent requirement of IALA R-129. | | | | |

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| **Title:** | **Cold Start** | | | | |
| **Identity:** | REQ-UT-62 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide in each minute all data required for a "cold start" of the R-Mode Sensor. | | | | |
| **Source(s):** |  | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Capacity - Goal** | | | | |
| **Identity:** | REQ-UT-63 | **Status:** | Ready | **Priority:** | High |
| **Text:** | The R-Mode System should, as a goal, allow an unlimited number of ships to use the system simultaneously.  The system capacity may be limited if using active ranging. | | | | |
| **Source(s):** | IMO A.1046(27); R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **UTC Accuracy** | | | | |
| **Identity:** | REQ-UT-88 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | When used within the Service Area, the R-Mode System shall provide Navigation Data and signal observables such that the Multi-system Shipborne Radionavigation Unit can estimate the time of the position solution, referenced to UTC, to one tenth of one second. | | | | |
| **Source(s):** | IMO MSC.401(95) | | | | |
| **Comments:** | GLA: What exactly is meant by 'to one tenth of one second'? | | | | |

### External Interface Requirements

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| **Title:** | **Mounting Interface - Ship** | | | | |
| **Identity:** | REQ-UT-64 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide a mechanical interface to enable the mounting of the shipborne system elements external to the Multi-system Shipborne Radionavigation Unit (such as the R-Mode antennas) on a maritime vessel. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Housing Interface - Ship** | | | | |
| **Identity:** | REQ-UT-65 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide a mechanical interface to enable the installation of the shipborne system elements internal to the Multi-system Shipborne Radionavigation Unit (MSRU) within the MSRU. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Mounting Interface - Shore** | | | | |
| **Identity:** | REQ-UT-66 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide mechanical interfaces to enable the mounting of the shoreside system elements at the shoreside facilities (Beacon Site; Monitoring SIte; Monitoring and Control Centre). | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **e-Navigation Service API** | | | | |
| **Identity:** | REQ-UT-67 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall provide an Application Programming Interface (API) for e-Navigation Services compliant with IALA Guideline 1128, 'The Specification of e-Navigation Technical Services'. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Communication Protocols - Goal** | | | | |
| **Identity:** | REQ-UT-68 | **Status:** | Ready | **Priority:** | High |
| **Text:** | The R-Mode System should, as a goal, use standardized communication protocols for interfacing (such as those defined by IEC 61162). | | | | |
| **Source(s):** | IMO MSC.1/Circ.1575 | | | | |
| **Comments:** |  | | | | |

### External Resource Utilization Requirements

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Shoreside Infrastructure** | | | | |
| **Identity:** | REQ-UT-69 | **Status:** | Ready | **Priority:** | High |
| **Text:** | The R-Mode System should, as a goal, make use of pre-existing shoreside infrastructure. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **VDES Channels** | | | | |
| **Identity:** | REQ-UT-70 | **Status:** | Ready | **Priority:** | Medium |
| **Text:** | Where the R-Mode System uses VDES, the system should operate on the VDE-TER frequency channels. | | | | |
| **Source(s):** | IALA ENAV, 2018 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **VDES Data Link Loading** | | | | |
| **Identity:** | REQ-UT-71 | **Status:** | Ready | **Priority:** | High |
| **Text:** | Where the R-Mode System uses VDES, the system should use at most 8% of the total VDES data link capacity (understood to mean 2250 time slots per 60 seconds) on any given VDES frequency channel. | | | | |
| **Source(s):** | GLA, 2019; IALA ENAV, 2018 | | | | |
| **Comments:** |  | | | | |

### Environmental Requirements

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| **Title:** | **System Initialization in GNSS-nominal Environment** | | | | |
| **Identity:** | REQ-UT-72 | **Status:** | New | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall meet all other requirements specified herein within TBD hours after the time electrical power is applied to the shoreside and shipborne system elements and the shoreside system elements have been subjected to the GNSS-nominal Environment. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **GNSS-disrupted Environment at Ship** | | | | |
| **Identity:** | REQ-UT-73 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall continue to meet all other requirements specified herein while the shoreside system elements are operated in the GNSS-nominal Environment and the shipborne system elements are subjected to the GNSS-disrupted Environment. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **GNSS-disrupted Environment at Shore** | | | | |
| **Identity:** | REQ-UT-74 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall continue to meet all other requirements specified herein for a period of at least 2 hours from the time the shoreside system elements are subjected to the GNSS-disrupted Environment (regardless of the GNSS service performance at the Ship). | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** | GLA: R-Mode as a contingency system. | | | | |

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| **Title:** | **GNSS-disrupted Environment at Shore - Goal** | | | | |
| **Identity:** | REQ-UT-75 | **Status:** | Ready | **Priority:** | Medium |
| **Text:** | The R-Mode System should, as a goal, continue to meet all other requirements specified herein while the shoreside system elements are operated in the GNSS-disrupted Environment (regardless of the GNSS service performance at the Ship). | | | | |
| **Source(s):** | IALA ARM, 2018 | | | | |
| **Comments:** | GLA: R-Mode as a backup system. | | | | |

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Ship Dynamics** | | | | |
| **Identity:** | REQ-UT-76 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall meet all other requirements specified herein during static and dynamic ship operations (TBD). | | | | |
| **Source(s):** | IMO MSC.401(95) | | | | |
| **Comments:** | IALA ENAV WG3: One critical issue with this respect is the measurement update rate.  GLA: MSC.401(95) does not define the term ‘dynamic operations’ but states that: ‘Receiver equipment, capable of combining measurements from multiple GNSS and an optional terrestrial radionavigation system, with or without augmentation, to form a single resilient PVT solution, can be used for navigation purposes on ships of speeds not exceeding 70 knots.’ | | | | |

### Other System Qualities

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| **Title:** | **Interoperability** | | | | |
| **Identity:** | REQ-UT-77 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall be interoperable with other terrestrial PNT systems (such as eLoran). | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** | IALA ENAV WG3: If possible, using the same time base, geodetical coordinate systems, etc. | | | | |

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| **Title:** | **RF Signal Security** | | | | |
| **Identity:** | REQ-UT-78 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall be designed to consider cyber-attacks (including jamming and spoofing) so that such events can be detected and their effects mitigated. | | | | |
| **Source(s):** | IALA ENG, 2018 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Self-testability** | | | | |
| **Identity:** | REQ-UT-79 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall support self-testability. | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** | GLA: This may need some clarification. | | | | |

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| **Title:** | **User Security** | | | | |
| **Identity:** | REQ-UT-80 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall allow only authorized users access to the System Monitoring and Control Function and System Configuration Function. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

### Regulatory Requirements

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **ITU Radio Regulations** | | | | |
| **Identity:** | REQ-UT-81 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall be designed and operated in accordance with ITU Radio Regulations, Article 28. | | | | |
| **Source(s):** | ITU RR, 2016 | | | | |
| **Comments:** | IALA ENAV WG3: 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.  THE MF Beacon frequency band already has a radionavigation allocation. | | | | |

### Design and Construction Requirements

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| **Title:** | **MF R-Mode** | | | | |
| **Identity:** | REQ-UT-82 | **Status:** | Ready | **Priority:** | Medium |
| **Text:** | The R-Mode System should use the IALA Marine Beacon DGPS System for the ranging signal and Navigation Data transmission (noting that this may require modifications to some components of the MB DGPS System). | | | | |
| **Source(s):** | R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **VHF R-Mode** | | | | |
| **Identity:** | REQ-UT-83 | **Status:** | Ready | **Priority:** | Medium |
| **Text:** | The R-Mode System should use the VHF Data Exchange System for the ranging signal and Navigation Data transmission (noting that this may require modifications to some components of the VDES). | | | | |
| **Source(s):** | GLA, 2019; R-Mode Baltic, 2019 | | | | |
| **Comments:** |  | | | | |

### Trade-off Requirements

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| **Title:** | **Weighting** | | | | |
| **Identity:** | REQ-UT-84 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall use the value aggregation algorithm and value weights defined in the Objectives Hierarchy section of this document. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Value Curves** | | | | |
| **Identity:** | REQ-UT-85 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The value curves for the bottom-level attributes in the objectives hierarchy are to be determined. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

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| **Title:** | **Trade-off Objective** | | | | |
| **Identity:** | REQ-UT-86 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The R-Mode System shall achieve the highest overall value among all candidate system designs. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

## Refinement Phase

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| --- | --- | --- | --- | --- | --- |
| **Title:** | **Applicability of Utilization Phase Requirements** | | | | |
| **Identity:** | REQ-RF-1 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | During the Refinement Phase, the R-Mode System shall meet all requirements specified in the Utilization Phase section of this document, unless otherwise stated in this section. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

## Retirement Phase

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| **Title:** | **Retirement Phase Requirements** | | | | |
| **Identity:** | REQ-RT-1 | **Status:** | Ready | **Priority:** | Mandatory |
| **Text:** | The requirements for the Retirement Phase are to be determined. | | | | |
| **Source(s):** | GLA, 2019 | | | | |
| **Comments:** |  | | | | |

1. Use Case Scenarios for the Utilization Phase

This annex provides example scenarios for the R-Mode System use cases identified in Section 7. Only the main flow of events has been defined for each use case at this point; alternate / exception event flows may be explored at a later stage.

Note: In the following, the term ‘shoreside system elements’ is considered to include R-Mode Beacons that may be installed on off-shore platforms.

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| **Use Case:** | **Use Ranging Services** |
| **Identity:** | UCD-7.1 |
| **Pre-conditions:** | The R-Mode System has received a command from the MSRU instructing it to start a Ranging Service (e.g. MF Beacon Ranging Service, VDES Passive Ranging Service). |
| **Main Flow of Events:** | The R-Mode System outputs Ranging Service data for the requested service(s) to the MSRU until it receives a command from the MSRU instructing it to stop the service. |
| **Post-conditions:** | The R-Mode System has stopped outputting Ranging Service data to the MSRU. |

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| **Use Case:** | **Configure & Control Shipborne System Elements** |
| **Identity:** | UCD-7.2 |
| **Pre-conditions:** | The R-Mode System has received a configuration and control command from the MSRU. |
| **Main Flow of Events:** | The R-Mode System processes the received command, executes the requested operation(s) and returns a response to the MSRU, including an indication of whether the operation has been successful. Example commands include: (i) Start Ranging Service; and (ii) Stop Ranging Service. |
| **Post-conditions:** | The command has been processed and a response has been returned to the MSRU. |

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| **Use Case:** | **Authenticate User** |
| **Identity:** | UCD-7.3 |
| **Pre-conditions:** | User is authorized to access the R-Mode System. |
| **Main Flow of Events:** | The R-Mode System prompts the User for authentication information;  User provides authentication information;  The R-Mode System determines whether the authentication information is valid. |
| **Post-conditions:** | Minimum Guarantees:  The R-Mode System has determined whether the User has provided valid authentication information.  Success Guarantees:  The R-Mode System has determined the identity of the User and their privileges within the system;  User has been informed of a successful authentication. |

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| **Use Case:** | **Monitor System Performance** |
| **Identity:** | UCD-7.4 |
| **Pre-conditions:** | Operator - Monitoring & Control is authorized to perform monitoring operations within the R-Mode System and has successfully authenticated to the system. |
| **Main Flow of Events:** | The R-Mode System provides near real-time information to Operator - Monitoring & Control on the R-Mode signal quality and other system performance characteristics (to be determined at a later stage) selectable by the operator;  Operator - Monitoring & Control logs out of the R-Mode System. |
| **Post-conditions:** | Operator - Monitoring & Control has been logged out of the R-Mode System. |

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| **Use Case:** | **Control Shoreside System Elements - Remote** |
| **Identity:** | UCD-7.5 |
| **Pre-conditions:** | Operator - Monitoring & Control is authorized to perform control operations within the R-Mode System and has successfully authenticated to the system. |
| **Main Flow of Events:** | Operator - Monitoring & Control issues a control command to the R-Mode System;  The R-Mode System processes the command, executes the requested operation(s) and provides feedback to Operator - Monitoring & Control indicating whether the operation has been successful;  Example commands include: (i) Set up a Beacon Down-time Announcement; (ii) Stop Beacon Transmission; and (iii) Start Beacon Transmission;  Operator - Monitoring & Control logs out of the R-Mode System. |
| **Post-conditions:** | Operator - Monitoring & Control has been logged out of the R-Mode System. |

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| **Use Case:** | **Monitor Shoreside System Elements - Local** |
| **Identity:** | UCD-7.6 |
| **Pre-conditions:** | Operator - Field Engineer has physical access to the R-Mode System element to be monitored (such as an R-Mode Beacon or a Far-field Monitoring Station);  Operator - Field Engineer is authorized to perform monitoring operations within the R-Mode System and has successfully authenticated to the system. |
| **Main Flow of Events:** | The R-Mode System provides near real-time information to Operator - Field Engineer on selected performance characteristics (to be determined at a later stage) of the R-Mode System element being monitored;  Operator - Field Engineer logs out of the R-Mode System. |
| **Post-conditions:** | Operator - Field Engineer has been logged out of the R-Mode System. |

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| **Use Case:** | **Control Shoreside System Elements - Local** |
| **Identity:** | UCD-7.7 |
| **Pre-conditions:** | Operator - Field Engineer has physical access to the R-Mode System element to be controlled (such as an R-Mode Beacon or a Far-field Monitoring Station);  Operator - Field Engineer is authorized to perform monitoring operations within the R-Mode System and has successfully authenticated to the system. |
| **Main Flow of Events:** | The Operator - Field Engineer issues a control command to the R-Mode System element to be controlled;  The R-Mode System processes the command, executes the requested operation(s) and provides feedback to Operator - Field Engineer indicating whether the operation has been successful;  Example commands include: (i) Stop Beacon Transmission; and (ii) Start Beacon Transmission;  Operator - Field Engineer logs out of the R-Mode System. |
| **Post-conditions:** | Operator - Field Engineer has been logged out of the R-Mode System. |

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| **Use Case:** | **Configure Shoreside System Elements - Remote** |
| **Identity:** | UCD-7.8 |
| **Pre-conditions:** | Operator - System Administrator does not have physical access to the R-Mode System element to be configured;  Operator - System Administrator is authorized to perform configuration operations within the R-Mode System and has successfully authenticated to the system. |
| **Main Flow of Events:** | Operator - System Administrator selects the R-Mode System element to be configured;  Operator - System Administrator issues a configuration command to the R-Mode System element to be configured (the configurable system parameters will be determined at a later stage);  The R-Mode System processes the command, executes the requested operation(s) and provides feedback to Operator - System Administrator indicating whether the operation has been successful;  Operator - System Administrator logs out of the R-Mode System. |
| **Post-conditions:** | Operator - System Administrator has been logged out of the R-Mode System. |

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| **Use Case:** | **Configure Shoreside System Elements - Local** |
| **Identity:** | UCD-7.9 |
| **Pre-conditions:** | Operator - System Administrator has physical access to the R-Mode System element to be configured, is authorized to perform configuration operations within the R-Mode System and has successfully authenticated to the system. |
| **Main Flow of Events:** | Operator - System Administrator issues a configuration command to the R-Mode System element to be configured (the configurable system parameters will be determined at a later stage);  The R-Mode System processes the command, executes the requested operation(s) and provides feedback to Operator - System Administrator indicating whether the operation has been successful;  Operator - System Administrator logs out of the R-Mode System. |
| **Post-conditions:** | Operator - System Administrator has been logged out of the R-Mode System. |

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| **Use Case:** | **Provide R-Mode e-Navigation Services** |
| **Identity:** | UCD-7.10 |
| **Pre-conditions:** | The R-Mode System has received an R-Mode e-Navigation Service request from an e-Navigation Client and (where applicable) has successfully authenticated the client. |
| **Main Flow of Events:** | The R-Mode System processes the received request, executes the requested operation(s) and returns a response to the e-Navigation Client. Examples of information that may be requested includes: (i) R-Mode System configuration parameters, including the service area and predicted performance; (ii) R-Mode Beacon signal quality data; and (iii) Real-time system status. The same request-response mechanism could also be used to send information from the client to the R-Mode System - information such as reports of an R-Mode service outage or issue. |
| **Post-conditions:** | R-Mode e-Navigation Service data has been exchanged between the R-Mode System and the e-Navigation Client. |

1. Modelling Conventions
2. IDEF0

IDEF0 is part of the ICAM Definition for Function Modelling (where ICAM stands for Integrated Computer Aided Manufacturing) family of modelling languages, used to produce a structured representation of the functions, activities or processes within a system or subject area.

IDEF0 defines two basic semantical elements: functions and flows (of resources, energy or information).

A function is a transformation that turns inputs into outputs, represented by a box annotated with a verb-noun phrase and a number which provides context within the model.

A flow is represented by an arrow or an arc labelled by a noun phrase. The label represents the items being passed to/from the function to which the flow is attached.

Inputs enter the function box from the left, controls that guide the transformation of inputs into outputs enter from the top, mechanisms (physical resources that perform the function) enter from the bottom and outputs leave from the right, as illustrated in the diagram below.

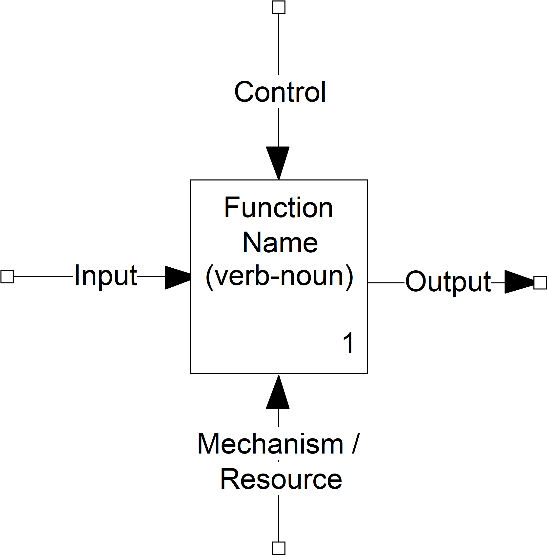


Figure 11 - IDEF0 Box format.

For clarity, the number of functions in an IDEF0 diagram should not exceed five or six. An IDEF0 diagram thus usually represents a particular viewpoint from which the system is observed rather than the system in its entirety.

For more information on IDEF0, see for example the IEEE 31320-1-2012 standard.