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Integrating IEC and ISO information models into the S-100 Common Maritime Data Structure

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Abstract

The implementation of new e-navigation services will be heavily dependent on the Common Maritime Data Structure (CMDS) based on the IHO S-100 framework. Much work is already being committed to this. However, the development of CMDS is not trivial and there are in particular two issues that deserve more attention:

1. S-100 is a geographic information system (GIS) type data modelling framework. A significant part of the information exchanged in e-navigation applications will not be geographical in nature, but rather operational. Information on hazardous materials or waste is an example of data elements that cannot easily be mapped to a GIS feature. There is a need to develop a principle for how such information shall be incorporated into the CMDS.
2. There are already a number of data structures that have been standardized for use in the maritime domain. Examples of this is EDIFACT messages for ship reporting, ISO 28005 for electronic port clearance and IEC 61162 for digital interfaces on the bridge. One will also have to develop principles for how the CMDS can incorporate these data models.

This presentation will show some more details of the examples of issues and suggest some possible ways to resolve them.

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List of abbreviations and terms

AtoN	Aid to Navigation (light house, marker, etc.)
CDM	Canonical (or Common) Data Model
CMDS	Common Maritime Data Structure
GNSS	Global Navigational Satellite System
GIS	Geographic Information System
ECDIS	Electronic Chart Display and Information System (ENC plotter)
EDIFACT	Electronic data messages in UN/EDIFACT format
ENC	Electronic Nautical Charts
FAL	IMO Facilitation Committee
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities (http://www.iala-aism.org/)
IEC	International Electrotechnical Commission (www.iec.ch)
IHO	International Hydrographic Organization (www.iho.int)
ISO	International Organization for Standardization (www.iso.org)
MEPC	IMO Maritime Environment Protection Committee
MSC	IMO Maritime Safety Committee
PKI	Public Key Infrastructure
S-100	GIS type data modelling framework developed by IHO
SIP	(e-navigation) Strategic Implementation Plan
TC	Technical Committee
VDES	VHF Data Exchange System (includes AIS)
VTS	Vessel Traffic Services
WCO	World Customs Organization

1 Introduction

The administrative burden on seafarers has been recognized as a significant problem by IMO and others. This burden is diverse, but in this paper we will look at the ship's mandatory reporting requirements in relation to port calls. It is generally agreed that automation of reporting procedures is an important step to reduce this burden and automatic reporting is included as solution 2 in the e-navigation SIP (see below). Reporting requirements differ much between ports and countries and here we will mainly look at international ship traffic and corresponding international requirements and solutions.

In its Strategic Implementation Plan (SIP) for e-navigation, IMO has defined the *Common Maritime Data Structure* (CMDS) as "at the heart of e-navigation". IMO has agreed to use the International Hydrographic Office (IHO) S-100 data modelling system to implement the CMDS. Thus, the CMDS is a central part of the e-navigation strategy and will have a significant impact on all the strategic priorities in e-navigation.

However, the S-100 system is a geographic information system (GIS) type information model environment and CMDS will both incorporate GIS type data, e.g. intended for display on an ECDIS, and more operational data used, e.g. in mandatory reporting to shore. An important question is if both these data types can be equally easy incorporated into the S-100 system. There are also existing information models from various domains, e.g., digital interfaces between bridge equipment, electronic ship reporting formats and machinery data that should be taken into consideration by new S-100 based models. Some other issues have not been fully solved, e.g. related to streaming of data rather than file transfers, but these issues will not be discussed here.

Cyber-security, including protection of ship and shore systems as well as authentication of originators of S-100 data files, is also an issue that requires special attention within e-navigation. This is closely related to the legislative framework for data exchanges which in the case at hand – international ship reporting – are various IMO instruments as well as national legislation.

To succeed, the CMDS and S-100 implementation must consider and find a good solution to how different data or information types can be incorporated, how to link to existing and established data models as well as how cyber-security and the legislative framework is supported. This paper will discuss some of these challenges and suggest some possible directions for the development process.

2 Capturing data definitions in a Canonical Data Model

A Canonical Data Model (CDM) is the simplest possible data model that can represent all relevant data entities and their relationships in a specific domain. This type of model is also sometimes also called a Common Data Model. The implication is that there are no duplicates or ambiguous definitions and that the model is fully consistent as far as definitions go. In principle, it should also be complete, i.e. include all relevant data entities, but this is normally not possible: The CDM will normally have to grow when new services or elements are added in the domain. The establishment of a CDM is important to ensure simple and consistent interoperability between computer services that operate on or in the specific domain.

Given this definition it seems obvious that the CDMS by many will be viewed as the CDM for the e-navigation domain. However, as will be discussed in this section, this is not a trivial development task and one can ask if this ambition is at all possible. Furthermore, if it is not possible to develop a CDM, how shall interoperability in the e-navigation domain be ensured? Some possible solutions to this problem will also be offered in later sections.

2.1 CMDS and other existing information models

The first problem to be discussed is the relationship between CDMS and other and already established data models. Figure 1 shows the five prioritized e-navigation solutions as defined in the SIP and the relationship to some ongoing standardization initiatives that will be discussed in this paper.

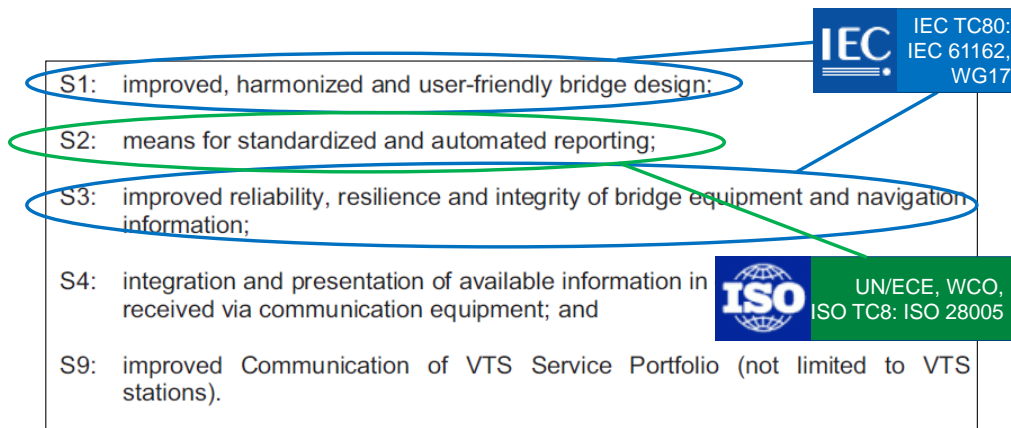


Figure 1 – Prioritized e-navigation solutions and other standardization activities

The relationships are:

- Bridge design and relationship to IEC 61162 series of standards on digital interfaces in bridge data networks.
- Automated reporting and relationship to ISO 28005 on electronic port clearance as well as other standards from the UN/EDIFACT domain and World Customs Organization (WCO).
- Improved reliability of bridge information and relationship to IEC 61162.

The standards referenced above are limited in scope and there is obviously a need to develop a much more extensive data model for e-navigation than these can supply. However, it is also of paramount importance for CMDS to maintain compatibility with existing standards and specifications that have been in use since before year 2000, in this case mainly the IEC 61162 and ISO 28005 standards. This is not straight forward because the different models are in different formats and it is necessary to normalize the elements and definitions before harmonization can be done. This issue is relatively easy to handle by creating one "master" or canonical data model – the CMDS – and create mappings from that to the relevant representations in the other information models.

However, there are more difficult obstacles than this that are more general in nature and will impact how the CDMS can be constructed. One is an issue of increasing semantic details as one moves downwards in the e-navigation system hierarchy, another is the differences between sub-domains within e-navigation. These issues will be discussed in the following.

2.2 Semantic differences in information sub-domains

The domain of e-navigation is larger than one may believe. As shown in Figure 1 and within the main prioritized solutions one may distinguish between four sub-domains: Integrated bridge systems; Ship reporting; Navigation information received from shore; and VTS interactions. Some of these, in particular Ship reporting, may even be further subdivided. The main reason for this is that ship reporting involves a large number of parties and responsible organisations for reporting data formats [16]. Some of these are illustrated in Figure 2 where it is shown how the information element "ship name" can be semantically understood in three sub-domains of ship reporting.

One domain can be called "Safety at Sea" which represents the safety and security interests of nautical officials in port and coast state authorities. The ISO 28005 standard is developed for this domain primarily. In this case the identity of **the ship** is a first class object and the name of the ship is an attribute to this object.

Another important domain is "Customs" where the UN/EDIFACT message CUSCAR is used to report on a ships arrival to or departure from port. In this message, the ship name is coded as part of the **transport means** segment (TDT).

Finally, in the FAL Compendium, the EDIFACT message INVRPT (Inventory Report) is suggested used to report on ship stores. This is a message originating from the “Trade” domain and here the ship name is coded in the **contact information** segment (NAD).

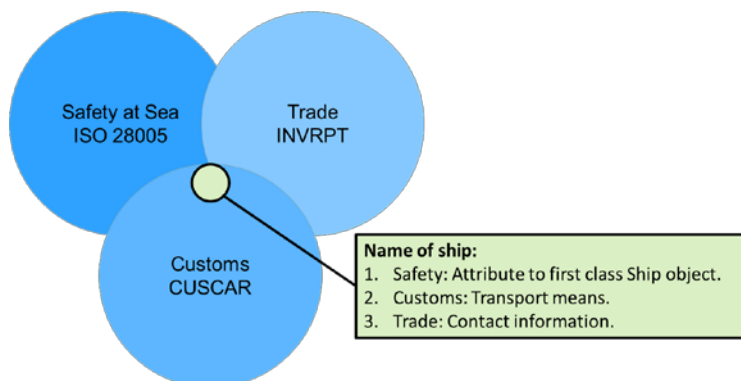


Figure 2 - Different semantics in different domains

The differences in the three definitions cause no problems in the FAL Compendium as the document specifies exactly how the elements are to be interpreted in the different messages. This can be looked at as if the compendium creates a “meta-model” on top of the individual domain data models. However, if one takes, e.g. one of the "Safety at sea" objects out of the FAL meta-domain context and tries to interpret it, e.g. in the Trade domain alone, there is a significant risk that important semantic details are lost. This risk will be greater the farther the domains are logically and operationally separated.

Another problem caused by this issue occurs when one wishes to integrate data models from different domains. This means that each shared data object requires an "integrated" semantic definition that covers the meaning of that object in all the domains it is used in. The more domains it is shared among, the more complex the integrated definition get. This may severely complicate both use and maintenance of the model and require specially training for any users. This may also severely limit the usefulness of the model for organisations that cannot afford to acquire or hire this expertise, which is often the case in the maritime area. The approach used in the FAL compendium, i.e. operating with a meta-model over the domain models may in many cases be preferable to trying to create one integrated model.

2.3 Increasing semantic complexity in hierarchical data systems

Another problem in establishing a general canonical data model is that semantic complexity tends to increase as one move down in abstraction hierarchies. As an example, the concept of hierarchical system architecture for integrated ship control (ISC) systems has been around for many years and was a main element of the MiTS (Maritime Information Technology Standard) project [14]. It has later been refined in various other projects and is now typically presented as in Figure 3.

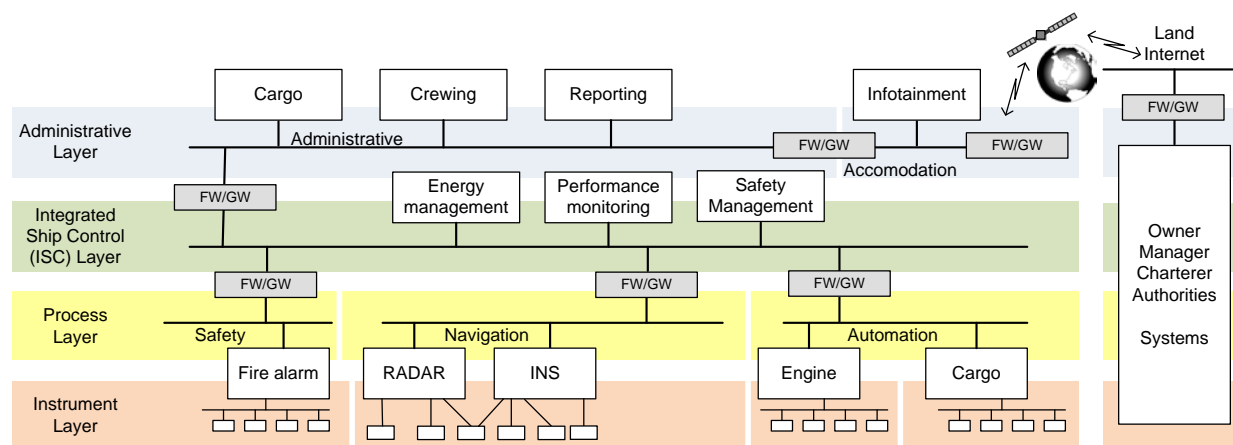


Figure 3 – Integrated ship data networks – adapted from [15]

Typically, the ship networks are organized in layers, possibly with segmentation within layers. Some form of firewall or gateway (FW/GW) may be used to interconnect segments and layers. This figure is idealized and few ships, if any, have fully integrated ship data systems today. However, the individual layers with or without interconnections can be found in most modern ships.

The main layers of the integrated ship control system are:

- *Administrative layer:* This represents administrative or public data networks on the ship. Administrative functions like ship reporting, crewing, port operation planning etc. will normally be found here.
- *ISC layer:* This is not normally formalized on most ships, but represents interconnections between the different process segments to provide higher level integrated monitoring and control functions, e.g. for energy optimization, performance monitoring and technical safety management.
- *Process layer:* This is an integration level for the main ship processes, typically on the bridge (navigation), automation (engine, cargo, ballast etc.) and safety (fire, watertight doors, etc.). On the bridge, IEC 61162-450 [3] is starting to become a commonly used integration standard.
- *Instrument layer:* These are fieldbus type and other localized networks interconnecting sensors with control systems. On the bridge, IEC 61162-1 [4] is traditionally used on this layer.

On the land side one will find a similar layered system where, e.g. an owner's office may have a connection to on-board automation systems on the process layer to do remote maintenance or diagnostics. This may be through a direct link via a dedicated satellite channel or may be implemented, e.g. with virtual private network (VPN) technology through the administrative level satellite link and specially configured firewalls on the ships. Today one will normally see most land applications on the administrative layer, but with the introduction of e-navigation this need to change and many more land based functions will also appear on the ISC and process (navigation) layers.

As one moves down in layers one will generally find that each data element requires more and more additional context information to be useful. Much of this context information is related to the specific network topology and the source of the data element in that network. This information is implicit when the data element is used in its original context, but if the data element is taken out of the original network context it may have to be made explicit as part of the data object. This is illustrated in Table 1 where a simple position fix from the instrument level is used as example. The level column specifies on what abstraction level the data object will be used which determines the required additional explicit context information.

Table 1 – Increasing context requirements on lower levels for position information object

Level	Required context information for external use of data object
Administrative	None; accuracy +/- 100 m.
ISC	May need reference point on ship, ship size; accuracy +/- 5m.
Process/bridge	Integrated Navigation System position with attributes as for ISC, need reference.
Instrument/INS	Source of measurement, accurate timestamp, source quality attributes etc.

The accuracy is dependent on various factors and is only indicative, but as a typical example, for reporting purposes and general ship control, the accuracy needed is much lower than for direct track or position control that normally takes place on lower levels.

This increase in required context information on lower network levels is directly related to the corresponding reduction in abstraction levels from the top and downwards. On the administrative level the ship position is a very high level abstraction of several dynamic parameters that are required on lower levels for automatic control purposes. If one compare ISO 28005 (ship reporting) [10] with IEC 61162-1 (instrument level bridge system) [4], this is quite clear. ISO 28005 has one single object for ship position

while IEC 61162-1 has at least five different representations as shown in Table 2. On the instrument level, the implicit context information would consist of the sentence formatter as well as talker identifier, knowledge of network topology and usually exact time of data reception to correctly use the position data. The sentences themselves will also contain additional quality and acquisition parameters.

Table 2 – Different IEC 61162-1 positions

Sentence formatter	Detailed description
GGA	GPS position fix
GLL	General ship position
GNS	GNSS position fix
RMA	LORAN-C position fix
RMC	GNSS position fix

2.4 A Canonical Data Model for IEC 61162

IEC TC80 (Maritime navigation and radio-communication equipment and systems) has established a new working group number 17 (WG17) to develop standards and specifications that connect the CMDS with data models and standards developed by IEC TC80. The initial work will be directed towards the IEC 61162-1 equipment interface standard and the route exchange format specified in IEC 61174.

One of the discussions in WG17 has been if it is possible to define a CDM for IEC 61162-1. Without concluding that discussion here, most of the arguments have pointed to the problems outlined in sec. 2.3: It seems to be extremely complex to define a CDM for instrument level standards as too much context information need to be attached to each data element definition. This will partly make the task of defining a CDM very complex and it will also lead to a data model that will be very difficult to use. Thus, at the moment this does not look like a viable proposal.

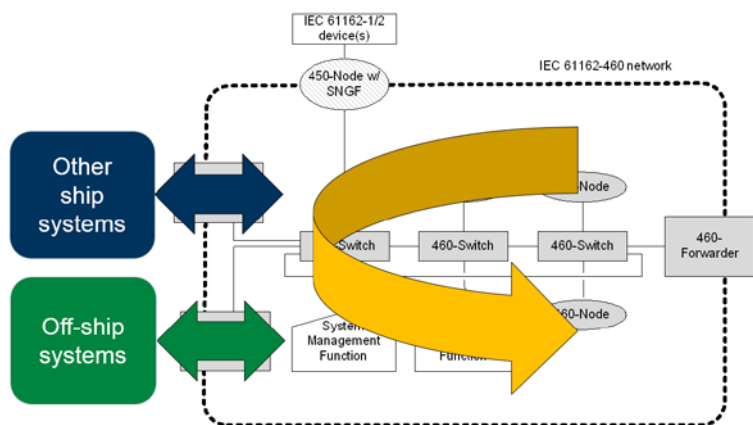


Figure 4 – Different types of data transfers in IEC 61162-1

Figure 4 illustrates the identified possibilities for mapping IEC 61162-1 to CDMS. The underlying diagram is from IEC 61162-460 [2] which is an Ethernet data network using IEC 61162-1 text sentences as basis for the data messages. There are three types of mappings that are illustrated:

1. *Internal information modelling (yellow)*: It is of interest to see if the S-100/CMDS system can be used to describe the internal information transfer in the bridge data network itself. As discussed above, this may be very complex and may not be practical, at least in the form of a CDM.
2. *Other ship systems (dark blue)*: There may be a need to transfer data from or to the bridge data network to other on-board computer networks. These data objects will have less complicated semantics, but additional context information may still be needed, e.g., time stamps, quality attributes and data source.

3. *Reporting to off-ship systems (green)*: This is data with high abstraction level semantics which is typically used to generate status or other types of reports which may be sent, e.g. to shore. It is expected that relatively little context information is needed.

The link to other ship systems in item 2 is an interesting proposition, but retains many of the problems from the general internal mapping proposed in item 1. Item 3, concentrating on off-ship systems and relatively high abstraction level data objects is probably the most useful first step in this work as it has very clear links to e-navigation and has probably a manageable complexity level.

2.5 A Canonical Data Model for ISO 28005

ISO 28005 is mainly intended for use in mandatory ship reporting between ship and port state authorities and is clearly in category 3 referenced to Figure 4. This means data is on a fairly high abstraction level and with corresponding low requirements to additional context information. Thus, it should be well suited to a CDM.

The data objects defined in ISO 28005-2 is organized in sub-domains as shown in Figure 5. These correspond to reporting requirements in the FAL Convention and in SOLAS. The numbers in the figure refer to the clauses of the standard that defines the specific group of elements.

Adapted XSD Types (Clause 5)								
General data types (Clause 6)								
Ship ID 7.2	Cargo 7.3	Crew and passenger 7.4	Class and certificates 7.5	Security 7.6	Service related 7.7	Ship particulars 7.8	Vessel operation 7.9	Waste and environment 7.10

Figure 5 – ISO 28005-2 sub-domains [10]

Looking at ship reporting as one domain it is easy to define a CDM for ISO 28005. In fact, the standard is more or less organized with a canonical data model in mind where ISO 28005-2 defines the data model and ISO 28005-1 [9] defines messaging structures and data exchange patterns.

On the other hand, an important compatibility issue will occur if the ISO 28005 CDM is to be integrated into CMDS. This is because the sub-domains of ISO 28005 overlap with sub-domains of other standards managed by other organizations. This issue was discussed in sec. 2.2.

2.6 A canonical data model for CMDS

There are a number of issues that needs to be discussed before one starts to develop a CDM for CMDS. Many of these have been discussed above and will be briefly summarized below. Others have not been discussed and will be given a more extensive explanation.

Who are the users? This question can be used to determine a structure for the CMDS in terms of sub-domains. One may go for one integrated CMDS or a number of more isolated sub-domain if the user groups are very different. Currently, it is mainly ship-shore reporting that has been used as a main case and this may probably be handled in one integrated domain. If, e.g. detailed emission reporting is included, one may have to divide it into more sub-domains. In this case, one also needs to consider the issue of meta-models.

Right abstraction level? As was discussed above, it is important to consider the abstraction level for the main components of the CMDS. Very detailed models will be very difficult to maintain other than as specialized sub-domains and not part of the CDM.

Key data elements? Some data elements tends to become main indexes for various messages or queries. One example is the identity of ships or shore stations. Such elements needs to be defined very carefully. As an example of a difficult key elements one can look at "**Voyage number**". This has been suggested as key for retrieving voyage information, but the problem with this element is that it is not well defined. Coastal states put a very different meaning into the voyage number than the ship operators. A voyage

number may also be cancelled and reissued for some voyages if, e.g. the destination port is changed. This happens quite frequently for many bulk cargos that may be rescheduled or sold during voyage.

Links to existing standards? This will probably have to be handled through product specifications as discussed later.

Links to other parts of S-100? The author's feeling is that the CMDS should be a separate entity in the framework and use "light" links o link to other components. However, this needs to be descised.

3 Other issues related to the use of S-100 for the CMDS

In addition to the problem of defining one canonical CMDS as discussed above, there are also other problems that have to be solved for efficient use of S-100. This section will look at two of these issues, one related to the differences between operational and geographic information system (GIS) data and one related to stream or real-time transfer of data packages.

3.1 Operational data versus GIS data on the ship

Somewhat simplified, one can say that operational data is data objects that are intended used in a computational process to analyse historical developments, predict possible outcomes, calculate statistics or do other numerical operations on the data set. The data objects are often, but not always varying with time. Examples of operational data objects could be engine RPM, ship trim, speed through water etc. GIS type data objects are intended for graphical rendering on a computer display in some form of geographic map context. Examples of GIS objects could be an approaching ship, a sailing mark, a dangerous area or similar.

In practical terms, it is more or less the same high level objects one is dealing with: Own ship, other ships and objects, sailing restrictions etc. The main difference between operational and GIS data is the different domains or sub-domains in which the data objects are used (see sec. 2.2). This is tentatively illustrated in Figure 6 where parts of the own ship operational domain (based on IEC 61162-1) and an ECDIS domain are shown together with their various sub-domains.

In the bridge data network one will mainly find information collected from various systems and sensors on the ship. This typically includes many objects related to the ship itself, external environment conditions, observations of other ships (AIS or radar targets) as well as Maritime Safety Information received, e.g. from NAVTEX and also some system status indicators, including various alarm sources for the bridge.

To provide an updated ECDIS display, the system requires the relevant ENC data files, any updates, e.g. in the form of notices to mariners (NtM) as well as information on own ship and other ships, if observed targets are to be displayed.

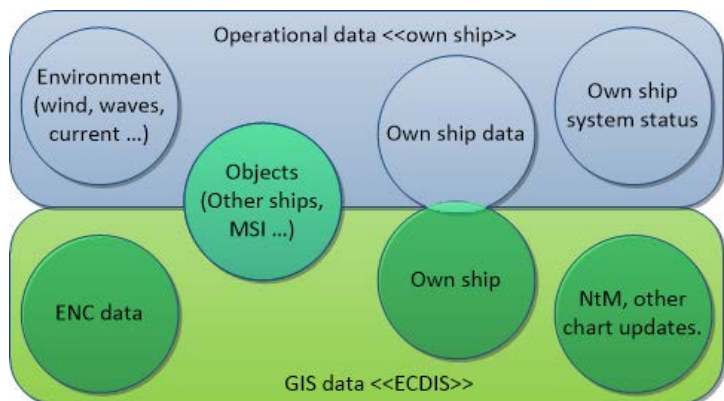


Figure 6 – ECDIS and Own Ship Operational data domains

The main overlaps are in other objects data which is more or less the same in both domains. The ECDIS will use AIS and radar input from the bridge data network and possibly NAVTEX information (MSI) to

display this information. The ECDIS also needs a small set of the own ship data set (speed, heading, rate of turn etc.) to display own ship attributes correctly on the map.

While this is a very simplistic view of the system integration and domain overlaps, it illustrates some the different types of relationships between operational and GIS data:

- *Full overlap*: In this case, other ship data and MSI is available on the ship data network mostly for display on radar or ECDIS. The ECDIS domain data model has in a sense been used to define messages in the ship operation domain.
- *Partly overlap*: Objects from the ship operational domain has been used as attributes in the "own ship" object in the ECDIS. This is in a sense a mapping between the two domains and is based on the ECDIS translating the relevant IEC 61162-1 messages to internal object representation.
- *No overlap, but related objects exists in both domain*: This is not illustrated here, but could happen in an e-navigation context if messages to the bridge data network contain overlapping information as that used by the ECDIS from other sources. This could, e.g. be related to reporting requirements from the ship to a ship reporting area.
- *No overlap*: Observed environment data will never be used by the ECDIS other than for general display of the raw data elements as received by the ECDIS. Conversely, general ENC data has no application in today's operational domain.

Note again that the figure is very much simplified. As an example, the ECDIS will normally also use ship system status to detect if position input is valid etc.

The main difference between the two data models will be driven by their respective primary uses. The ECDIS model will be based on geographic structures as primary objects reflecting the real world objects that have to be rendered. The operational model will most likely be based on primary objects that are main components in the computational operations performed. Within the sub-domain own ship one will find primary objects for speed through water, speed over ground, course, heading etc. Other sub-domains may have other forms of primary objects, but the overall model should still be integrated and canonical.

3.2 Operational data in S-100

The discussion in the previous section should have shown that the difference between operational and GIS data is more a question of the usage domain than of different realities being modelled. However, this still means that the problems identified in 2.2 remain and that it normally is a non-trivial task to provide one common data model for both domains.

As S-100 has been selected as the basis for the CMDS we need to look at how operational or non-GIS data can usefully be incorporated in the framework. Some work has been done in this area; see e.g. [12], [13] and [11]. While the two first references use the S-100 framework directly and as specified, the last reference also suggests some changes in the structure.

Looking at the S-100 specification [6], the text is very much oriented towards GIS type objects and models. However, there does not seem to be any formal restriction on, e.g. feature catalogues consisting only of information objects (no GIS or feature objects at all) or product specifications referencing only such catalogues. One may want to look at the suggestions in [11] related to the organisations of the registries and general organisation of the system to get a better structure on the CMDS.

In general, the identified issues related to operational data seem not to be reasons why S-100 cannot be used for CMDS. There may have to be some changes in S-100 to support it (see also next sub-section), but the main challenge is to establish a standardized process for implementing this type of data model in the system.

3.3 Streaming data versus file data

Another issue related to S-100 is that it is too data centric and does not sufficiently well support exchanges of data messages that vary over time (“stream”). This has been pointed out by IALA in [1]. This is also a minor issue that seems to be fixable by changing only parts of the specification.

For operational data messages one need to check if there are additional requirements to how S-100 data can be transferred and how this is defined in the product specifications. In general, one may use the ISO 28005 data messaging system as basis and look at the typical data format there. This is based on a standardised message structure with different body formats, dependent on message purpose. The main report format is a flat structure of data elements from the ISO 28005-2 canonical data model. These message area sent and received asynchronously with acknowledgement messages (acknowledgement of reception, not of any embedded request) being sent immediately after successful reception.

Normally, it may be acceptable to send the message as a standard XML message, but in some cases the message should be compressed or serialized, dependent on transmission cost, message sizes and bandwidths available. Minor delays on the order of minutes or even hours are not normally an issue.

4 How to implement CMDS in S-100

This section will summarize the discussions from previous sections and provide some suggestions as to how the CDMS more efficiently can be implemented in the S-100 framework. The baseline is the current S-100 specification [6] and the premise that this framework’s primary purpose is to represent GIS type data. Here it will be discussed how operational data can be added to the framework. The sub-sections represent the main issues to be resolved according to the author’s opinion.

4.1 Operational and streamed data

This does not in principle seem to be a major problem, but it would be useful to update the S-100 specification so that it is less focused on GIS data and also points to how non-GIS data can be incorporated. Some suggestions have already been made by IALA [1].

One will need some new guidelines and rules as to how these data elements shall be managed in the context of S-100. This may or may not be part of S-100.

4.2 Semantic differences in sub-domains

The main problem will be to handle the differences in semantic meaning in the sub-domains that will have to be incorporated. For ship reporting and data that has already been incorporated into ISO 28005, we see the following main issues that need to be addressed:

1. It would be useful to establish one canonical data model for the reporting data. This would make it easier to use it for different new reporting formats. Data elements from IEC 61162-1 could probably also be modelled in a similar way.
2. Many elements from ISO 28005 do most likely already exist as attributes to various GIS objects already incorporated into S-100. One may also risk seeing that that different attributes in different GIS object have the same meaning as one ISO 28005 or IEC 61162 data object.

As stated earlier, it is not probable that the IEC 61162 CDMS component will cover all semantic details for low level system integration directly in the data model, so that will not cause much problems. We also believe that even reporting and other types of e-navigation data will not cause serious semantic problems in the context of S-100 and CMDS. There will be some semantic incompatibility issues related to external standards, but that will be discussed in the next sub-section.

4.3 Link to existing standards

The main issue related to external and existing standards is that one needs to maintain a form of mapping between the external standard and the CMDS. As external standards or CMDS is updated, this mapping

may also need to be modified. This mapping does not fit in the S-100 framework today, but it could be included as a form of product specification. This specification could then define how the S-100 object can be mapped to (part of) the external standard. This would, however, require some changes to the product specification format.

For ship reporting this may also have some semantic incompatibility issues as the ISO 28005-2 may need to be aligned with other standards from the ISO and UN/CEFACT domain. These are typically more customs or trade related and there is a need to harmonize object meaning between the standards. However, this should not impact the CMDS.

4.4 A possible solution

Figure 7 shows in general terms how an S-100 based solution could be designed. The figure indicates traditional GIS type data models to the left, semi-GIS data models such as for Maritime Safety Information (MSI) messages and Maritime Information Objects (MIO) in the middle and the new non-GIS operational data to the right.

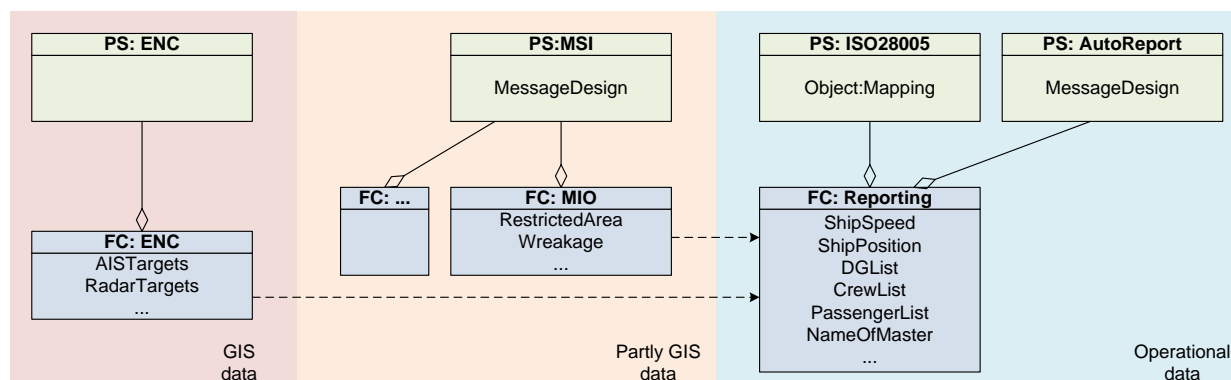


Figure 7 – Possible S-100 organization

The green boxes tagged "PS:" represent possible product specifications while the blue boxes tagged "FC" represent possible feature catalogues.

This is a much generalized figure and only the main principles are shown:

1. The operational data model could be implemented as a canonical data model with the help of InformationType object or FeatureType objects if the data object has a reasonable graphical representation. The objects could be collected in a special and dedicated Feature Catalogue (FC).
2. Product specifications (PS) can be defined for the mapping to the original external standard (ISO 28005 in this case) and for any other application of the feature catalogue. Here a product specification for automatic reporting is indicated. The latter will need instructions as to how the automatic report messages can be formatted.
3. GIS or semi-GIS type domains should retain their separate feature catalogues, but one may add mechanisms to link features in these domains to “identical” features in the different operational domains. This association should probably explain any necessary semantic differences or translations that are required for using these objects. This would allow more automatic links between operational data objects moving on ship networks or through wireless data links and rendering on GIS platforms while it would simplify maintenance as each sub-model can be maintained in its own domain. This avoids the semantic complexity discussed in section 2.2.

Using this approach will probably require some changes in the basic S-100 model definition. This paper will not go further into that investigation.

5 S-100 and cyber-security in e-navigation – electronic signatures

Maritime cyber-security gets increasingly more attention as shipping becomes more reliant on digital control systems and communication between ship and shore. Cyber-security needs to address physical attacks, attacks via removable memory devices, attacks on ship data networks via Internet or on-board data networks and attacks on wireless data transmissions. For the latter it may be a case of encrypting data exchanges, but it is also necessary to look at authentication of the messages.

The mechanisms used for encryption are basically the same as those used for signatures and are normally based on *public-key cryptography*, which is a system by which pairs of cryptographic keys can be generated so that the public key can be used to decode information encoded by the private key. This system is efficient and very common in the Internet domain and elsewhere, but it requires a system for distribution of both public and private keys. This is called a public key infrastructure (PKI).

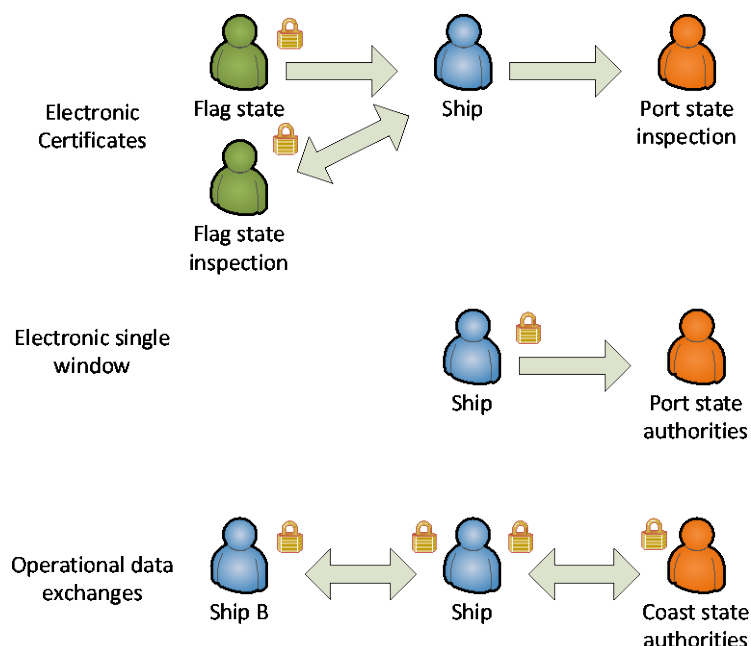


Figure 8 – Electronic signatures in e-navigation

Figure 8 shows some relevant data exchanges that will be necessary in e-navigation. At the top is shown exchanges of electronic ship certificates where the flag state or its recognized organisation need to sign the certificate so that it can be verified, e.g. by port state control. The next line shows ship reporting to a single window where the ship needs to sign the report so that the port or port state can verify the sender. Finally, the last line shows e-navigation message exchanges, e.g. between VTS and ship, where all parties need to sign their messages so that they can be verified as genuine before they are used in safety critical operations.

In addition to this, one may also have distribution of navigational information from private parties to the ship, where there is also a need for authentication.

This paper will not go into the details of cyber-security requirements and electronic signatures. This is discussed, e.g. in [8] and [17]. However, for further work on this issue it is important to be aware of the following points:

1. Several IMO Committees are involved in this work and it is necessary to harmonize this work so that we do not end up with different standards and different approaches to the public key infrastructure. Shipping is very cost sensitive and require technology that can operate world-wide. It is not acceptable to get many competing and incompatible solutions.
2. Compatible solutions should be found for all relevant applications, including, but not limited to ship certificates, single windows and e-navigation message exchanges. This also includes

technical systems like VDES and similar. In fact, looking at the different applications, one will see that technical requirements are very similar.

3. A major factor in a successful public encryption system is that it is acceptable to all member nations in IMO. Acceptance must include technology, operation as well as costs.

The main committees involved in this today are FAL and MSC. MEPC may also have to be considered as they work with electronic log books. The main challenge may be point three above: Defining a low cost solution that can be acceptable to all IMO members.

Note that one also may want to include private parties in this work as many ship documents may be delivered electronically by various non-governmental parties. This includes electronic charts and updates as well as port arrival information and voyage related data exchanges between charterer, owner and manager. One should also keep in mind that many ships reports are in fact sent by the ship agent. It is important to analyse all relevant work processes before solutions are selected.

6 Conclusions

This paper has discussed the complexity of integrating operation data into the S-100 based CMDs. This is not a trivial task and needs to be met with good technical solutions, flexibility and cooperation between the different involved parties. In particular, one needs to consider how to maintain compatibility with already existing standards.

Some high level solutions have been outlined and these may also require that some changes are made to existing S-100 infrastructure. However, it looks as this can be made without impacting ongoing work on the ENC and GIS-based specifications.

Finally, it has been pointed out that electronic signatures and maritime cyber-security also need to be considered. This theme is also one that involves many parties and require careful considerations before solutions are selected. It is of outmost importance that the international shipping community can agree on one integrated approach in this area.

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