TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 10
Number 1
March 2016
DOI: 10.12716/1001.10.01.05

Bridging IMO e-Navigation Policy and Offshore Oil and Gas Operations through Geospatial Standards

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ABSTRACT: In offshore industry activities, the suitable onboard provision of assets location and geospatial marine information during operations is essential. Currently, most companies use its own data structures, resulting in incompatibility between processes. In order to promote the data exchange, oil and gas industry associations have pursued initiatives to standardize spatial information. In turn, the IMO - International Maritime Organization - started the implementation of e-Navigation policy, which is the standardization of technologies and protocols applied to maritime information and navigation.
This paper shows relationship and integration points between maritime activities of oil and gas industry and e-Navigation technologies and processes, highlighting geospatial information. This paper also preludes out an initiative for a suitable product specification for the offshore oil and gas industry, compliant with e-Navigation and IHO S-100 international standards.

1 INTRODUCTION

Currently, more than a third of the world's oil and gas production comes from offshore fields. The exploration, development, construction, production, logistics, maintenance and decommissioning of these fields are necessarily made by maritime units, which can be vessels or floating platforms. For such operations to occur, the provision of appropriate maritime information, including the positioning of subsea and surface assets, becomes essential (Cain et al. 2008).

Offshore operations are planned and monitored by ashore teams and are performed by onboard professionals. The ashore teams have a wide infrastructure that includes broadband networks and direct multidisciplinary support. The onboard teams have limited telecommunications and due to space limitations, they must rely on experts in key disciplines only. This highlights technicians and coordinators in lead offshore specialties as well as deck officers dealing with vessels positioning and navigation.

Figure 1. Ashore team, Offshore specialist and Deck officer.

Over the past decades, offshore companies have been developing or incorporating several applications and spatial information systems for ashore and offshore activities. Due to the competitive nature of these services and the diversity of operational specialties, each of these systems has been developed using different spatial data concepts and schemas. Ashore planning and control systems are generally based on GIS (Geographic Information System) architecture, allowing for complex spatial analysis, but requiring professionals with intermediate or advanced knowledge of geomatics (McLay 2000). Offshore specialty systems dealing with spatial information are generally limited to visual queries or measurements and in a few cases, data entry; but on the other hand, the user is required to merely have a basic knowledge of geomatics (Shukla & Karki 2016).

Unlike offshore specialties, the IMO (International Maritime Organization), the United Nations agency for maritime affairs, internationally standardizes navigation systems, which essentially use the spatial information. In 2006, the IMO initiated the e-Navigation policy, which includes resolutions, technologies and harmonized protocols for the provision of maritime information. However, the e-Navigation concept is designed primarily for merchant shipping and passenger transport and to this day does not address the peculiarities of offshore activities (IMO 2007).

As a result of this diversity, the information exchange between planning, execution and offshore navigation is limited, most often making use of pictures, printed maps, vectorial files without aggregated information and lists of coordinates. In result, the restrictions on sharing spatial information inevitably bring about an operational inefficiency. When it comes to spatial data in a region with several maritime units, subsea facilities, underwater vehicles and the production of oil or gas, any mistake may result in an accident of huge proportions (Koppaetzky 2013).

This paper shows the use of spatial information on offshore oil and gas operations, existing spatial data frameworks and the e-Navigation policy. This paper also shows integration points between offshore operations and e-Navigation policy, including the use of its indicated data framework, the IHO S-100.

2 OFFSHORE OPERATIONS, SPATIAL INFORMATION AND E-NAVIGATION

2.1 *Offshore Operations and Spatial Needs*

The offshore industry, especially at oil and gas production, requires a range of operations to be performed by platforms or vessels. Production platforms are stationary and do not usually execute processes that require spatial information, while vessels and drilling rigs inevitably require spatial data. To perform the offshore activities, most of these vessels use DP (Dynamic Positioning), which is a system that automatically controls the position and heading of a vessel by means of active propulsion, and other devices that deal with spatial data (Sii et al. 2006).

In addition, the accuracy positioning of offshore activities is important with respect to national and international maritime boundaries and oil and gas lease allocation. Knowledge of the geospatial boundaries of these interests are instrumental in the final positioning of production platforms (ACLS & CHA 2006).

The following is a brief description of the main offshore operations groups and their sensitive spatial information for onboard teams:

2.1.1 *Supply and Offload*

Supply are shipping operations of supplies among platforms and shore ports. Offload are shipping operations for gathering the oil produced on platforms. The monitoring of distances between vessels and platforms is essential. The spatialized awareness of safety zones as well as cranes reach, ***DP*** (Dynamic Positioning) reference devices and hose connectors increases the safety of these operations (GOMO 2013a).

2.1.2 *Rig-move and anchoring*

Operation of platform towage and placement by vessels, including the handling, launching and recovery of platform anchors. The spatial knowledge of local subsea infrastructure and anchor launch points is essential. The monitoring of the exact position of all vessels involved, the platform and its connections, significantly increases the safety of these operations (GOMO 2013b).

2.1.3 *Survey*

Operations for mapping or gathering samples from the seabed, sub-seabed or water. The spatial information is the product of these operations. The monitoring of sensors for exact positioning is essential. Prior knowledge of subsea infrastructure is important. In geophysical mapping operations, it is important for the safety of navigation to broadcast the mapping plan area to nearby vessels (IOGP 2013).

2.1.4 *Subsea Engineering Operations*

Operations dealing with pipelines, subsea equipment or other devices, using unmanned vehicles or human diving support. The spatial knowledge of subsea infrastructure and the exact monitoring of underwater vehicles, as well as the devices during their installation is essential (Bai & Bai 2010). The main subsea operations are:
- Installation or removal of pipelines and cables;
- Installation or removal of subsea equipment;
- Subsea inspection, maintenance or repair.

2.1.5 *Subsea wells construction*

These operations, including drilling and intervention, are performed by platforms known as drilling rigs that as per international norms are considered equivalent to vessels (IMO 2009). The spatial knowledge of seabed and subsea infrastructure increases these operations safety. For DP rigs, accurate monitoring and permanence of their position relative to the well location is a necessity (Chen et al. 2008).

Figure 2. Subsea operations (source: IMCA)

2.1.6 *Contingency control (oil-spills)*

Operations in readiness, control, gathering or dispersion of oil spills or other offshore emergency response. This kind of operation does not usually require an onboard specialized software. The spatial awareness of targets or perimeters received from the operations center, as well as navigation, positioning and orientation in relation to these targets and the perimeters is essential (Chaves 2004).

2.1.7 *Simultaneous Operations (SIMOPS)*

Condition where two or more potentially clashing operations occur simultaneously. In a SIMOPS, beyond the sensitive spatial information for each operation, monitoring the distances between vessels and platforms involved is essential as well as the spatial knowledge of waiting, restriction, approach, action and escape sectors (IMCA 2010).

Figure 3. SIMOPS illustration (source: kongsberg.com)

2.2 *Offshore Spatial Data Standards*

In order to carry out an offshore vessel operation, the spatial and non-spatial information has to transit through ashore and onboard systems. In the absence of a unique offshore data pattern, each company uses its own systems and consequently their own standards for the information exchange.

Since the 90s, councils have created spatial data standards for generic purposes. Actually, the two majors councils are OGC (Open Geospatial Consortium), that specify spatial data content and sharing, and TC 211 (Technical Committee 211 of International Standardization Organization), that maintain the ISO 19100 series of standards of Geographic Information (Westdijk 2015).

In recent years, the oil and gas industry has tried to standardize data structures. Institutions such as IOGP (International Association of Oil & Gas Producers), OGC, PODS Association and POSC Caesar Association have been meeting in SLC (Standards Leadership Council) looking at harmonizing existing initiatives (Hollingsworth & James 2015).

It follows some of the main spatial data standards related to offshore activities:

2.2.1 *UKOOA P-formats*

Offshore positioning data exchange standards of former UKOOA (UK Offshore Operators Association), absorbed by Geomatics Committee of IOGP. The P1, P2 and P6 standards deal with positioning in geophysical mapping, P5 with pipeline position and P7 deals with wells position. For data schemas, the obsolete P5, published in 1994, had already specified attributes and a list of possible pipeline components (UKOOA 1994).

2.2.2 *APDM – ArcGIS Pipeline Data Model*

Spatial data model for pipelines that uses the ArcGIS proprietary system of ESRI company. The APDM is maintained by a user group of the model, but it is unrelated to the SLC. The current version, 6.0, does not have offshore particularities, but could be adapted by the user. Currently, ESRI recommends UPDM (Utility and Pipeline Data Model) not recognized by the SLC either (APDM 2014).

2.2.3 *PODS – Pipeline Open Data Standard*

Data model for pipelines and their accessories, maintained by the PODS Association. The PODS model is not spatial, although it is usually implemented in GIS architecture, but not following neither ISO 19100 series nor OGC recommendations. The current version, 6.0, has several functional modules, one for offshore particularities. Onboard systems do not currently use PODS model (PODS 2013).

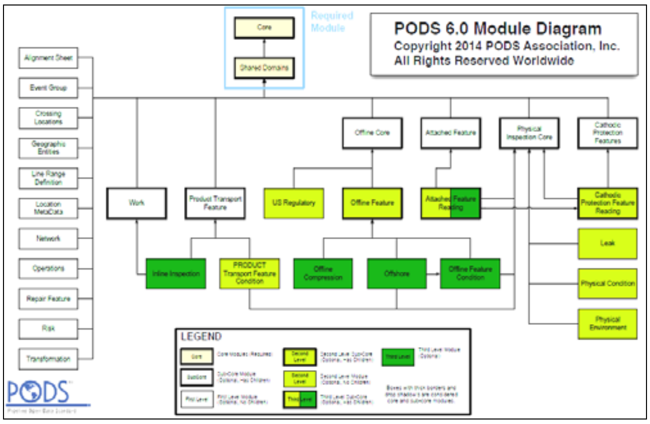

Figure 4. PODS 6.0 modules diagram (source: pods.org)

2.2.4 *PipelineML*

Spatial data exchange standard for pipelines and their accessories, maintained by OGC. The PipelineML began at a memorandum between PODS Association and OGC, is based on GML (Geography Markup Language) open schema and is currently under development. Unlike data management models, such as PODS and APDM, PipelineML aims to the information exchange between applications (Tisdale et al. 2015).

2.2.5 *ISO 15926*

Set of standards for data integration between industrial components, including oil and gas industry. The ISO 15926 series is composed of a semantic web ontologies library and a generic data model, but it is incompatible with ISO 19100 or OGC standards. The ISO 15926 series is maintained by a group of institutions, and the POSC Caesar Association provides the ontologies library on its website (Leal 2005).

2.2.6 *SSDM – Seabed Survey Data Model*

Data exchange standard for subsea mapping and sampling, maintained by Geomatics Committee of IOGP. It was launched in 2011 on an ESRI proprietary schema and in 2014 was published on GML open schema as SeabedML, following some ISO 19100 standards. The SSDM is designed to represent natural features or isolated devices that are not part of a subsea engineering infrastructure (IOGP 2014).

2.2.7 *Oil Spill Response COP*

Set of recommendations for oil spills response, OSR-COP (Oil Spill Response - Common Operating Picture) is maintained by IOGP and IPIECA (International Petroleum Industry Environmental Conservation Association). OSR-COP was published in 2015 with support from OGC and recommends a common scenario and portrayal to act in a OSR, but without determining a spatial data schema (IPIECA & IOGP 2015).

2.3 *e-Navigation*

For the early twenty-first century, the IMO has defined the implementation of e-Navigation as a priority, which is the policy that meets standards, resolutions, technologies and international protocols for providing maritime information.

In 2008 the IMO has established the following definition: *"e-Navigation is the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment."*

In coordination with IMO, other international organizations such as IHO (International Hydrographic Organization) and IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities) have led the e-Navigation policy. Unlike the international oil and gas associations, which suggest technical standards, the IMO resolutions have legal force in member countries (IMO 2008b). Technologies that are based on e-Navigation include:

2.3.1 *AIS – Automatic Identification System*

System for exchanging safety messages between vessels. AIS onboard equipment provides automatic sending and receiving real time position information between vessels, as well as other short messages for the safety of navigation. AIS uses VHF (Very High Frequency) and its information can also be received and sent by equipment on land and as of lately can also be received by low orbit satellites (IALA 2012).

2.3.2 *ASM – Application Specific Message*

AIS generic message available for use in specific applications. IALA, through the e-Navigation policy, standardizes international ASM. Examples of standardized ASM are Hydrographic Meteorological Data for broadcasting wind and current information and Area Notice for transmitting geometries with text to warn of circumstances at sea (IMO 2010).

2.3.3 *ECDIS – Electronic Chart Display and Information System*

Onboard equipment for navigation information queries. The ECDIS brings and represents spatial information from electronic charts, vessel position, AIS, radar information, among others. On several offshore vessels, IMO requires a certified ECDIS, while in the others the simplified equipment ECS (Electronic Chart System) may be used (IMO 2008b).

2.3.4 *ENC – Electronic Navigational Chart*

Nautical Charts for ECDIS use. The IHO defines the ENC data structure through IHO S-57 data exchange standard and IHO S-52 symbolization standard. The IHO S-57 architecture, designed in the 90s for merchant shipping, does not allow expansion to specificities of other marine applications (IHO 2000).

2.3.5 *IHO S-100 – Universal Hydrographic Data Model*

Spatial data framework for any use related to the sea in systems such as GIS and ECDIS. The IHO S-100 standard, released in 2010 by IHO, is based on the ISO 19100 series of standards (IHO 2015). It was chosen by IMO as the e-Navigation data framework and will be compulsory for navigation systems after a transition period with IHO S-57. Any maritime activity could develop an S-100 based product specification for its purpose and if it is desired to make it official, it should go through the IHO registration process (Astle & Schwarzberg 2013). Below, some IHO S-100 official product specifications:
- S-101 - ENC, under development schedule;
- S-102 - Bathymetric surface, published in 2012;
- S-411 - Sea ice information, published in 2014.

Figure 5. AIS equipment, ECDIS and ENC portrait (imo.org)

2.3.6 *INS – Integrated Navigation System*

Onboard equipment that integrates all functions related to navigation, such as ECDIS or AIS. The INS aims to simplify the deck officer's duties. It may also include functions that are non-navigational (IBS - Integrated Bridge System). The latest IBS integrates DP control system, which may imply the need for future e-Navigation patterns usage in the Dynamic Positioning control subsystems (Alexander et al. 2004).

3 OFFSHORE AND E-NAVIGATION JOINING

By IMO definition, the e-Navigation policy harmonizes maritime information and includes not only onboard systems but also ashore ones. The oil and gas industry has already started to use information in accordance with e-Navigation standards (IMO 2008a). Within this integration, we highlight the AIS use for monitoring vessels, the e-NOffshore project led by Petrobras and the UFF (Universidade Federal Fluminense) project for the offshore operations product specification overture based on IHO S-100 framework. Such examples are explained below:

3.1 *AIS monitoring of offshore vessels*

Offshore operations are planned ashore and the monitoring of its progress is very important to the compliance certainty or to start a contour process. AIS has an open data protocol and since 2002, its use is mandatory in almost all offshore vessels. In light of these factors, companies performing offshore activities usually prioritize this technology for monitoring their maritime operations or the archiving of trajectories. Thus, the use of AIS for offshore monitoring is already established and recommended by a number of industry guidelines (IPIECA & IOGP 2015).

The AIS data availability in planning and control systems occurs through receivers on the coast, platforms, ships, or low-orbit satellites, which then relay these messages to a data network. For onboard offshore specialties, some systems use AIS as a monitoring auxiliary way. For deck officers, AIS is routine and its information is consulted at ECDIS or ECS and in some cases on the AIS device itself or other systems (Ahmed & Al-Marzooq 2008).

3.2 *e-NOffshore Project*

In 2014, Petrobras began the e-NOffshore Project in order to evaluate offshore operations using only onboard e-Navigation systems. As the AIS and S-57 current patterns do not represent a platform and operational details dynamically, an ASM was developed for this purpose. Another need was to display subsea infrastructure components in ECDIS or ECS, nonexistent in S-57 standard. Since then, a test was performed in an offshore operation. The following is a brief description of ASM, the subsea data displayed and the performed test:

3.2.1 *OUD – Offshore Unit Dimensions*

ASM developed to describe the edges, surrounding safety area, cranes range, as well as control points and other features of a platform. OUD protocol associates the usual platform's position AIS message, then the OUD representation on the vessel ECDIS moves as the platform moves. The OUD message can be received by any AIS vessel, but the ECDIS connected to these receivers should have the OUD protocol on library in order to display the message content. The company CNS Systems has implemented the OUD, decoding it in its ECS. The OUD message was published under the status "draft" in the IALA e-Navigation repository (Modesto 2014).

3.2.2 *S-57 for Subsea infrastructure*

As the project intends to only use navigation systems and the current ENC´s do not provide complete offshore subsea infrastructure, the spatial database was converted to the S-57 standard. Pipelines and cables are basically represented in the S-57 standard, but wells and subsea equipment, and other features are not considered in this standard. To represent such features, it was necessary to use the S-57 generic object "obstruction", with a literal description associated with the feature type. Offshore features and some of its attributes have been converted to the S-57 standard with the support of CARIS company using the software S-57 Composer (Quick et al. 2009).

3.2.3 *e-NOffshore Testbed*

The first test of e-NOffshore project took place in 2015, in a SIMOPS involving a barge installing a pipeline and a vessel launching and recovering the barge anchors. The ASM OUD, representing the barge edges and characteristics, and ASM Area Notice, representing where the barge anchors were spiked, were sent from the barge to the vessel. For each barge movement, a corresponding Area Notice circle was sent, signaling the anchor to be picked up and the point of new release. The ECS vessel also displayed the pipeline laying project line together with other pipelines in the region, which helped avoid throwing anchors on them. Onboard experts and nautical officers said that the tested procedure was more efficient and reliable than the usual procedure. The e-NOffshore Testbed is under a recognition process by IALA (Modesto 2015).

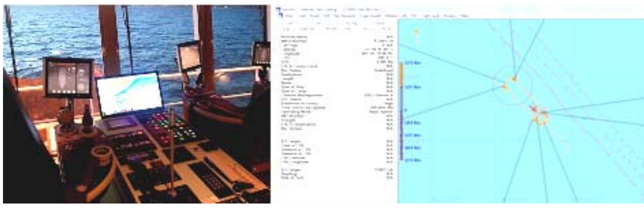

Figure 6. e-NOffshore Testbed : Operation portrait on ECS.

3.3 *IHO S-100 for Oil and Gas Infrastructure*

The IHO S-100 standard is a potential point of contact for the exchange of operational spatial data of oil and gas infrastructures, in particular on board. The following factors illustrate reasons for using the IHO S-100 framework:

– The OSR-COP Work Package sets out eleven spatial information concerns that should be standardized for a contingency operation, and Oil and Gas Infrastructure is one of them, but does not identify or suggest a currently existing data structure in this concern.
– The OSR-COP strongly recommends the IHO S-100 use as "*framework for the development of the next generation of ENC products, as well as other related digital products required by the hydrographic, maritime and GIS communities*".
– The pipeline data models, such as PODS and APDM, are focused on database management but not data exchange, having unnecessary relationships and classes for onboard operations, as well as they are incompatible with onboard specialized or navigation systems.
– The Existing standards for pipeline data exchange, as the former UKOOA P5 and the under development PipelineML are not currently implemented neither onboard specialized systems nor navigation systems.
– The ISO 15926 series defines ontologies for network use, which is limited onboard by telecommunications constraints, requires long development of an offshore semantic model and is unsuitable with onboard systems.
– The subsea infrastructure data of the e-NOffshore project were limited by the IHO S-57 standard inability to represent offshore basic objects, which would be solved through the IHO S-100.
– The IMO e-Navigation Strategy Implementation Plan, beyond choosing IHO S-100 framework for navigation systems, identifies six areas for the delivery of Maritime Service Portfolios, and the offshore area is one of them.
– Currently, the IHO Geospatial Information Registry, available online by IHO, does not include any product specification for the offshore domain.

Considering these facts, a research project currently underway at UFF with the support of Petrobras, aims to develop an Oil and Gas Infrastructure product specification, fully compliant with the IHO S-100 framework and focused on maritime operations. The research also proposes improvements on the offshore objects of IHO FCD (Feature Concept Dictionary) in order to be usable at offshore operations (Modesto & Bazilio 2016).

The intended proposal for a Oil and Gas Infrastructure product specification based on the IHO S-100 will include the subsea engineering, the basic characteristics of platforms and the operational sectors. The subsea engineering includes pipelines, wells, equipment and other subsea structures or inspection features. The platforms characteristics include anchoring systems and references for vessels approaching or operation. Operational sectors include restriction, wait, approach, act and escape areas near platforms, as well as disclosure of geophysical mapping areas or oil spill response areas.

This Oil and Gas Infrastructure product specification takes the SLC related existing standards as benchmarks and try to inherit most of their characteristics and offshore domain knowledge. It would hold a wide industry expertise and allow for an easy interchange of information amongst related applications, whether ashore management systems, onboard specialist systems or vessel navigation systems.

The UFF Project uses as benchmark:

– Framework and constraints: IHO S-100
– Initial Application Schema: PipelineML
– Feature Catalogue: PODS (offshore module)
– Additional Feature Catalogue Items: UKOOA P5
– FCD (offshore domain): ISO 15926
– Data Product format: GML (PipelineML)
– Portrayal: OSR-COP and related documents

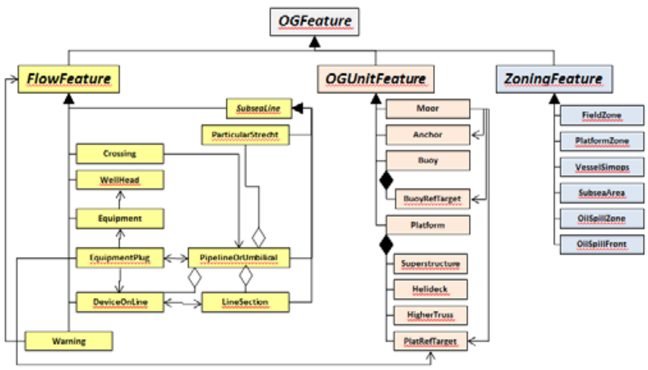

Figure 7. UFF Oil & Gas S-100 draft application schema

4 CONCLUSION

Currently, companies that provide services in offshore operations use a diversity of data structures for spatial information exchange, which brings inefficiency or risk of accidents. In recent years, some standards have been developed for the offshore industry, especially in institutions associated with the Standards Leadership Council. But so far no standard meets the stages of planning, onboard specialties execution and navigation. For navigation in general, the IMO e-Navigation policy directs the standardization of spatial data for the IHO S-100 framework.

The integration of offshore specialized systems through e-Navigation policy has a great potential. Currently there is already e-Navigation technology applied to offshore operations, while other initiatives are under development. Research conducted at UFF, which aims to propose an exchange data specification for oil and gas infrastructure, using the S-100 framework and referenced by other standards related to SLC is a potential means for this integration.

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