S-100WG 6-06.6

**Paper for Consideration by S-100WG**

# Future-proof handling of geodetic references and coordinate encoding in S-100 and S-xxx product specifications

| | |
|---|---|
| Submitted by: | Sweden |
| Executive Summary: | Proposal to start a structured overhaul of geodesy and coordinate encoding related parts of S-100 and S-xxx product specifications, in order to remove inconsistencies that may lead to problems with the encoding of 2D or 3D coordinates, coordinate transformations and the use of accurate geodetic datums (horizontally and vertically). |
| Related Documents: | S-100, future versions post ed. 5, in particular Part 6<br>S-1xx product specifications (future versions) |
| Related Projects: | ISO 19111 |

## Introduction / Background

Regarding the implementation of Coordinate Reference Systems (CRS), S-100 is intended to be compliant with ISO 19100 and specifically ISO 19111. One motivation behind is that S-100 shall be seen as a standard that also supports use cases beyond navigation. Instead, S-100 is supposed to be the base for marine data exchange formats used in a much broader way: "The primary goal for S-100 is to support a greater variety of hydrographic-related digital data sources, products, and customers" and "S-100 is designed to be extensible and future requirements such as 3-D […]". Therefore, compatibility with other existing and future technology is essential. The encoding of coordinates, as specified in S-100 Part 6, is one vital aspect of this.

## Analysis/Discussion

However, there are inconsistencies in S-100 Part 6, which may lead to practical implementation difficulties or a lack of support for the requirements of future marine geodata applications, such as autonomous navigation. Furthermore, there are product specifications, which currently do not fully honour the requirements that S-100 Part 6 imposes, or which implement S-100 Part 6 in a rather restrictive way. With the intended broad use of S-100 based products in the future, potentially for applications that are still unknown today, Sweden finds it important to design the S-100 standards based on commonly agreed best practice (such as ISO 19111) and with flexibility in mind.

Still, at present many details regarding CRS in the product specifications clearly originate from S-57. It seems that known restrictions existing in S-57 are being carried over into S-100. Workarounds that once were deemed sufficient for S-57 ECDIS use could turn out insufficient for future broader S-100 use cases. One example is the convention of positive soundings and negative drying depths, which together with their position cannot easily be interpreted as coordinate tuples in a 3D space.

Sweden believes that any S-100 based standard must be capable of handling coordinates and positions according to well-defined geodetic references, vertically as well as horizontally. The way geographic data is stored should be independent from its presentation on-screen.

In order to enable precision vessel navigation, such as under keel clearance management, or eventually allow for MASS navigation (Maritime Autonomous Surface Ships according to the IMO definition), S-100 based standards must be able to support coordinate transformations between the reference frames of the S-100 data on one side, and the vessel's GNSS positioning equipment or service on the other side. However, the ambiguity between various versions of WGS84 used for geographic coordinates probably, at some point, will become a hinder for the use of more accurate positioning services for navigation. As global and even more accurate positioning services become available, the preconditions for interoperability at high accuracy levels will become more and more complex. Soon, global positioning services with 20 cm accuracy, possibly even in 3D, will be available. The S-100WG should already now take into consideration that S-xxx standards eventually will need to support e.g.

3D reference systems, more complex dynamic reference systems and transformations or dedicated geoid and land uplift models.

A clear, concise and unambiguous structure to accurately define coordinate reference systems and positions, horizontally and vertically, in S-100 and S-xxx product specifications is therefore essential.

The following examples of potential geodetic shortcomings in S-100 are by no means an exhaustive list, but rather included here to highlight the problem.

(1) A vertical datum in S-100 potentially does not have any clear connection to a geodetic reference level. Presently it is not possible in S-100 to define a "model" of the datum, e.g. its height above a geodetically well-defined ellipsoid or the geoid for any location. Such model would be needed e.g. to transform S-102 depths by applying S-104 data, that may potentially come from a different source and with another vertical reference. Data transformations like this are essential to, as an example, facilitate real time or predicted under keel clearance management services.

(2) In S-101, depth information currently is encoded in the same way as in S-57: Generally as positive depth values, i.e. with the vertical axis pointing down towards the nadir. In the case of intertidal areas, however, depths are encoded as negative values. The same convention applies to S-102 since ed. 2.1.0. As a consequence, and depending on the applicable vertical datum, a depth sounding together with its 2D position, cannot easily be interpreted as a 3D (x,y,z) coordinate tuple. In essence, the hydrographic presentation requirements deviate from a common vertical axis definition, and lead to an incompatibility with land elevation data, such as LiDAR point clouds.

(3) Presently, CRS are not always defined in a unambiguous way, see for example the problem described in S-100WG 6 agenda item 04.3B (Detected GML Issues Related to Spatial Reference Systems). CRS should always be defined according to Part 6, strictly following ISO standards. However, presently there seem to be product specifications that override such definition.

(4) In relation to this, S-100 should trust one dedicated repository for well-defined, existing CRS. Strictly using one centrally maintained definition reduces the risk of potentially introducing inconsistencies or errors when re-defining the same CRS in S-1xx or the GI Registry.

(5) For future highly accurate positioning systems, such as Galileo's commercial services (e.g. High Accuracy Service HAS) or local/regional RTK solutions, the requirement to use only WGS84 geographic coordinates is a limitation. For example, in Europe at present WGS84 coordinates differ by several decimetres horizontally from the European reference frame EVRF. A commonly employed workaround is to produce ENC data with coordinates in the regionally used CRS nevertheless. Doing so prevents vessels, which use land-based GNSS corrections in the same CRS, from being mis-positioned in relation to the ENC data on the ECDIS screen. However, this would hardly work with global GNSS augmentation services and high accuracy requirements.

**Conclusions**

The solutions for these problems are complex and touch upon various S-1xx product specifications, parts of S-100 and the GI Registry. In a first step, a much closer inspection of these and other geodesy related issues in the standards is needed. In a second step, potential solutions should be proposed to the relevant working groups. Overall, this work would lead to cleaner, more future proof standards with fewer undesired issues inherited from the current S-57 world.

**Recommendations**

As a long-term solution, aiming at S-100 post ed. 5 (time plan and version to be agreed upon), Sweden proposes to start a structured overhaul of geodesy and coordinate encoding related parts of S-100 and S-1xx product specifications. The focus of such work should be to remove inconsistencies that may lead to problems with the encoding of 2D or 3D coordinates, coordinate transformations and the use of accurate geodetic datums (horizontally and vertically).

This effort will take some time to finish. Therefore, Sweden proposes that this work should be carried out with future editions of S-100 and the relevant product specifications in mind, post S-100 ed. 5. It is also clear that this only can be done in close collaboration between S-100WG and the responsible WGs under HSSC as well as relevant S-1xx Project Teams.

**Justification and Impacts**
Examples to solve some of the above mentioned issues could be as follows.

With regard to item (2) above (positive/negative soundings) one should distinguish between data storage and data presentation, i.e. store the sounding according to its correct position with regard to the vertical datum as a negative number, and display it after applying a factor -1. Related to this, also the possibility to apply an offset to the vertical reference should be taken into consideration to simplify dealing with inland waters, where the water level is above sea level. For example, the reference level of the Swedish lake Vänern is by definition +44.1 m above the Baltic Sea Chart Datum 2000. By storing a sounding in its correct 3D position and applying an offset for presentation, comparability with adjacent land elevations could easily be achieved.

Related to item (3) above (potentially ambiguous CRS definitions within S-100 data), probably some revisions of Part 6 and product specifications need to be made, in order to get rid of these ambiguities and to further enforce that product specifications strictly implement CRS definitions according to Part 6.

When it comes to a well-maintained "trusted repository" for existing CRS definitions, the International Association of Oil & Gas Producers' (IOGP) EPSG registry could be a suitable candidate to rely upon, instead of risking to introduce inconsistencies or errors when re-defining the same CRS in S-1xx or the GI Registry.

In summary, the S-100 standard and S-1xx product specifications could benefit from a revision of the geodesy and coordinate encoding related parts of the standard. By doing so in an up-coming version of S-100 (post ed. 5), catering for future requirements would become easier and continued development around these aspects will become more straightforward. To some extent, S-57 specific heritage in the standards probably can get in the way for the original ambition of S-100: to be the general basis for future maritime data formats, for safe navigation but also other applications beyond navigation.

**Action Required of S-100WG**
The S-100WG is invited to:

a. Note this paper.
b. Endorse that the following work items are added to the S-100WG work plan:
   - Analyse potential issues related to the handling of geodetic reference systems and coordinates in S-100 and S-100 based product specifications.
   - In liaison with related WGs and PTs propose possible solutions for these issues that, on a long-term basis, could be implemented in future versions of S-100 (post ed. 5), S-100 based product specifications, and the GI Registry,.
c. Propose any further guidance as deemed appropriate