

# Development of Requirements for Communication Management on Board in the Framework of the E-navigation Concept

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**ABSTRACT:** The current separation of communication systems and navigational systems on the ships bridge doesn't meet the requirements of the e-navigation concept of the International Maritime Organization (IMO) for safe navigation to include all means and information in the decision making. Hydrographical, meteorological and safety related information is presented on the communication equipment without filtering or as print-outs solely. A task oriented integration and presentation of this information on the navigational displays will support the officers in their decision making and enhance the safety of navigation. The core element onboard for the integration is the INS (Integrated Navigation System) concept of the IMO where a task and situation dependent presentation of information is specified based on a modular concept. Information should be automatically processed, filtered and integrated in the navigational information systems to support the users in their tasks. To achieve this goal a concept for communication management was developed. An Applied Cognitive Work Analysis (ACWA) is conducted to identify requirements for the design of a communication management system based on the cognitive processes of the operators. This paper describes the concept for communication management and, as a first result, gives the description of the domain of maritime communication that provides a basis for the identification of requirements for communication management in the framework of the e-navigation concept.

## 1 INTRODUCTION

The International Maritime Organization (IMO) identified the need to equip shipboard users and those ashore responsible for the safety of shipping with modern, proven tools optimized for good decision making in order to make maritime navigation more reliable and user friendly. In this framework the IMO decided on proposal of several member states to develop an e-navigation strategy to integrate and utilize new technologies in a holistic and systematic manner to make them compliant with the various navigational, communication technologies and services that are already available.

The e-navigation strategy aims to enhance berth to berth navigation and related services by harmonizing the collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means (IMO, 2007a). The e-navigation strategy is supposed to be user-driven not technology driven to meet present and future user needs (IMO, 2007a).

On behalf of the German Ministry of Transport, Building and Urban Affairs (BMVBS) an e-navigation user needs survey was conducted (Höckel

& Motz, 2010; IMO, 2009a; IMO, 2009b). One of the major issues which were identified was the need for user-selectable presentation of information received via communication systems on the navigational displays of the ships bridge. This need relates to, e.g., hydrographical, meteorological and safety related information, and was also found in user needs assessments of other member states and organizations provided to the IMO (IMO, 2009c).

The integration and presentation of information on board pertaining to planning and execution of voyages, assessment of navigational risk and compliance with regulations is an essential part of the e-navigation concept. The current separation of communication systems and navigational systems doesn't meet the e-navigation requirements of safe navigation to include all means and information in the decision making. Hydrographical, meteorological and safety related information is presented on the communication equipment without filtering or as print-outs solely. Technical as well as legal conditions (separation of responsibilities in the Safety of Life at Sea Convention – SOLAS chapters IV and V) hamper the integration of information provided

by communication equipment in the navigational systems, which reduces their utilization.

A task-oriented integration and presentation of this information on the navigational displays considering the fact that all necessary information for the respective task and situation, is on its disposal fast, reliable, consistent and easily interpretable will support the officers in their decision making and enhance the safety of navigation. The task-oriented approach for presentation and integration of navigational information as introduced with the revised performance standards for Integrated Navigation Systems (INS) (IMO, 2007b) based on the modular concept (IMO, 2008a) forms the basis for the integration of further information on board. Modular Integrated Navigation Systems (INS) according to the revised IMO performance standards for INS (IMO, 2007b) combine and integrate the validated information of different sensors and functions and allow the presentation on the various displays according to the tasks.

A communication management system should be employed on the bridge as an aid for the mariner in the accomplishment of communication tasks and as a mean for the provision of information to INS.

## 2 INS AND MODULAR BRIDGE

The aim of the INS specified according to the IMO performance standards (IMO, 2007b) is to promote safe procedures for the integration of navigational information and to allow that an INS is considered as "one system" that is installed and used as other means under SOLAS Chapter V regulation 19, instead of stand-alone navigational equipment onboard ships. These performance standards can be applied via a modular concept for either comprehensive integrations which are specified as INS or only partial integrations.

The purpose of an INS is to enhance the safety of navigation by providing integrated and augmented functions to avoid geographic, traffic and environmental hazards. The INS aims to be demonstrably suitable for the user for a given task in a particular context of use. An INS comprises navigational tasks such as "Route planning", "Route monitoring", "Collision avoidance", etc. including the respective sources, data and displays which are integrated into one navigation system. An INS is defined as such in the performance standards, if it covers at least two of the following navigational tasks / functions:

- Route monitoring
- Collision avoidance

An alert management is a required functionality of the INS as well as the presentation of navigation

control data for manual control. Other navigational tasks may also be integrated into the INS.

The following six navigational tasks are described in detail within the performance standards for INS (IMO, 2007b):

- Route planning
- Route monitoring
- Collision avoidance
- Navigation control data
- Alert management
- Status and data display

The scope of the INS may differ dependent on the number and kind of tasks and functions integrated into the INS. The performance standards for INS (IMO, 2007b) allow for a differentiated application of the requirements depending on integrated task and functionality.

With regard to the integration of information received via communication systems on the navigational displays the INS performance standards allow for the provision of tidal and current data, weather data, ice data, and additional data of the tasks 'navigation control' and 'route monitoring' on the status and data display. For 'route planning' the INS provides means for drafting and refining the route plan against meteorological information if available in the INS, while for navigational purposes, the display of other route-related information (e.g., monitoring of SAR manoeuvres, NAVTEX, weather data, etc.) on the chart display for 'route monitoring' is permitted.

With the modular bridge concept (Fig. 1), operational/functional and sensor/source modules are specified. This allows clear separation between operational requirements for the task orientated use and presentation of information on equipment and systems, and between the sensor specific technical requirements. The interfacing module specifies the connection and data exchange with other systems. Based on the modular bridge concept the design of future systems becomes flexible, task and situation orientated.

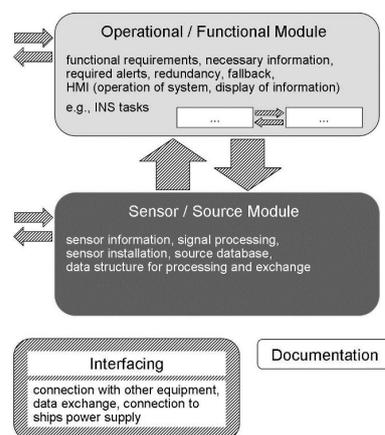


Figure 1. Modular Bridge Concept

### 3 CONCEPT FOR INTEGRATION OF INFORMATION RECEIVED VIA COMMUNICATION SYSTEMS

For developing a concept for communication management for the ships bridge the current communication infrastructure and procedures on board were analyzed. A literature review was conducted with regard to GMDSS required systems and additional technology. To identify further aspects for the determination of user requirements regarding communication management and conditions regarding the transfer of information from the communication systems into the navigational systems interviews with potential users were carried out.

Based on this information a concept for communication management was developed with the following objectives:

- Presentation of information received via communication systems on the navigational displays (INS) of the ships bridge
- User-selectable automatic filtering and processing of information to prevent information overload
- Provision of source and channel management (selection of best connection according to criteria, e.g., content, integrity, costs)
- Increased availability and reliability due to efficient use of different communication channels

Figure 2 provides a content-related visualisation of the communication management concept.

Basically an INS task for “Communication Management” is introduced to cluster information from different communication systems according to information type. Information is then routed to the navigational and other bridge systems or may be provided on request. Information clusters reflect the information types identified in the analysis of the communication infrastructure:

- Emergency messaging
- Navigational information
- Meteorological information
- Hydrographical information
- Reporting
- Communication with office
- Crew and passenger communication
- Special purpose applications

While data acquisition and data communication remain with the established communication systems, the communication management system provides source and channel management. This means that the connection for data communication may be selected based on certain criteria, e.g., integrity, content and costs. Criteria are adjusted at the human machine interface of the communication management.

Within the communication management system data is evaluated and clustered according to information type. Further processing and filtering allows for updating of previously received information, avoidance of information doubling, and selection of information relevant to the vessels’ type and route.

Data is stored in a database to be provided to other, e.g., navigational, systems on request, but also for presentation on the user interface of the communication management system. This presentation gives an overview of the data according to information type, data source, and time of reception. The user interface also serves as input device for the setting of parameters for filtering as well as source and channel management.

This concept for communication management provides the functionality for the presentation of information received via communication systems on the navigational displays of the ships bridge. The basis of this integration, however, lies in the modular, task-oriented bridge design.

The introduced communication management functionality can be integrated in the task-orientated concept described within the INS performance standards (IMO, 2007b) and the modular bridge concept (Motz et al., 2009b). It can be specified as a new INS task or as part of the INS task “status and data display” to allow for the management and routing of the information received via communication systems into the bridge systems for presentation and use.

The concept, nevertheless, is provisional and needs to be further investigated. In the following an approach for designing a communication management system is introduced, which examines the human cognitive processes for decision making. In order to develop requirements for the graphical user interface of the communication management system on board an Applied Cognitive Work Analysis (ACWA) is conducted.

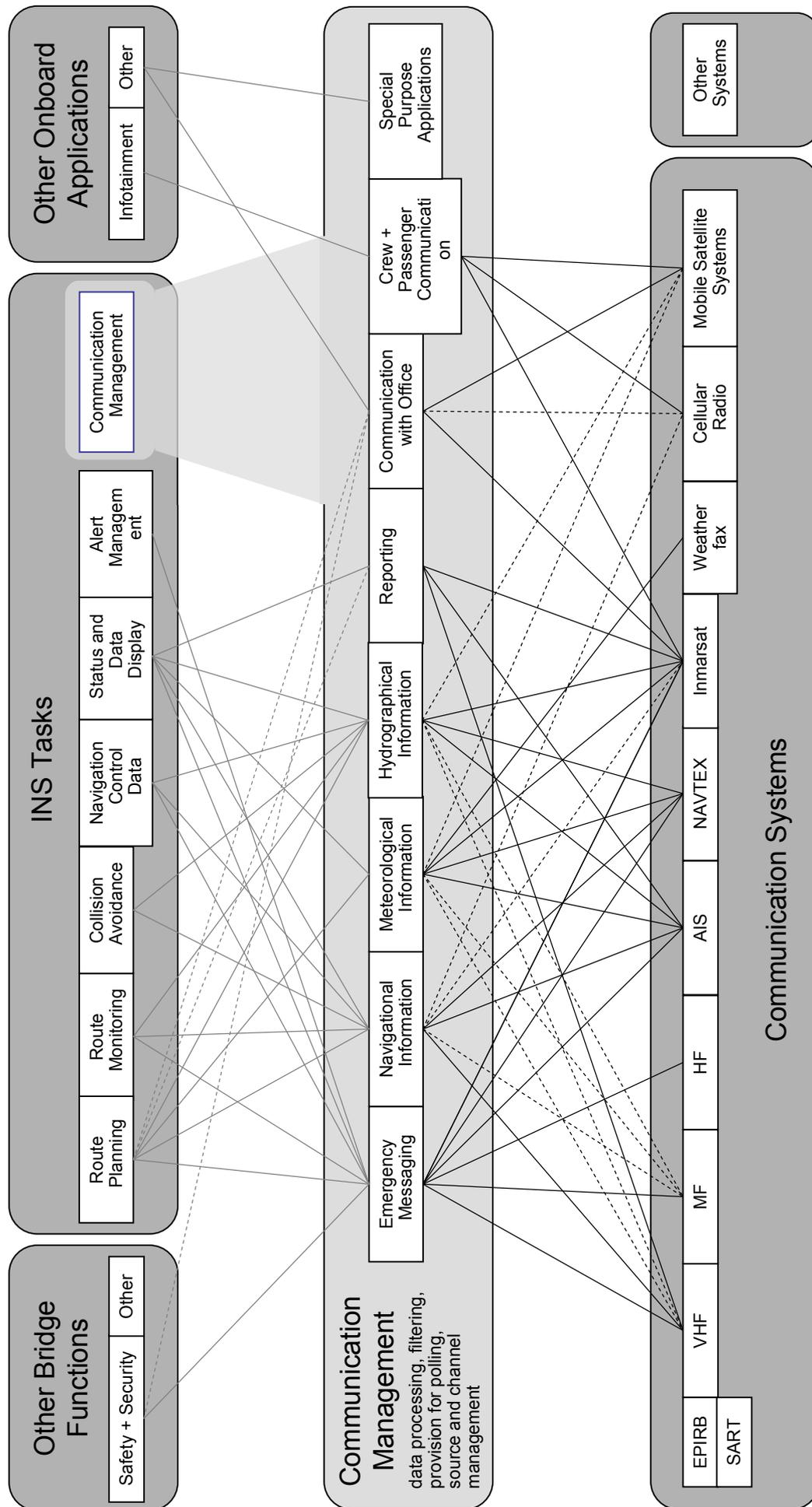


Figure 2. Concept for the integration and management of information received via communication systems

## 4 METHOD FOR DETERMINATION OF REQUIREMENTS FOR COMMUNICATION MANAGEMENT

### 4.1 *Problem description*

Ship's bridge systems are often designed by aggregation of different computer-based systems, which are developed independent from each other by different suppliers. In this manner new technologies are developed and integrated separately and the displays are designed according to the equipment, which is behind it, and not according to the cognitive demands of the task. The system development based on new technology is a bottom-up approach, where smaller subsystems are defined before linking them together to a large top-level system. To develop interfaces, which support efficient decision making of nautical officers, a top-down approach is required with design methods, which examine human cognitive processes and determine human cognitive needs.

Supporting the decision-making process of nautical officers demands understanding how decisions are made in real-world situations. The design of the navigation systems should take into account the cognitive demands of nautical officers to support them in their work.

A communication management system must not only manage the transfer of information, but also the integration of information, which are received via the communication systems, as this information must be processed and forwarded to a relevant task station in real-time to guarantee quick response.

### 4.2 *Applied Cognitive Work Analysis (ACWA)*

Cognitive Systems Engineering (CSE) is a design framework, which focuses on analysis of cognitive demands in order to identify cognitive processes of operators. For understanding cognitive demands of the people it is necessary to understand the environment in which people are acting. The environment can be the physical properties of a workplace, the demands of the tasks, the structural characteristics of the work domain or the organizational structure of the company. CSE is primarily focused on the work domain, its constraints, and goals to be reached in the domain. Methods of CSE help to understand, how experts make decisions and why they make certain decisions, what cues they need, what knowledge and strategies they use. Applied Cognitive Work Analysis (ACWA) is a method of CSE for the analysis, design and evaluation of complex systems and interfaces. ACWA applies the Rasmussen's abstraction hierarchy (Rasmussen, 1985) which describes the human information processing. With the ascending in the hierarchy the understanding for goals to achieve rises. Moving to deeper levels yields better

understanding for the system's functions with a view to achievement of these goals.

ACWA comprises the following process steps (Elm et al., 2003):

- Development of the Functional Abstraction Network (FAN) – a model to represent the functional relationships between the work domain elements. Each node in the network represents a goal, links represent support.
- Identification of cognitive demands which arise in the domain and need support – Cognitive Work Requirements (CWR) or decision requirements. At this step decisions, which are to be made to achieve the goals defined in the FAN, should be identified.
- Identification of the Information / Relationship Requirements (IRR) for effective decision-making. At this step the information required for each decision should be defined, which is of particular importance, given that the decision making is based upon the interpretation of information. Incorrect or incomplete information leads to wrong decisions.
- Definition of a relationship between the decision requirements and visualization concepts – Representation Design Requirements (RDR). This step defines how the information should be represented. The decision-aiding concepts should be developed on the basis of information requirements taking into account human perception and cognition.
- Implementation of representation requirements into a powerful visualization of the domain context – Presentation Design Concepts (PDC). A prototype, which supports the cognitive tasks through appropriate visualization, should be developed.

The ACWA depicts an iterative process, as with the development of a prototype to evaluate the effectiveness of the new system additional cognitive and information requirements for decision support, which were missed in the first steps, could be identified.

## 5 WORK DOMAIN ANALYSIS OF MARITIME COMMUNICATION

The first step of ACWA (building of FAN) was applied to the domain of maritime communication. Diverse knowledge elicitation techniques, such as reviewing relevant documents and interviews, were used to gain understanding of the domain. The purpose of FAN is to provide a base for definition of design requirements for a user interface for the communication management on board.

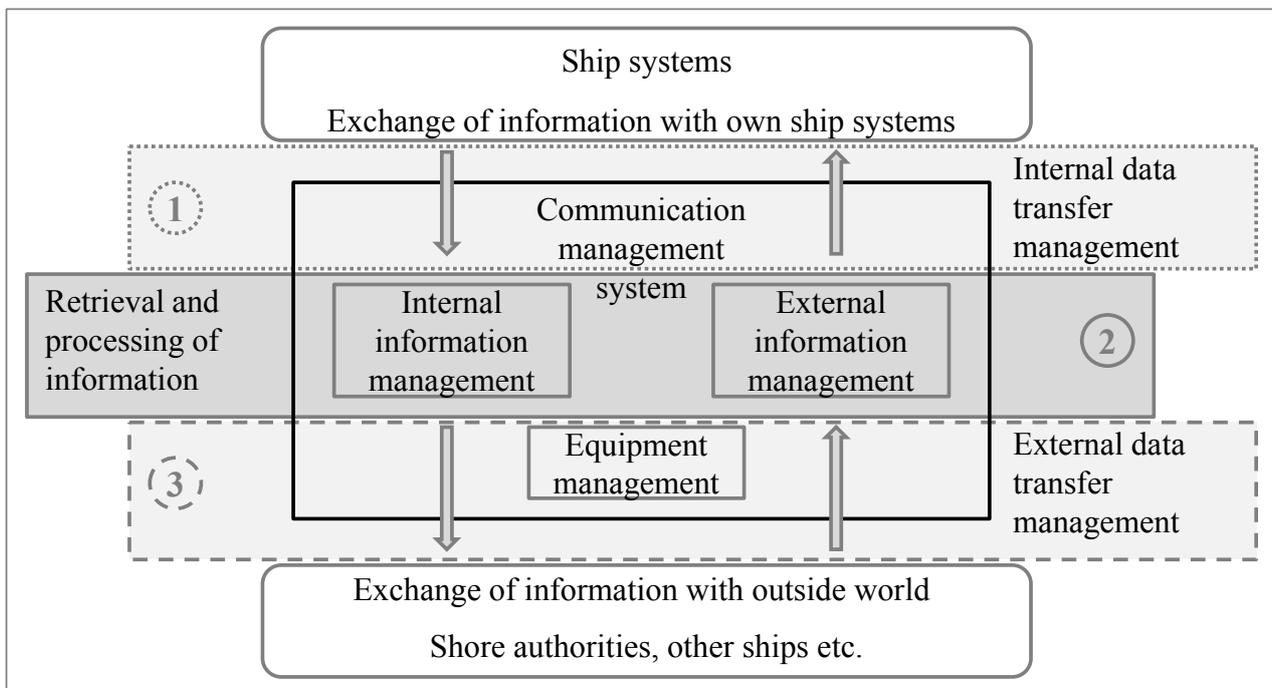


Figure 3. Three main functional areas of the communication management.

In Figure 3 the three main functional areas of the communication management are presented. One of the functions of the communication management is the exchange of information with the outside world, e.g., shore authorities, other ships (3). Another function is the exchange of information with own ship systems such as INS tasks (1). The exchange of information comprises the forwarding of information received through the communication equipment to systems on the bridge or INS tasks and the request of information from systems or INS tasks, which is intended for transmission via communication systems. Another function is the information management, which comprises retrieval and processing of both external and internal information (2).

Figure 4 represents the FAN for the domain of maritime communication. The goals are marked according to corresponding functional areas of the communication management system (see Fig. 3).

First of all the purposes and external constraints in the work domain were identified. The high-level goals are:

- Ensuring safety and security
- Attending administrative matters (organizational norms and goals)
- Attaining commercial goals (achieving the optimum turnover)

It is important to keep these high-level goals in mind while specifying the goals on the lower levels because of the norms and constraints that they define. To ensure these goals it is necessary to

- Navigate the ship safely
- Navigate the ship efficiently

– Keep the ship in an operable state  
 One of the most important goals, which supports all of the goals mentioned above, is the faultless management and maintenance of communication and information processing (G1). Communication plays an important part in gaining and forwarding information. The ship needs to provide information to diverse authorities on shore. The shore authorities, e.g., Vessel Traffic Services (VTS), shipping companies or port facilities, need to communicate important information to ships. Furthermore, the ship needs to receive (updates of) navigational, hydrological, meteorological and other information on a regular basis.

To successfully manage the communication and information processing (see Fig.4) the management of transmission and reception of information and also forwarding of the received information to eligible ship systems are required. To successfully manage the information transmission (G2) first of all it is necessary to summon the relevant information, which is requested by others or is scheduled to be transmitted (e.g., as a report). After the information is sent the storage of transmitted data takes place in order to provide a proper documentation of communication activities.

To manage the information reception (G3) it is important to control the incoming information in order to enable secure and faultless data transfer, which comprises recovery, decoding, and verification of received data. All information received via communication systems must be identified, evaluated and stored before it can be forwarded to other systems or used in any other manner.

To successfully manage the internal information forwarding (G4) the observation of incoming information must take place. The actual information, which is necessary to fulfill navigational or other tasks must be forwarded to eligible on-board systems and information requests from those systems must be processed.

Monitoring of the received information (G6) enables detection of new information or changes, so that notifications of the availability of new information can be made or existing information can be updated. It is essential to enable secure and error-free data transfer and provide the possibility to restore messages in case of transfer failures. Reliability control of information (G7) is, therefore, important to ensure security and safety of ship operations. On the other hand the classification of information must take place in order to identify the belonging of information to a certain information type.

Additionally, plausibility checks should be made with information sources onboard and between information provided by external domains to avoid possible errors and inconsistencies, which information from different sources could contain.

In order to transmit or receive information it is necessary to successfully perform data transfer (G5),

which includes providing of appropriate equipment for transfer and monitoring of data transfer in order to determine failures. The important step in the performance of data transfer is the determination of appropriate equipment (G8) for reception or transmission of information. This includes the determination of communication area (G9) and assignment of equipment to area (G10), which is important for planning the data transfer. First of all the area, where the ship operates, must be identified. Before choosing the appropriate equipment it is essential to determine, which communication equipment necessary to fulfill a certain communication task is available and/or adequate for the task. And that means to check, whether the available equipment is optimal, suitable or inappropriate in respect to its content, required bandwidth, costs... The equipment management (G11) comprises checking of functions, configuration (channel management) or troubleshooting of equipment. To enable successful equipment management a proper equipment inventory (G16) must exist. Location, connections, description and state of the communication equipment must be provided to support the decision maker in taking required measures, e.g., in case of failures.

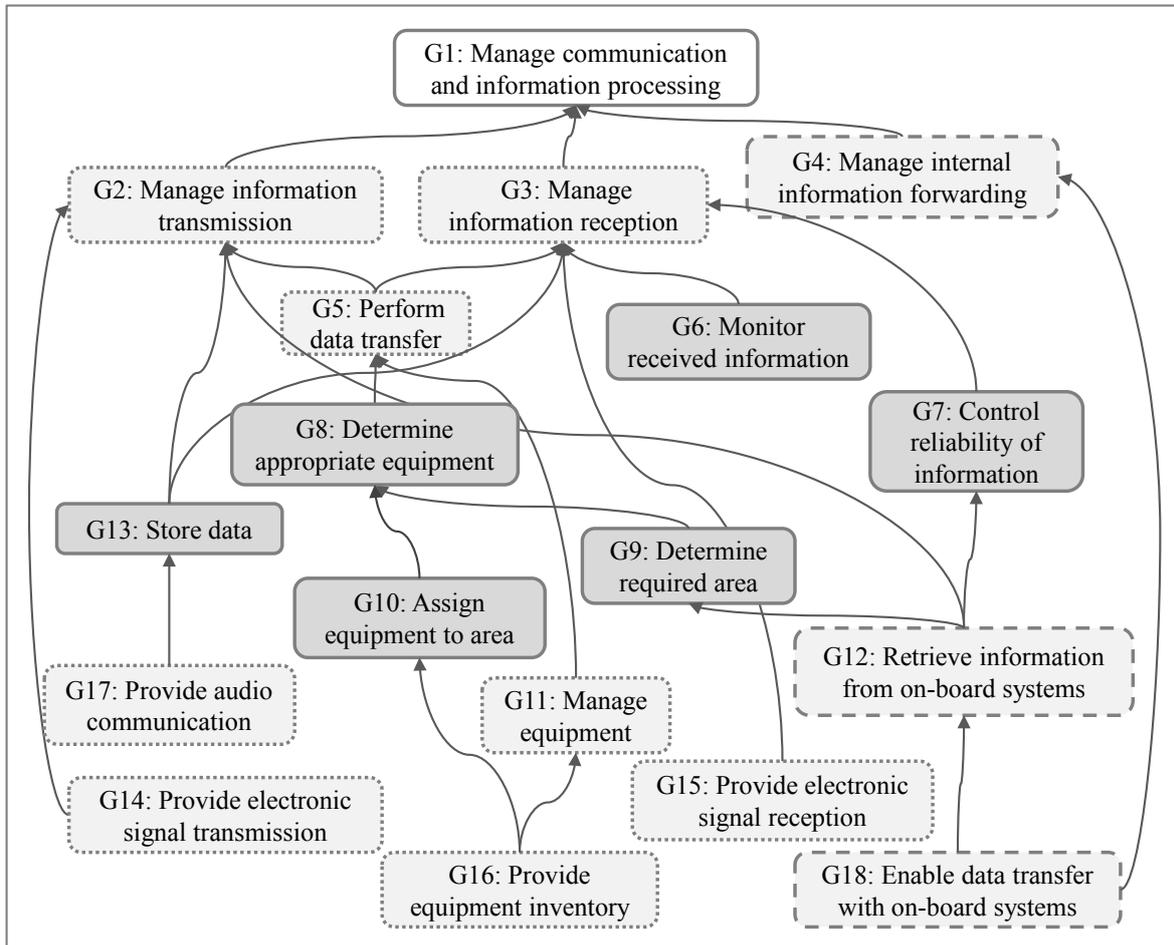


Figure 4. The FAN for the domain of maritime communication.

Further, transferred data must be stored (G13) and communication log must be generated. The information, which is received via communication systems, contains, e.g., navigational, meteorological, hydrographical, geographical and voyage data. Arrangement of data according to the type of communication equipment, the information type or the transmitting station must be provided.

Information retrieval from on-board systems (G12), which comprises the sending of a data request to other own ship systems and the reception of data from them, is necessary to provide intern ship information in order to transmit it via communication equipment, to compare incoming information with intern ship data for verification purposes, and to determine the communication area. The supporting goal (G18) is to enable the data exchange with on-board systems.

At last the supporting goals at the lower level, such as reception and transmission of audio and digital maritime communication information, are to be mentioned: the provision (G14) and reception (G15) of electronic signal transmission, as well as the provision of audio communication (G17). The latter is necessary to allow for the possibility to log audio communication information.

## 6 CONTINUATION

The FAN provides a basis for the definition of requirements for a user interface for the communication management on board. In further ACWA steps for each goal of the FAN the decision requirements, information requirements and decision-aiding concepts will be identified.

The relationship between the goals in the domain, the cognitive demands of nautical officers and the information required to make decisions are factors, which provide a basis for designing visual aids for decision support. The further steps are the development of a prototype for the graphical user interface of the communication management system on board and its evaluation.

The concept for communication management will be evaluated in expert reviews, e.g., with members of the national e-navigation working group. Interviews and observations will be conducted onboard ships to gain further insight into the circumstances and challenges of communication during usual operating procedure, and what kind of information is required for which INS task.

First solutions for the design of the human machine interface of the communication management

will be developed as paper prototypes and evaluated in brief user tests.

## ACKNOWLEDGEMENTS

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