Revision of IMO Res A. 915(22)

**Objective**: revision of IMO Res A.915(22)

**1 Rationale for revision**

**1.1 what objective? What title?**

**The IMO A.915(22) is dated 2001 (more than ten years ago) and is expected to be revised.**

The IMO Res A.915(22) “Revised maritime policy and requirements for a future global navigation satellite system GNSS” , among other actions,

* “adopts general and operational maritime requirements for future GNSS as defined in its annex.
* Requests the Maritime safety Committee to keep this policy and requirements under review and to adopt amendments thereto, as necessary.”

Moreover in its paragraph 4.1 it says “ the maritime requirements given in this annex should be continually reassessed and updated on the basis of new developments and specific proposals”.

**This awareness of the need to be updated/amended is therefore clear from its adoption in November 2001 (cf paragraph 1.8 “These requirements have been limited to basic user requirements and may need to be revised”)**

Indeed the Resolution was adopted at a time where two military controlled satellite navigation systems were available for civilian use, GPS and GLONASS (both of them, with augmentation system were recognised as WWRNS according to IMO res A.1046(27)), and future civil GNSS were **at a design stage.** The Resolution was based on the recognition of the need **to identify at an early stage the maritime user requirements for a future GNSS** to ensure that such requirements are taken into account in the development of such a system.

De facto, the resolution addresses the GNSS systems which were at a design stage in 2001 and therefore “future” at that time. These systems are now operational but not used by the maritime community which needs to better assess its operational requirements.

This concern leads to the need to review the title of the resolution. Will it deal only with maritime requirements (as the Annex of IMO Res A 1046(27) ) or will it lead to GNSS system requirements?

What will be the exact objective? If the scope is an improved definition of maritime operational requirements, the work of the revision of IMO Res 915(22) may result in an updating of IMO Res A 1046(27).

**According to a better definition of the objective of the resolution, section 1 (introduction) shall be updated and section 2 (present situation ) shall be removed.**

**1.2 Operational requirements**

In the IMO A.915(22) resolution,

-several navigation phases and maritime applications are identified.

- Operational requirements are detailed for each of them.

-these requirements are expressed using the same performance parameters adopted for aviation applications.

-These performance parameters are based on the actual performance at the user level ( **see Annex**). Therefore, the properties of a “GNSS system” includes the properties of both:

* the “GNSS service” (i.e. the properties of the Signal in Space, SIS, provided by the space and the ground segment of the GNSS); and
* the user receiver.

**A number of discussions with the maritime community representatives indicated that:**

1. **There is no universal consensus on the requirements defined in the resolution .**
2. **Many of the specified operational requirements are either Not Applicable (N/A) or simply determined based on the same criteria used for aviation applications but not strictly assessed by the maritime community.**
3. **Some requirements have been already identified as “To Be Modified.” An example is the operation duration of three hours, together with the values for the accuracy and the Alert limit specifications..**

More in particular

The most critical aspect is the underlying integrity concept, which is at the user level. This, in turn, requires the calculation of PLs, whose derivation cannot be independent from the “Operational Concept,” i.e. from the intended use of the navigation system in a specific operation.

Several aspects linked to a given operation need to be clarified to develop a suitable scheme for PL calculation. These include, but are not limited to:

* The consolidation of the user requirements, together with the underlying operational concept (especially in terms of operation duration, AL and IR) and operational scenario;
* The identification of possible Feared Events (FEs) which might take place during the operation (in general, the longer the operation duration, the larger the number of possible FEs which might need to be considered); and
* The characterisation of the user environment, together the definition of appropriate error models for the local sources of error (e.g. multipath or interference); and
* The identification of alternative solutions (e.g. possible integration with measurements from other sensors or other GNSS)

All of this information is currently missing and should be derived via theoretical studies, simulations, laboratory testing, field campaigns and coordination with stakeholders and maritime community (“end users”) representatives. As a result, no standardised solution has been identified so far for the provision of integrity at the user level.

It is finally noted that, compared to aviation applications:

* The duration of a typical maritime operation is, generally, longer, so the number and the type of FEs to be considered might be different;
* Because of the different duration, the associated IR and Continuity Risk (CR) requirements might be different;
* The propagation environment around the user is completely different, especially in terms of multipath and interference; and, finally,
* The user dynamics (ship, boat or vessel) is completely different from that of an aircraft.

For these reasons, the PL calculation used for aviation applications (as, for example, that indicated in the [RTCA 229D] for SBAS) cannot be directly extended to maritime operations.

**More in general IMO Res. A 915 (22) is derived from the Target Level of Safety (TLS) methodology fully compliant with aviation requirements but not directly applicable to the maritime sector**.

**2. Main Questions**

* Are performance parameters for navigation in harbours entrances, harbours approaches and coastal waters satisfactorily defined in IMO res A 1046(22)? What else is needed?
* What about port/harbours entrance and port/harbours operations??

**Specific questions**

* Wording: IMO Res 915 (22) specifies “minimum maritime user requirements”: shouldn’t they be “operational system requirements” converging to what IMO Res A 1046(27) defines?
* The resolution identifies minimum maritime user requirements for general navigation and for positioning: do both have to be kept? (IMO Res A 1046(22) only refers to navigation.
* Res IMO 915 (22) breaks down positioning requirements into operations, traffic management, SAR, Hydrography, Oceanography, Marine engineering, construction, maintenance and management, aids to navigation management, port operations, casualty analysis, offshore exploration and exploitation, fisheries, recreation and leisure. These classes are further broken down. Do these classes represent all the possible ones? are there any more? Are they coherent? Is there any worldwide recognised classification of maritime operations classes and subclasses?
* Phases of navigation: IMO Res 915(22) introduces a separate coastal phase of navigation and a port approach and restricted waters. Does this phase of navigation include harbour entrances? (cf IMO Res 1046(22)?)
* Parameters: No probability is given for requirement on accuracy: is this needed?

**3.Suggested way forward**

After some iterations with the NMSP within the WG set up by ESA in cooperation with GSA and taking into account the resilient PNT receiver as a pillar of IMO e-NAV strategy it is proposed to endorse the following approach:

* down to Coastal Waters and Harbour Entrance/Approach, general requirements applicable to SOLAS ships should be maintained also in the post 2020 timeframe according to IMO Resolution 1046. There is no evident trend for the maritime community to evolve further from this level as the minimum common required performance prescription. Should specific nautical tasks during these operational phases require additional shipborne PNT capabilities, they would not be prescribed as a general IMO Resolution different from 1046. So IMO Res A.1046 should be the reference for these phases of navigation.
* For Port operations, it becomes more and more evident that different shipborne PNT unit configurations can support different nautical tasks, with different combinations of navigation sensors and different level of required performance. This is expected to be very fragmented such that:
  1. there cannot be a general GNSS requirement defining and prescribing a minimum set of performance requirement like today defined in IMO Resolution 915.
  2. it is therefore residing within the works on future guidelines for shipborne PNT unit that one can propose different levels of data type, quality and operational performance to support different functions and diverse nautical tasks and applications.
  3. Until such guidelines are not finalised, it will be not possible to assume and propose required GNSS integrity type and level of navigation performance in support of Port operations.
  4. In particular, the current level of accuracy (1m) and the user-integrity ‘aviation’-type defined for Port operations in IMO Res 915 seem not to be justified yet, even if applied to some specific nautical tasks.

ANNEX

### Performance parameters and underlying integrity concept

As mentioned, requirements for future GNSS use similar parameters as adopted for aviation applications. Specifically, six parameters are considered, i.e.:

* Accuracy;
* Integrity;
* Continuity;
* Availability;
* Coverage; and
* Fix rate.

They also include requirements for inland waterways.

*Accuracy*

For a future GNSS system, “accuracy” is defined as “*the degree of conformance between the estimated or measured parameter of a craft at a given time and its true parameter at that time. (Parameters in this context may be position coordinates, velocity, time, angle, etc.)*” [Ref 22].

In general, accuracy requirements are expressed in terms of the absolute accuracy, which is also referred to as “Geodetic or Geographic accuracy.” This is defined as *“the accuracy of a position estimate with respect to the geographic or geodetic coordinates of the Earth*” [Ref 22].

It is finally noted that, in order to quantify the “degree of conformance” between the estimated (or measured) parameter and the corresponding true value, the 95% value of the difference, evaluated over a given period of time, is normally used.

*Integrity*

According to [Ref 22], “integrity” is “*the ability to provide users with warnings within a specified time when the system should not be used for navigation.*”

As mentioned, GNSS systems include both GNSS SIS and the user receiver. Therefore, the underlying integrity concept requires the user to be protected from both:

* System-related failures; and
* Possible performance degradation due to local sources of errors (e.g. multipath, interference, shadowing or other propagation phenomena).

This concept is normally referred to as “integrity at the user level.” Compared to that (“integrity at system level”) adopted for a component of the WWRNS, this concept provides an additional protection against the effects due to local sources of errors.

The need for integrity at the user level has a direct impact on the integrity monitoring process, which has the objective of determining, at each user receiver, “*whether the system performance (or individual observations) allow use for navigation purposes*” [Ref 22].

Specifically, “*overall GNSS system integrity is described by three parameters: the threshold value or alert limit, the time to alarm and the integrity risk. The output of integrity monitoring is that individual (erroneous) observations or the overall GNSS system cannot be used for navigation.*” In particular:

* The “Alert Limit” (or threshold value, AL) is “the maximum allowable error in the measured position, during integrity monitoring, before an alarm is triggered;”
* The “Time To Alarm” (TTA) is “the time elapsed between the occurrence of a failure in the system and its presentation on the bridge;” and, finally,
* The Integrity Risk (IR) is “the probability that a user will experience a position error larger than the threshold value without an alarm being raised within the specified time to alarm at any instant of time at any location in the coveragearea.”

The concept is represented in Figure 2 for a generic RNS which, in this case, is a future GNSS system. More in detail, integrity at the user level is ensured by calculating, at the user receiver, a maximum error bound (Protection Level, PL) for the Navigation System Error (NSE).

This estimation is done at each epoch and normally uses:

1. navigation signals (observables);
2. system integrity information; and
3. suitable models for the effects due to the local sources of errors.

It is underlined that the definition of the models mentioned at point 3 requires a detailed characterisation of the operational environment. This includes, but is not limited to, the analysis of the expected levels for multipath and interference.

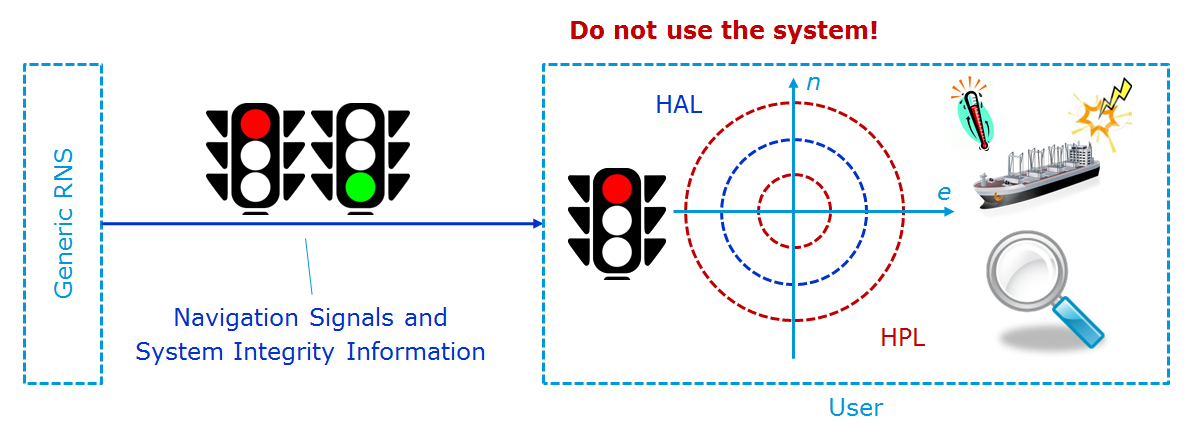
Based on the input data provided at points 1), 2) and3), the resulting PL estimation takes into account both system-related failures and possible effects due to local sources of errors. In this context, it is also noted that PL calculation can be:

* either completely autonomous (e.g. through Receiver Autonomous Integrity Monitoring, RAIM, techniques); or
* based on additional information provided by the system (e.g. a Satellite Based Augmentation System, SBAS, for aviation application).

If the user wants to perform a given operation, the PL is compared with the AL requirement associated with that operation. If the PL exceeds the AL, the receiver will promptly warn the user that the position estimation cannot be trusted.

The PL calculation should always over-bound the actual Position Error (PE), thus avoiding critical situations where the PE exceeds the AL, while the estimated PL is below the AL (). These events are referred to as “Hazardous Misleading Information” (HMI) events and their probability of occurrence shall be below the IR requirement.

It is finally noted that the PL calculation has also a direct impact on the performance for continuity and availability..



**Figure 2:** Integrity at the user level (HPL and HAL denote the Horizontal PL and AL, respectively)

*Continuity*

“Continuity” is defined as “*the probability that, assuming a fault free receiver, a user will be able to determine position with specified accuracy and is able to monitor the integrity of the determined position over the (short) time interval applicable for a particular operation within a limited part of the coverage area*” [Ref 22].

The definition is based on a conditional probability, as the system is assumed to be fault free (no failure) at the beginning the operation. In this context, a failure is defined as “*the unintended termination of the ability of a system, or part of a system, to perform its required function*” [Ref 22].

It is noted that:

* The definition of continuity focuses on the actual performance experienced by a user. This is expressed in terms of both accuracy and integrity at the user level. It is therefore related to the probability of having, at the user receiver, an accurate and reliable position estimation throughout the whole duration of a given operation.
* This is conceptually different from the “service continuity” used to specify the operational requirements of a component of the WWRNS (section 3.1.1) which, in contrast, does not consider the actual user performance and is only related to the uninterrupted broadcasting of navigation signals and system integrity information within the coverage area.

Availability

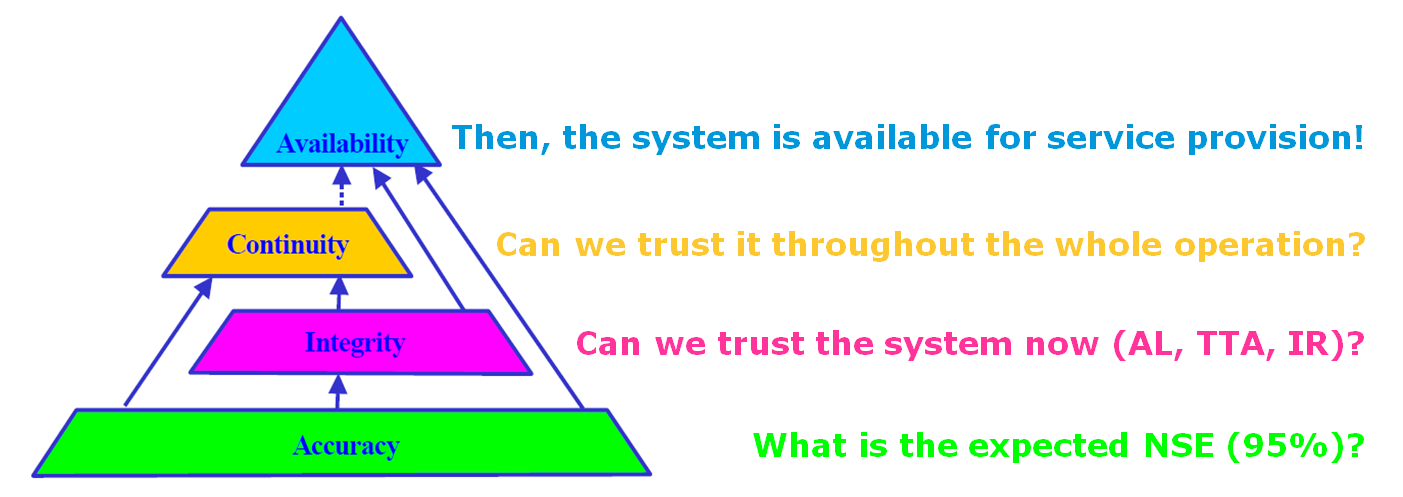
“Availability” is defined as “the percentage of time that an aid, or system of aids, is performing a required function under stated conditions. The non-availability can be caused by scheduled and/or unscheduled interruptions” [Ref 22].

Similar to what is done for a component of the WWRNS (section 3.1.1), two types of availability are considered for a future GNSS system. Specifically:

* “Signal availability” is “the availability of a radio signal in a specified coverage area” [Ref 22].
* “System availability” is “the availability of a system to a user, including signal availability and the performance of the user’s receiver” [Ref 22].

In this context, it is noted that:

* The definition of signal availability exactly matches that used for a component of the WWRNS (section 3.1.1);
* The definition of system availability is, in contrast, significantly different. In particular:
* As a GNSS system includes the properties of both the GNSS service (SIS) and the user receiver, the system availability for a future GNSS system focuses on the actual availability of the system to a user for navigation purposes. As a consequence, it must consider the signal availability and the actual performance at the user receiver. Before starting a given operation, this performance shall include:
  + - Accuracy;
    - Integrity (at the user level); and
    - Continuity (throughout the whole operation).
* On the contrary, system availability for a component of the WWRNS (section 3.1.1) does not consider the actual performance at the user level. As mentioned, it is only related to the capability of the system of providing reliable navigation signals in the coverage area.
* This difference originates from the two different integrity concepts, “integrity at system level” and “integrity at the user level,” used for a component of the WWRNS and for a future GNSS system, respectively. Because of this difference:
* Signal availability is used as performance parameter to define the operational requirements of a component of the WWRNS; while
* System availability, including signal availability and the performance at the user receiver, (i.e. as defined in [Ref 22]), is used as parameter to define the requirements of a future GNSS system.
* As system availability for a future GNSS system includes the user receiver performance in terms of accuracy, integrity (at the user level) and continuity, the four requirements are actually related and can be represented using a “pyramid,” which is normally referred to as “Required Navigation Performance, RNP, pyramid.”
* The pyramid, which is reported in Figure 3, represents the decision-making process which is performed by a user before starting a given operation. In summary: if the system is accurate and reliable at the beginning of the operation; and if the system can be trusted throughout the whole operation, then the system is available to perform that operation and can be actually used.



**Figure 3:** RNP pyramid

The RNP pyramid highlights that a key element in the decision-making process is the assessment of the integrity at the user level, i.e. the decision, at the user receiver, whether the system can be trusted or not.

As discussed above, this decision is based on the PL estimation and on the subsequent comparison with the AL requirement associated with the operation to be performed. As a consequence, the more conservative the PL estimation, the larger the possible performance degradation in terms of continuity and availability. For that reason, it is essential not to overestimate the PL while, at the same time, being compliant with the IR requirement.

*Coverage*

“Coverage” is defined as “*that surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of performance*” [Ref 22].

Again, this definition highlights the importance of the expected performance at the user level.

*Fix Rate*

The fix rate is defined as “*the number of fixes per unit time*,” where a fix is defined as “*a position determined by processing information from a number of navigation observations*” [Ref 22].

It is noted that the fix rate might be an important aspect when post-processing techniques are used to further improve the accuracy provided by a RNS. A typical example is Kalman filtering, where subsequent “snapshot” fixes are used in conjunction with a model which properly estimates the user dynamics.

### Operational Requirements

Maritime user operational requirements for a future GNSS system includes specifications for both:

* General navigation applications; and
* Positioning applications.

These requirements are detailed in Appendix 2 and 3, respectively, of the IMO A.915(22) resolution [Ref 22]. The following table taken from [Ref 22], indicates the maritime user requirements for general navigation. It has to be noted that this resolution introduces level of performance more stringent than IMO Res A.1046(27), in particular for accuracy where 1m is required for navigation in port and the integrity requirements are given at user level.

