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| From: e-NAV Committee | e-NAV12/output/4 |
| To: Co-ordinator of IMO Correspondence Group on e-Navigation | 28 September 2012 |

Liaison Note

Draft report of the IMO Correspondence Group on e-Navigation

# Introduction

The IALA e-Navigation Committee reviewed the most recent (September 2012) report of the IMO Correspondence Group (CG) on e-Navigation (input paper to e-NAV12, e-NAV12/81 refers) which contains the “post IMO NAV 58” tables on Risk Control Options, Potential Solutions, and Examples of Maritime Service Portfolios.

# Discussion

The committee has made a number of editorial changes and comments, which are contained (in track changes). These are forwarded separately as e-NAV12/output/5. The majority of editorial suggestions pertain to Annex 2 “Preliminary List of Potential e-Navigation Solutions” as it is recognised that these proposed solutions will be subject to risk and cost benefit analyses.

Also attached at Annex A, is information on the resilience of PNT to aid the identification of risks and cost-benefits of proposed solutions (as required by the IMO strategy development plan).

With respect to Annex 4 “Examples of Maritime Service Portfolios”, the Committee recognised that these were recently-developed examples and needed further development in the future. Therefore, only a brief scan was undertaken by the committee. However, a few comments were noted:

1. It was noted that the MSPs listed in Annex 4 were just examples at this time and need further development in terms of scope and detail.
2. It was noted that IALA is currently developing the concept of MSPs in support of the IMO e-Navigation concept.
3. It was noted that there was no MSP for Aids to Navigation (AtoN) as yet, and that IALA could contribute in this area.
4. With reference to MSP 8 (Digital Information Exchange with Portable Pilot Units), there was some controversy. The strategic level of this issue seemed out of line when compared with the other MSPs. It was noted that MSP 8 might be better placed within MSP 6 (Pilotage Service). Additionally, the description declared PPUs as *“an essential tool for safe navigation in clear and restricted visibility”* - which they are not, nor is it a tool for information exchange from ship to shore. However, it was also noted that the PPU maybe be further developed in future. The Committee further noted that there had been a number of inputs from pilots (including from IMPA) directly to the CG Co-ordinator (Norway), expressing their views on this issue. The committee recognised that the use of PPUs could enhance safety in specified areas and their use of accurate and reliable data was within the concept of e-Navigation (but needed to be defined more thoroughly).

The following statement was made by Jean-Daniel Gilles, French Federation of Maritime Pilot / IMPA, about Annex 4, MSP8 of the report of the CG

*Beyond the comments and discussions that have been made during the working sessions during this e-NAV session, IMPA considers that PPUs should not be mentioned in the Maritime Service Portfolios, first because it is not a shore based service, but an equipment used on board by the pilot for certain pilotage assignments, and second because its inclusion in the Annex 4 is not in relation to any previous work of the CG*.

# Action requested

The Co-ordinator of the IMO Correspondence Group on e-Navigation is requested to consider the comments provided by the IALA e-Navigation Committee (contained in this cover note and at Annex A and separately in e-NAV12/output/5) and decide as appropriate.

1. EXAMPLE SYSTEMS THAT MAY PROVIDE A POTENTIAL SOLUTION TO THE IMO e-NAVIGATION GAP ANALYSIS

The IALA e-NAV Committee has considered in detail one item on the list, solution S3.4, as detailed in the table below.

Table 1: Extracted GAP from the IMO GAP Analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Short description** | **Primary user need** | **User type** | **Other user needs** | **Hazard description** | **Origin** |
| **S3** | **Improved reliability, resilience**  **and integrity of bridge equipment**  **and navigation information** | | | | | |
| S3.4 | Improved reliability and resilience of on-board PNT systems by robust integration with alternative systems | Improved reliability, interoperability, efficiency, adaptability | Shipboard user | Improved, reusability, flexibility | Suboptimal performance or accident due to poor information from PNT systems. | 132-Gte01  132-Gre01 |

In order to fill this gap, it is first necessary to clarify what is meant by reliability and resilience. The definition of Reliability is extracted from the IALA dictionary, however resilience is not defined in the IALA dictionary, and the lose definition, based on the work within R-129 is used instead.

* Reliability - Ability of a device or system to satisfy the requirements of its intended use within defined limits, and for a stated period of time.
* Resilience - The ability of the PNT system to detect and compensate external and internal sources of disturbances, malfunction and breakdowns in parts of the system. This shall be achieved without loss of PNT data provision and preferably without degradation of their performance[[1]](#footnote-1).

Therefore, to put it simply, reliability is how well the system can complete its intended function within the normal operational limits, while resilience is the systems ability to overcome, or mitigate a failure or series of failures of different systems and signals.

The primary user needs identified in Table 1 can be addressed through the provision of reliability and resilience and WG2 have been working to clarify how systems can be made more resilient through the latest revision of R-129[[2]](#footnote-2), and how different systems can be integrated and provide the necessary level of system information through the development of the modular PNT approach and multi-system receiver performance standards.

R-129 on GNSS Vulnerabilities and Mitigation methods, introduces the concept of mitigation and also different types of alternative system, namely; fully redundant, backup and contingency[[3]](#footnote-3). A description of these is included in Annex A. Each can be defined as:

* 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.

Therefore to fill this gap, PNT information could be made more resilient through the provision of one or more alternative systems that meet the required performance; resulting in a reliable system.

The required performance, in terms of accuracy, integrity, continuity and availability has not been formally defined; however R-129 suggests initial figures for consideration (provided in Annex B).

To enable greater integration of PNT sensors, WG2 has also been working on a modular PNT approach to system architecture with the aim that PNT and other sensor information is passed to an integrated navigation system (INS), which then calculates the best result. Figure 1, extracted from e‑NAV11-output-19, provides an outline of the process.

The approach is being developed to meet the identified user needs, such as to improve reliability and should enable any receiver or system to be used as a sensor, thereby increasing interoperability. As Figure 1 shows, the data from a variety of PNT relevant sensors and other vessel systems would be passed to the PNT processing unit, within the INS.

* The combined use of the many sensors available exploits the available redundancy by processing raw data to generate the best PNT. The utilization of PNT relevant augmentation coming from different services, the integration of additional PNT relevant data sources (e.g. ePelorus, Racon), and the application of future PNT relevant MSI (Maritime Safety Information) is supported by this approach. By implementation of integrity monitoring the PNT unit has the potential to identify and provide the best PNT data and to indicate the current accuracy and integrity. Integrity information taking into account the achieved performance level is the basis for automatic reporting and improved alert management for individual sensors and the complete PNT process. At present the PNT unit is a concept for enhanced PNT data provision that would require the development of performance standards at a later stage. Today’s INS concept supports the integrated PNT approach. Such an approach will enable greater information exchange, mitigating for the hazard description outlined in Table 1.

In addition a draft performance standard for ship-borne receiving equipment using multiple [radionavigation] systems has been developed for consideration by the IMO. Such a receiver performance standard is required to enable the provision of the required data, along with the relevant integrity information, whilst also providing a generic receiver performance standard that can replace the legacy system specific receiver performance standards which are becoming antiquated.

A copy of the proposed multiple system receiver performance standard is included in Annex C, extracted from e-NAV12/15.

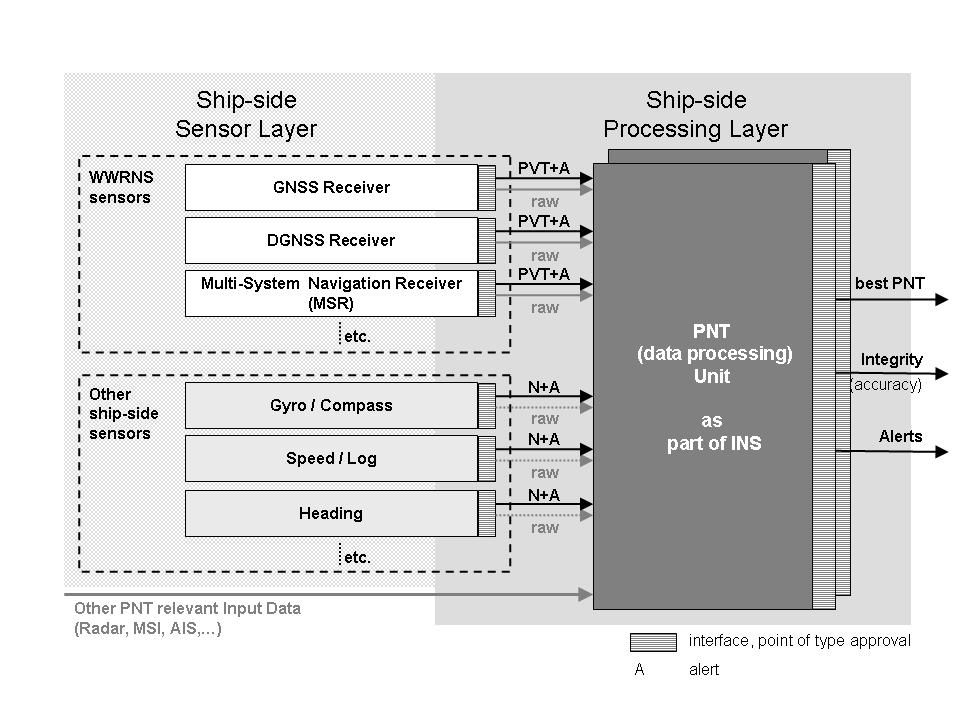


Figure 1: Ship-side PNT module with PNT (data processing) Unit

Conclusions

This paper provides some thoughts on how this gap can be addressed; however for a cost benefit analysis to be conducted it would be necessary to identify particular users, applications and the conditions they are to be performed under. This has not been addressed in this paper.

1. R-129 DESCRIPTIONS OF ALTERNATIVE SYSTEMS.

Alternative systems can be defined as:

* 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.

### Redundant System

Fully redundant systems should provide equivalent performance levels in terms of positioning and timing accuracy, integrity, availability and continuity. GLONASS represents a potential redundant system for GPS, with additional systems such as COMPASS and Galileo due to become operational by 2020.

It must also be noted that such similar systems may also have common failure modes. For example a jammer or interference source could deny multiple GNSS services, since it is very likely that the two systems will use the same frequency bands. It is also expected that most receivers will employ both systems; thus an attack on one may affect both. Counter-measures against jamming and interference are being developed and are likely to be quite effective by the time Galileo and later generations of GPS become operational.

### Backup Systems

Backup systems may include existing or planned terrestrial systems such as:

* Loran C;
* Enhanced Loran (eLoran);
* Radar and radar aids to navigation;
* Cellular telephone based systems;
* Ranging from DGNSS/AIS (R-Mode).

Loran is the only existing candidate as a terrestrial radionavigation alternative and provides a position sentence usable with electronic charting and other onboard systems. Loran provides independent position, navigation and timing with dissimilar failure modes to GNSS, however the coverage is limited. For example in European waters it is restricted at present to the north-western part, while in North America the decision was made to switch the service off in 2010, pending a decision on a backup for GPS. Loran receivers are not a required fit and very few vessels outside North American waters carry them.

eLoran has demonstrated comparable performance to GNSS[[4]](#footnote-4). In order to make eLoran into an effective redundant or backup system, receivers would need to be carried and there is little motivation for voluntary fitting of backup receiving equipment as long as GNSS continues to work well.

Although receivers for Loran are not a specific carriage requirement, they would be covered by the SOLAS Chapter V requirement for an Electronic Position Fixing System, suitable for the whole voyage, in the case of regional traffic. The current IEC test specification for the type approval of Loran receivers is based on out of date technology and may need to be revised.

Loran also has vulnerabilities to failure of onboard equipment or power supplies, damage to the ground infrastructure, loss of synchronisation due to interruption of communication systems and interference from ionospheric effects or power lines, which can carry both low frequency alternating current and higher frequency data signals.

Radar can be used for position-fixing, but it does not generally provide a compatible input to an electronic charting system; therefore different procedures are necessary for its use. However, radar is a required fit on SOLAS vessels and radar map-matching (echo referencing) techniques are well developed and used in waters such as the archipelagos between Sweden and Finland. The most serious limitation of radar as a backup is in areas with low-lying, featureless coastlines, for example in Europe those of Northern France, Belgium and the Netherlands or the East coast of England. In order to make radar a universal backup, such areas would need to be marked with sufficient radar aids to navigation.

This would not provide the same level of positioning service as Loran, nor would it give an alternative timing reference. However, this option could justify further investigation in regions where Loran is not a realistic option. Radar and radar beacons also have vulnerabilities to failure of equipment or power supplies, multipath, rain and sea clutter and masking effects.

Another possible backup in the future may be positioning using the Universal Mobile Telecommunications System (UMTS). This is the third generation cellular system and the first networks became operational in 2002. One of the main features of 3G cellular will be Location Based Services (LBS) in which location of the user will be achieved either by GNSS (vulnerable to the same failure modes as the ship’s GNSS receiver) or by systems that employ the cellular base-stations themselves. Such systems include cell identification (cell ID) and tri-lateration of signals at multiple base-stations. Deployment of such networks is likely to start with the more densely populated areas and coverage of coastlines is unlikely to be a priority; however, it may be possible to use multiple base-station techniques as a backup in some areas, such as estuaries. The use of these systems as a viable alternative has still to be proven; accuracy would not be as high as with GNSS and it is unlikely that such equipment would ever be type-approved for use on SOLAS vessels. These systems are likely to depend increasingly on GNSS for their timing and synchronisation, therefore they could be affected by any loss of GNSS. Cellular, radio and television signals could also be used within a Signals of Opportunity approach, where signals provided for alternative uses are used for ranging. While there are advantages of this approach, it is unlikely to achieve the level of service integrity required for navigation applications as the signals are provided for a different purpose and therefore may be altered or cease without notice.

Another possible future backup is the use of ranging signals from existing DGNSS or AIS infrastructure (R-Mode)[[5]](#footnote-5). Both systems have widespread distribution and maritime standards already exist for onboard equipment. The new functionality of R-Mode is the provision of timing information from shore to ship. The shipboard radio receiver may then calculate a distance (range) to the transmitter. Using several such calculations from a number of different transmissions, the shipboard equipment is able to calculate the ship position. R-mode is currently at the conceptual stage and factors such as coverage, geometry and interference would need to be investigated.

### Contingency Systems

The most obvious contingency system, allowing safe completion of a manoeuvre is the system of lights and buoys already provided in most parts of the world. Visual aids serve two specific functions, hazard-warning and position-fixing. They are not necessarily deployed in such a way as to allow for continuous navigation, except in the case of channel markers. Accuracy levels depend on the relative position of the visual aids and the scope of their movement in the case of floating marks, but accuracy could be expected to be considerably below that provided by GNSS. Visual (and radar) Aids to Navigation provide an essential alternative to GNSS although it is accepted that they are now rarely used as the primary means of position verification. They also form an essential safety function in physically marking hazards and in allowing the mariner to develop critical spatial and environmental awareness. These functions need to be borne in mind when users and service providers are assessing the continuing need for visual aids. It is considered essential that skills in the use of conventional aids to navigation should be maintained. Lights and buoys have limited visibility and achieving high levels of reliability represents a significant maintenance burden. In poor visibility and in the absence of Loran or radar, another system would be needed.

A future contingency system could be the inertial navigation system. These installations have previously been too expensive for non-military vessels, but lower cost devices with acceptable short-term performance are now becoming available. Integrated with a GNSS receiver, an inertial navigation system could provide continuity of service to electronic charts and autopilots, but only for a period limited by the rate of drift. It would be very important that the user was made aware of the change of position input from GNSS to an inertial navigation system and the consequent degradation with time in the confidence to be placed in positional accuracy.

Dead-reckoning is a contingency method of navigation. It relies on the use of onboard instruments, principally the compass and the log, for estimating speed and course and hence position. Accuracy depends on the quality of the last fix and degrades with time at a rate depending on the accuracy of the equipment and the sea and weather conditions.

Other onboard instruments can contribute to position-fixing, in particular the depth sounder, which is a mandatory fit on SOLAS vessels and very widely carried by non-SOLAS craft.

1. SUGGESTED MINIMUM MARITIME USER REQUIREMENTS FOR GENERAL NAVIGATION – BACKUP SYSTEM

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | System level parameters | | | | Service level parameters | | |  |
| Absolute Accuracy | Integrity | | | Availability  % per 30 days | Continuity  % over 15 minutes3 | Coverage | Fix interval (seconds) |
| Horizontal (metres) | Alert limit (metres) | Time to Alarm2 (seconds) | Integrity Risk (per 3 hours) |
| Ocean | 1000 | 2500 | 60 | 10-4 | 99 | N/A2 | Global | 60 |
| Coastal | 100 | 250 | 30 | 10-4 | 99 | N/A2 | Regional | 15 |
| Port approach and restricted waters | 10 | 25 | 10 | 10-4 | 99 | 99.97 | Regional | 2 |
| Port | 1 | 2.5 | 10 | 10-4 | 99 | 99.97 | Local | 1 |
| Inland Waterways | 10 | 25 | 10 | 10-4 | 99 | 99.97 | Regional | 2 |

* *Notes:* 1. This table is derived from IMO Resolution A.915(22).

*2.* Continuity is not relevant to ocean and coastal navigation

*3.* IMO Resolution A.1046(27) amended the Continuity Time Interval to 15 minutes, rather than 3 hours as originally required in IMO Resolution A.915(22).

4. This table should be read in conjunction with paragraph 2.1 and 2.2. Although these are suggested minimum requirements, a Risk Assessment will include many variables that may alter the minimum requirements. Refer to IALA Guideline on the Provision of Aids to Navigation for Different Classes of Vessels, including High Speed Craft, Dec. 2003 for details of the variables of different waterways, ships and environments

1. DRAFT PERFORMANCE STANDARD FOR SHIP-BORNE RECEIVING EQUIPMENT USING MULTIPLE [RADIONAVIGATION] SYSTEMS

**1 INTRODUCTION**

* 1. Global Navigation Satellite Systems such as Galileo, GLONASS, GPS and Compass are space-based positioning, velocity and time systems. Each GNSS space segment will normally be composed of up to 30 satellites, which may be deployed in several orbital planes. The spacing of satellites in orbit will normally be arranged so that a minimum of four satellites will be in view to users world-wide, with a position dilution of precision (PDOP) <6.
  2. Terrestrial Electronic Position Fixing Systems (EPFS) use ground-based transmitting stations. The signals can be processed in a similar way to those from GNSS, using times of arrival from at least three stations to establish a two-dimensional position.
  3. Augmentation systems use ground-based or satellite based transmitters to provide augmentation to improve accuracy and integrity for specific service areas (such as coastal and port).
  4. An integrated receiver, using a combination of signals from one or more GNSS and/or terrestrial EPFS, offers improved availability, integrity, accuracy and resistance to intentional and unintentional interference.
  5. Receiving equipment capable of combining individual measurements from a number of GNSS and/or terrestrial EPFS to form a single solution can be used for navigational purposes on ships of speeds not exceeding 70 knots. Such equipment should, in addition to the general requirements contained in resolution A.694(17)[[6]](#footnote-6), comply with the following minimum performance requirements.
  6. These standards cover the basic requirements of position-fixing, determination of course over ground (COG), speed over ground (SOG) and timing either for navigation purposes or as input to other functions.

1.7 The words “combined EPFS receiver equipment” as used in these performance standards include all the components and units necessary for the system to properly perform its intended functions. The equipment should include the following minimum facilities;

1. antennas capable of receiving GNSS and/or terrestrial EPFS signals;
2. GNSS and/or EPFS receiver and processor;
3. means of accessing the computed PVT data (latitude/longitude position, COG, SOG, timing, PVT source and navigational phase(s) that is currently supported[[7]](#footnote-7)) based on all available input data;
4. data control interface;
5. additional interface to enable the raw data from all available inputs to be interfaced to applications (such as Integrated Navigation Systems (INS)) for an enhanced assessment of provided PVT data; and
6. Alert management together with Bridge Alert Management (BAM) and INS.

2. **SENSOR REQUIREMENTS**

1. Antennas should be capable of receiving GNSS and/or terrestrial EPFS signals.
2. The antenna design should be suitable for fitting at a position on the ship which provides the best environment for the reception of GNSS and/or terrestrial EPFS signals.
3. The combined receiver should be designed to mitigate interference from out-of-band sources[[8]](#footnote-8).

### **3. OPERATIONAL REQUIREMENTS**

The combined EPFS receiver equipment should:

3.1 operate on at least one GNSS navigation signal provided in protected frequency band, carrying a range code (e.g. GPS: L1 and L5, GLONASS: L1, GALILEO: L1 and E5,…) with civil access.

3.2 be capable of receiving and processing GNSS in one or more protected frequency bands (e.g. L1, L5, E5…) and provide position information in latitude and longitude in a common worldwide geodetic reference system[[9]](#footnote-9) with co-ordinates in degrees and minutes to 4 decimal places.

3.3 have the facilities to process differential correction data fed to it, in accordance with the appropriate ITU-R Recommendations[[10]](#footnote-10);

3.4 be provided with means to transform the computed position into data compatible with the datum of the navigational chart in use. The display and/or any data output should indicate that the co‑ordinate conversion is being performed and should identify the co‑ordinate system in which the position is expressed;

3.5 given sufficient input sources, provide assessment of current achieved performance (e.g. accuracy and integrity) against each navigation phase simultaneously[[11]](#footnote-11). The unit should indicate when it is unable to provide such assessment.

3.6 be capable to provide COG in degrees to 2 decimal places, SOG in knots to 2 decimal places and timing information in UTC.

3.7 provide at least one output from which combined position information, COG, SOG, timing, PVT source and navigation phase for which performance requirements are met, to other equipment.

3.8 provide at least a second output from which raw data (e.g. code and carrier phase, navigation data, augmentation data) from the input sources can be supplied to other equipment.

3.9 Be capable of meeting the requirements for navigation under the various dynamic conditions that could be experienced onboard the vessel for the particular navigation phase in which the system is being used.

3.10 be capable of providing current PVT data within 15min of powering up;

3.11 be capable of providing current PVT data, within 2 min, when subjected to a power interruption or loss of signal of <60s.

3.12 meet the maritime user requirements for the appropriate navigation phase for the operation at hand, as detailed in A.915(22) and A.1046(27).

3.13 provide a means of autonomous integrity monitoring[[12]](#footnote-12).

3.14 The combined EPFS receiver equipment should provide as a minimum:

.1 a caution, should any of the following conditions exist for 3s for conventional vessel and 2s for high speed vessel:

.1.1 unable to estimate the supported navigation phase;

.1.2 new PVT data has not been calculated.

.2 If after 5s (high speed vessel) or 7s (conventional vessel) new PVT data has not been provided a warning shall be raised[[13]](#footnote-13).

.3 if at the next scheduled update, it is not possible to provide a new position update, the last known position, SOG, COG and the time of the last valid fix, with indication of this state so that no ambiguity can exist, should be output until normal operation is resumed.

.4 augmentation status indication of:

.1 the receipt of augmentation signals; and

.2 the validity of augmentation signals; and

.3 whether augmentations are being applied to the indicated ship’s position;

.4 provide the identification of the augmentation signals.

.5 provide position, COG, SOG, timing, PVT source, estimated navigation phase for which performance requirements are supported and augmentation text display either to a local display or interfaced to a separate display.

4. **INTERFACING AND TECHNICAL REQUIREMENTS**

The combined EPFS receiver equipment should:

4.1 generate a new position, COG and SOG at least once every 1s for conventional vessel and at least once every 0.5s for high-speed vessel. The update rate should be configurable.

4.2 provide a minimum resolution of position, i.e. latitude and longitude, in degrees and minutes to 4 decimal places.

4.3 provide COG in degrees to 2 decimal places, SOG in knots to 2 decimal places and timing information in UTC.

4.4 provide at least one output from which position information, COG, SOG, timing, PVT source and estimated navigation phase for which performance requirements are met can be supplied to other equipment.

4.5 output position, COG, SOG, timing, PVT source and estimated navigation phase for which performance requirements are supported in accordance with the relevant international standards[[14]](#footnote-14). For the VDR services, additional data on the multiple PVT sources applied should be provided.

4.6 provide at least a second output from which raw data (e.g. code and carrier phase, navigation data, augmentation data) from the applied radio navigation systems can be supplied to other equipment[[15]](#footnote-15).

4.7 have the facilities to take an input from at least one augmentation source[[16]](#footnote-16)

4.8 be capable of operating satisfactorily in typical L-band interference conditions.

4.9 ensure that no permanent damage can result from an accidental short circuit or grounding of the antenna or any of its input or output connections or any of the combined receiver equipment inputs or outputs for a duration of 5 min.

4.10 Provide an interface with the BAM or INS for alert management[[17]](#footnote-17).

4.11 provide at least one normally closed contact, which should indicate failure of the combined EPFS receiving equipment;

### **5 SYSTEM AND EQUIPMENT DOCUMENTATION**

5.1 Operating manuals that should contain:

1. An overall function description of the combined EPFS receiving equipment;
2. The redundancy concept and the availability of functions given the loss of one input;
3. A description of possible failures and their effects on the system (e.g. by using part of the failure analysis);
4. A statement on which navigation phases are supported;
5. A statement on which radio navigation systems and augmentations are supported;
6. Guidance for the adjustments of the navigation phase requirements;
7. An explanation of the method used for the applied indicators and thresholds;
8. An explanation of the fusion process and input selection within the receiver when multiple systems are available.

5.2 Installation manuals that should contain:

1. Details of the sources, components and the interconnections between them;
2. Details of the interfaces and connections for data import and export and the interconnection diagrams;
3. Configuration options and commissioning instructions;
4. Power supply and earthing arrangement;
5. Recommendations on the physical layout of equipment, including antenna mounting requirements and necessary space for installation and maintenance;

5.3 The onboard familiarization material should explain all configuration, functions, limitations, controls, displays, alerts and indications of the combined EPFS receiving equipment.

5.4 A failure analysis, at the combined EPFS receiving equipment functional level, should be performed and documented for the receiver. The failure analysis should verify that the receiver is designed on a “fail-to-safe” principle. The failure analysis should consider the impact of all failure modes “e.g. those caused by electrical, component, signal jamming…etc).

5.5 Information to support maintenance of the EPFS receiving equipment.

1. e-NAV11-output-19 INF paper to NAV 58 - e-Navigation implementation plan.doc. [↑](#footnote-ref-1)
2. R-129 is being revised at e-NAV12, with changes captured in e-NAV12/73 [↑](#footnote-ref-2)
3. As defined in various studies conducted by Booz-Allen & Hamilton on behalf of the US Federal Aviation Administration. [↑](#footnote-ref-3)
4. eLoran. Securing Positioning, Navigation and Timing for Europe’s Future. European eLoran Forum. April 2008. [↑](#footnote-ref-4)
5. German Federal Waterways and Shipping Administration. Contribution to the IALA World Wide Radio Navigation plan, IALA eNAV 4, February 2008 [↑](#footnote-ref-5)
6. Refer to Publication IEC 60945 [↑](#footnote-ref-6)
7. The requirements for different navigation phases are set out in IMO Resolution A.915(22) & A.1046(27) where it is noted some conflicts exist and further work is needed to resolve these conflicts. [↑](#footnote-ref-7)
8. Ref ITU-R M.823-4 [↑](#footnote-ref-8)
9. International Terrestrial Reference Frame, or some implementation of it, such as World Geodetic System (WGS) 84 in the case of GPS, or PZ-90 in the case of GLONASS. [↑](#footnote-ref-9)
10. ITU-R M.823-4 or other relevant standards [↑](#footnote-ref-10)
11. Refer to IMO A.1046(27) & A.915 (22) [↑](#footnote-ref-11)
12. This can include a combination of RAIM and CAIM as described in A.915(22). [↑](#footnote-ref-12)
13. Time durations include that expressed in 3.16.1 for each craft type. [↑](#footnote-ref-13)
14. Refer to IEC 61162 [↑](#footnote-ref-14)
15. Raw data should be provided in an open, interoperable format (refer to IEC 61162-450) [↑](#footnote-ref-15)
16. ITU-R M823-4 [↑](#footnote-ref-16)
17. Refer to IEC 61162 and IEC 61924-2 [↑](#footnote-ref-17)