IALA

GUIDELINE

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REQUIREMENT TRACEABILITY

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1 WHAT IS REQUIREMENT TRACEABILITY?

Requirement traceability is the capability to retrieve the originator(s) of a requirement for any given technical feature that is implemented in a technical system. A requirement can be specified in terms of performance, schedule, costs or otherwise (e.g. lifecycle management). Specifically, requirement traceability is the ability to describe and follow the life of a requirement as it changes over time, in both forward and backwards direction: i.e. starting from user needs or expectations down to final acceptance tests ('top-down') or reverse (i.e. 'bottom up').

Requirements can originate in the political domain (via e.g. public consultation processes, Marine Spatial Planning, etc.), in risk management for waterways (as Risk Control Options), in the end user domain (as user needs and/or specific user requirements), in the business cases of service providers that provide Maritime Services to the mariners, in regulatory bodies (e. g. by IMO instruments), in the lifecycle management, quality management, cyber security domains, and – last but not least – in both the technical and the technology domains themselves.

To describe a technical system for procurement and/or deployment, the requirement traceability analysis is an important task of a systems engineering process and is usually performed by means of developing a requirement traceability matrix or system. These requirement traceability systems assure that all initially stated as well as additionally derived requirements are associated with corresponding design elements, system components, modules and project deliverables. This 'top down' direction of requirement traceability is called forward trace. It is also possible to use the traceability to point out the original source of a requirement to justify to the final user why certain features were included (or *not* included), i.e. being able to perform a backwards trace.

2 RELEVANT ESSENTIAL FEATURES OF REQUIREMENTS

Requirements that describe the necessary functions and features of the envisioned technical system, are often organised hierarchically. The high-level requirements state what should be achieved, not how to achieve it. Also, requirements are specified at every level, from overall system to single hardware and software components.

Requirement traceability has a number of characteristics:

- Requirements can be individual, distinct and discrete, or can be broken down to individual, distinct and discrete requirements.
- There is (and there must be) at least one originator of any requirement: any requirement without an originator firmly committed to that requirement should be deleted.
- There should be clear-cut rationales for all individual requirements that explain why the requirements were established originally. If the rationale for establishing a requirement disappears or becomes unclear over time, then either the rationale should be updated or the associated requirement deleted.

Requirement traceability has a number of implications:

- If an individual requirement has more than one originator, then they should agree on the definition of that requirement.
  - If this harmonisation process fails, then individual requirements should be developed for each originator and rationale.
  - The resulting requirements are likely to be similar, yet unique. Proliferation of variants of a requirement is likely to lead to excessive implementation expense. In that case, the originator(s) for the variants need to be identified and connected to 'their' specific requirement; i.e. requirements need to be traced back to their originators.
- To handle the complexity incurred by many requirements thus established, a requirement management system should be used. Its scope should cover the envisioned technical system as a minimum.

- The existence (or absence) of an adequate requirement management system will influence the system engineering process as soon as the design, build and eventual operation of the envisioned system is started.
- To ensure the user gets what is needed, and/or required, it is paramount that an appropriate requirements management system is used – and that requirement traceability is achieved.
- The international standard ISO 19600:2014 on "Compliance Management Systems – Guidelines" [1] provides the foundational methodology for requirement management as a subset to compliance management by applying the well-established Plan-Do-Check-Act (PDCA) management cycle. The "Seilevel Requirement Management Tool Evaluation Report 2016" [2] introduces and systematically compares a large variety of such commercially available tools.

3 INDICATIONS IN THE INTERNATIONAL DOMAIN OF THE NEED FOR REQUIREMENT TRACEABILITY

There are several developments in the international domain which suggest that both requirement traceability and requirement management system(s) are required or at least implied. The following are some of those developments:

- The International Maritime Organization (IMO) has explicitly identified a plurality of ship-board, shore-based Search & Rescue stakeholders [3]. The identification of multiple stakeholders suggests the recognition of the importance of requirement traceability in the most abstract sense: the different stakeholders are all participating in the *same* maritime domain, hence they all need to use at least to some extent the same resources in the maritime domain because otherwise these resources would likely not viable or not cost efficiently deployable.

  The following questions were left, at least to some extent, unanswered: Which stakeholder has what requirements? Are they clearly stated? What are their relative bearings on the overall requirement setup? Which stakeholder should be approached for further clarification or refinement of the requirement, if that were needed in the course of system development and implementation? These questions highlight the need for comprehensive requirement traceability.
- The need to share resources to fulfil similar stakeholder requirements is particularly true for technical services and systems that interact with shipping, such as technical voice and data communication services. With the advent of the digital age, the need to share resources has led to the recognition that the Maritime Connectivity Platform [4] or an equivalent is needed.
- The advent of an 'overarching e-navigation architecture' in general and of the 'Maritime Services (MS) in particular highlight the importance of requirement traceability [5].
- Implicit to that architecture is the notion of a hierarchy of operational services and technical services; and amongst them (refer to [5], paragraphs 27.1/.2). The hierarchy between services leads inevitably to a hierarchical 'requirement chain' which further suggests the need for requirement traceability.
- There is an international trend towards further integration of shipboard systems and functions for the benefit of the mariner: integration of previously separate functionalities and systems lead to the need for harmonization of their respective requirements; thus leading to a need for requirement traceability from the integrated system or integrated functionality back to the respective originator or originators. IMO's ambitions for 'harmonization of bridge design and display of information received,' amongst others, 'via communications equipment' [6] are a point in case.

Consequentially, the international community already has developed and documented an initial recognition and acceptance of the necessity for requirement traceability and requirement management system(s). Some international organizations have already developed mature contributions to future international requirement traceability, as follows:

- The International Hydrographic Organization (IHO) incorporated the concept of requirement traceability into its S-100 Geospatial Information (GI) Registry [7, 8]: There, the objects entered into their Registry are tagged with an “owner” designation. There are also topical “Domains,” which have so-called “Domain Owners”. The concept of the “ownership” means that the tagged entity can only be amended, should there be a need in the due course of maintenance of the Registry, after the respective “owner” has been consulted.

  The process for this is described in the IHO S-99 standard [9]. To assign “ownership” and to procedurally run the associated mechanisms for any amendment is already an example of requirement traceability: “Somebody,” i.e. at least the “owner” of a specific entity, must have formulated a valid rationale for requiring the entry of that entity into the IHO GI Registry.
- IALA, when creating a strand of documents on shore-based system architecture, treated the notion of requirement derivation and requirement traceability as a matter of high importance, as illustrated by the following examples:
  - ‘Only clearly and consistently stated user requirement result in the technical service provided’ (IALA Recommendation e-NAV 140 [10], Recommends No. 2).
  - IALA Guideline 1113 [11], which directly support the above IALA Recommendation e-NAV 140, even provides a dedicated chapter on ‘Seamless and traceable derivation of system engineering requirements from user requirements’ (compare Table 1 overleaf).

Topic of layer and name of layer (if defined)	Sub-divisions ('sub-layers,' if any)	Administered item of layer	System engineering process
Processes of the (Sustainable) Maritime Transportation System ((S)MTS)	to be determined in due course	Identified logistic processes of the (S)MTS	Informs user requirements
IMO User Needs	Shipboard, shore-based, SAR	Identified user needs	
Risk mitigating measures	to be determined in due course	Risk Control Options	Informs user requirements
Maritime Services (MS) definitions	Operational services	Individual MS, services delivered to shipping from ashore, their request/fulfilment dependencies, service parameters and their quality level definitions; 'product' descriptions for service	Informs user requirements
	Technical services		Informs system engineering requirements
Normative Collection of harmonized user requirements for shore-based technical system(s) of stakeholders assembled at IALA (possibly collected in a register to exploit the maximum of commonality between user requirements)	user requirements common to some or all stakeholders;	user requirements	
	User requirements specific to stakeholder	user requirements	Top-Down Path
Normative collection of unified or at least harmonized information portrayal features of the Operational Presentation Surfaces (HMIs) to shore-based users (to be stored in the Portrayal Register of IHO GI Registry)	to be determined in due course	presentation library entries, portrayal descriptions, and/or presentation requirements	
Normative collection of harmonized or even unified data objects and their properties within 'IALA Domain' within the IHO's GI Registry	Feature Concept Dictionary Register	Features' = data objects which in turn are meta-level abstractions of real world entities	Bottom-Up-Path
	Meta-data Register	Meta-level description of above features, such as parameter quality tags and measures	
Normative collection(s) of harmonized or even unified application level encoding prescriptions ('exchange formats')	Generic sentence definition layer	Encoding-free "sentences" (syntax and semantics for data exchange without giving encoding constraints)	
	Technology-specific sublayer(s)	Internationally harmonized technology-specific encoded "sentences" (e.g. in IEC 61162, AIS VDL message, or XML)	
Shore-based technical system and its architecture in system engineering terms: Common Shore-Based System (Architecture) (CSS / CSSA)	Generic part: generic service model	Entities of the CSSA, in particular technical services and their descriptions.	
	Technology-specific part of CSSA: individual specific services		
Procurement documentation with National / regional adaptations by IALA members			
Implementation architectures of manufacturers of shore-based equipment			

Table 1 Requirement traceability supported by layer hierarchy and system engineering process

Source: ([10], Table 2); updated regarding Maritime Services and risk management aspect added. The IALA Guideline on a technical specification for the Common Shore-based System Architecture (CSSA) [11] describes in the section 'The CSSA's support of Maritime Service Portfolios (MSPs) definition' how that technical specification specifically supports requirement traceability (compare [9], in particular section 4.3).

4 GUIDELINES FOR IALA MEMBERS

The above discussion leads to the following guidelines for IALA members:

- IALA members should establish requirement traceability as part of their requirement management.
- To maximise the benefit of requirement management, IALA members should participate in a globally harmonised requirement management and traceability schema for use within IALA's remit.

5 DEFINITIONS

Requirement traceability is the capability to identify the originator or the originators of requirements for any given technical feature that is implemented in a technical system (either performances, schedule, costs and others (e.g. lifecycle management)).

6 REFERENCES

[1] ISO. ISO 19600:2014. 'Compliance Management Systems – Guidelines; Systèmes de management de la compliance - Lignes directrices'. There may be available translations into other languages besides French, e.g. a German version DIN ISO 19600:2016.

[2] [2] Seilevel. 2016. Requirements Management Tool Evaluation Report, Edition 2016. URL: http://content.seilevel.com/assets/Website%20Downloads/2016-Seilevel-RequirementsTool-Evauation-Report-FINAL.pdf. Last access: 11th April 2019.

[3] IMO. 'Strategy for the Development and Implementation of e-Navigation'; Attachments 'Shipborne users', 'Shore-based users', 'Search & Rescue Users'. In: IMO Maritime Safety Committee. Report of the Maritime Safety Committee on its 85th Session. MSC 85/26/Add.1, Annex 20, 6 January 2009.

[4] EfficienSea2 Project. 2017. How to run MCP (Maritime Connectivity Platform) – formerly known as the Maritime Cloud. Workshop at IALA Headquarters, 21-22 November 2017.

[5] IMO. 'Draft IMO e-Navigation Strategy Implementation Plan (SIP).' In: IMO Sub-Committee on Navigation, Communication and Search and Rescue. Report to the Maritime Safety Committee. NCSR 1/28, Annex 7. 16 July 2014. London. Adopted by IMO MSC 94, 17-21 November 2014.

[6] Australia, Denmark, Finland, Germany, the Netherlands, Norway, the Republic of Korea, ICS, IALA, BIMCO, CLIA, InterManager and the Nautical Institute. Implementing e-navigation to enhance the safety of navigation and protection of the marine environment. IMO MSC95/19/8. 03 March 2015. Compare in particular the Annexes 2 (revised Performance Standards for Integrated Navigation Systems (INS)) and 5 (guidelines on Harmonized display of navigation information received via communications equipment).

[7] IHO/International Hydrographic Bureau. S-100 – Universal Hydrographic Data Model. Edition 3.0.0. April 2017.

[8] IHO/International Hydrographic Bureau. Operational Procedures for the Organization and Management of the S100 Geospatial Information Registry (S-99). Edition 1.1.0 – November 2012.

[9] IALA Recommendation e-Nav 140 on The Architecture for Shore-based Infrastructure 'fit for e-Navigation,' Edition 2, May 2015.

[10] IALA Guideline 1113 on Design and Implementation Principles for Harmonised System Architectures of Shore-based Infrastructure, Edition 1, May 2015.

[11] IALA Guideline 1114 on A Technical Specification for the Common Shore-based System Architecture (CSSA), Edition 1.0, May 2015.