



Acquisition Directorate

Research & Development Center

Report No. CG-D-06-18

RDC Review/Status of IMO MSI Systems

Distribution Statement A: Approved for public release; distribution is unlimited.

October 2017



Homeland Security

NOTICE

This document is disseminated under the sponsorship of the Department of Homeland Security in the interest of information exchange.

For use outside the United States Government, the Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.



Mr. Jim Fletcher
E&W Branch Chief
United States Coast Guard
Research & Development Center
1 Chelsea Street
New London, CT 06320



1. Report No. CG-D-06-18		2. Government Accession Number		3. Recipient's Catalog No.	
4. Title and Subtitle RDC Review/Status of IMO MSI Systems				5. Report Date October 2017	
				6. Performing Organization Code Project No. 6211	
7. Author(s) USCG Research and Development Center (RDC) - Ms. Irene M. Gonin and Alion Science & Technology (ALION) - Dr. Gregory W. Johnson				8. Performing Report No. R&DC UDI # 1731	
9. Performing Organization Name and Address Sonalysts, Inc. 215 Parkway North Waterford, CT 06385 Alion Science and Technology 1 Chelsea St., Ste 200 New London, CT 06320		U.S. Coast Guard Research and Development Center 1 Chelsea Street New London, CT 06320		10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. HSCG32-14-D-R00002/HSCG32-16-J-100007	
12. Sponsoring Organization Name and Address US COAST GUARD COMMANDANT (CG-652) STOP 7710 COMMANDANT (CG-NAV) STOP 7418 2703 MARTIN LUTHER KING JR AVE SE WASHINGTON, DC 20593				13. Type of Report & Period Covered Final	
				14. Sponsoring Agency Code US Coast Guard Commandant (CG-652) Stop 7710 Commandant (CG-NAV) Stop 7418 Washington, DC 20593	
15. Supplementary Notes The R&D Center's technical point of contact is Ms. Irene Gonin , 860-271-2694, email: Irene.M.Gonin@uscg.mil					
16. Abstract (MAXIMUM 200 WORDS) Maritime Safety Information (MSI) is data and information delivered from shore authorities to mariners at sea to improve safety and efficiency of navigation. MSI has a very specific international definition as promulgated by the International Maritime Organization (IMO). MSI consists of navigational warnings, meteorological information, and urgent safety-related information broadcast to ships. Presently, MSI is disseminated in a text-based message via Navigation Text (NAVTEX), SafetyNET, and High Frequency (HF) Narrowband Direct Printing (NBDP). Global Maritime Distress and Safety System (GMDSS) modernization includes several new communications systems for possible inclusion in the modernized GMDSS and the distribution of MSI: VHF Data Exchange System (VDES), Iridium Enhanced Group Calling (EGC) Service, and Navigation Data (NAVDAT). In addition, the International Hydrographic Organization (IHO) S-100 series of standards is being developed as a flexible hydrographic data standard to support imagery, gridded data and time-varying data. The ongoing GMDSS modernization plan will result in significant changes in the way that MSI is delivered and in the type of information that can be delivered by 2024. The USCG will need to stay abreast of these developments over the next few years to ensure that it is ready for modernization. This report provides a synopsis of the current state of MSI and the existing distribution mechanisms in Section 2. Section 3 gives an overview of the various agencies involved with MSI. A discussion of the new technologies being pursued as part of the GMDSS modernization effort is in Section 4 and some recommendations for action by USCG are in Section 5.					
17. Key Words Maritime Safety Information, MSI, International Maritime Organization, IMO, International Hydrographic Organization, IHO, VHF Data Exchange System, VDES, Iridium, SafetyNET, NAVTEX, NAVDAT, S-100, AIS, Global Maritime Distress and Safety System, GMDSS, Enhanced Group Calling, EGC		18. Distribution Statement Distribution Statement A: Approved for public release; distribution is unlimited.			
19. Security Class (This Report) UNCLAS//Public		20. Security Class (This Page) UNCLAS//Public		21. No of Pages 42	
				22. Price	



(This page intentionally left blank.)



EXECUTIVE SUMMARY

Maritime Safety Information (MSI) is data and information delivered from shore authorities to mariners at sea to improve safety and efficiency of navigation. MSI has a very specific international definition as promulgated by the International Maritime Organization (IMO) in Resolution A.705(17) [1]. MSI consists of navigational warnings, meteorological information, and urgent safety-related information that is broadcast to ships (currently) via Navigation Text (NAVTEX), SafetyNET, and by High Frequency (HF) Narrowband Direct Printing (NBDP) in areas outside of SafetyNET coverage. Navigational Warnings (NW) are disseminated as part of the World-Wide Navigational Warning Service (WWNWS) which is part of the International Hydrographic Organization (IHO). Meteorological forecasts and warnings are issued by the World Meteorological Organization (WMO) World-wide Met-ocean Information and Warnings Service (WWMIWS). NAVTEX is an antiquated 50 bps system that can broadcast text-based messages over Medium Frequency (MF) which is suitable for coastal waters. HF NBDP provides a similar service over longer ranges using HF frequencies. SafetyNET disseminates the same information over Inmarsat satellite and thus provides coverage globally (except for the high latitudes).

The USCG Research and Development Center (RDC) has been testing the transmission of enhanced MSI (eMSI) over Automatic Identification System (AIS) using Application Specific Messages (ASMs). eMSI is information to improve the safety and efficiency of navigation. It consists of meteorological, hydrological data, and other dynamic data of significance to mariners such as locations of wrecks, shoals, danger areas etc. as well as ordering of vessels through locks and single passage channels. All of this information is transmitted in binary format and intended to be displayed as an overlay on an Electronic Charting System (ECS).

The distribution of MSI is part of the Global Maritime Distress and Safety System (GMDSS). The international maritime community is in the midst of a modernization effort for the GMDSS which will bring about major changes in both how MSI is disseminated and what format will be used for MSI by 2024. The IHO S-100 series of standards is being developed as a replacement for the existing S-57 standard; it is designed to be more flexible and able to support a wider range of hydrographic data such as imagery, gridded data and time-varying data. One of the Product Specifications (PS) being developed under S-100 is the S-124 PS for Navigational Warnings (NW). This, like other PSs will provide for information to be defined as geo-coded text or graphics instead of solely text. There are several new communications systems being pursued for possible inclusion in the modernized GMDSS: VHF Data Exchange System (VDES), Iridium Enhanced Group Calling (EGC) Service, and Navigation Data (NAVDAT). VDES is an expanded form of AIS consisting of two additional 25 kHz channels for use in transmitting AIS eMSI using ASMs and two, 100 kHz blocks of spectrum for use by both terrestrial and satellite radios for high bandwidth data transmission. Iridium is in the process of applying for approval to provide SafetyNET type services over their satellite system, which has global coverage (including the polar regions); this is expected to be approved and in place by 2020. Iridium is also in the process of rebuilding their constellation to provide new, higher bandwidth services. NAVDAT is being proposed as a replacement for NAVTEX; it will provide 300 times the data rate (allowing for S-100 services) over both MF and HF frequencies, enabling global coverage, including Arctic areas.

The ongoing GMDSS modernization plan will result in significant changes in the way that MSI is delivered and in the type of information that can be delivered by 2024. The current state is shown in Figure ES-(top) and reflects the delivery of text information at a low bit rate. The developments being considered as part of the GMDSS modernization, have been mapped into the same framework in Figure ES-(bottom). In this new, potential architecture the information being delivered is not limited to only text but can include geo-coded text,



RDC Review/Status of IMO MSI Systems

graphics, and binary data all defined by S-100 series standards. The information sources can also be expanded to include other local MSI such as PORTS¹ data and other information relevant to the safety and efficiency of navigation. Receivers may be stand alone or combined with the use of software defined radio (SDR).

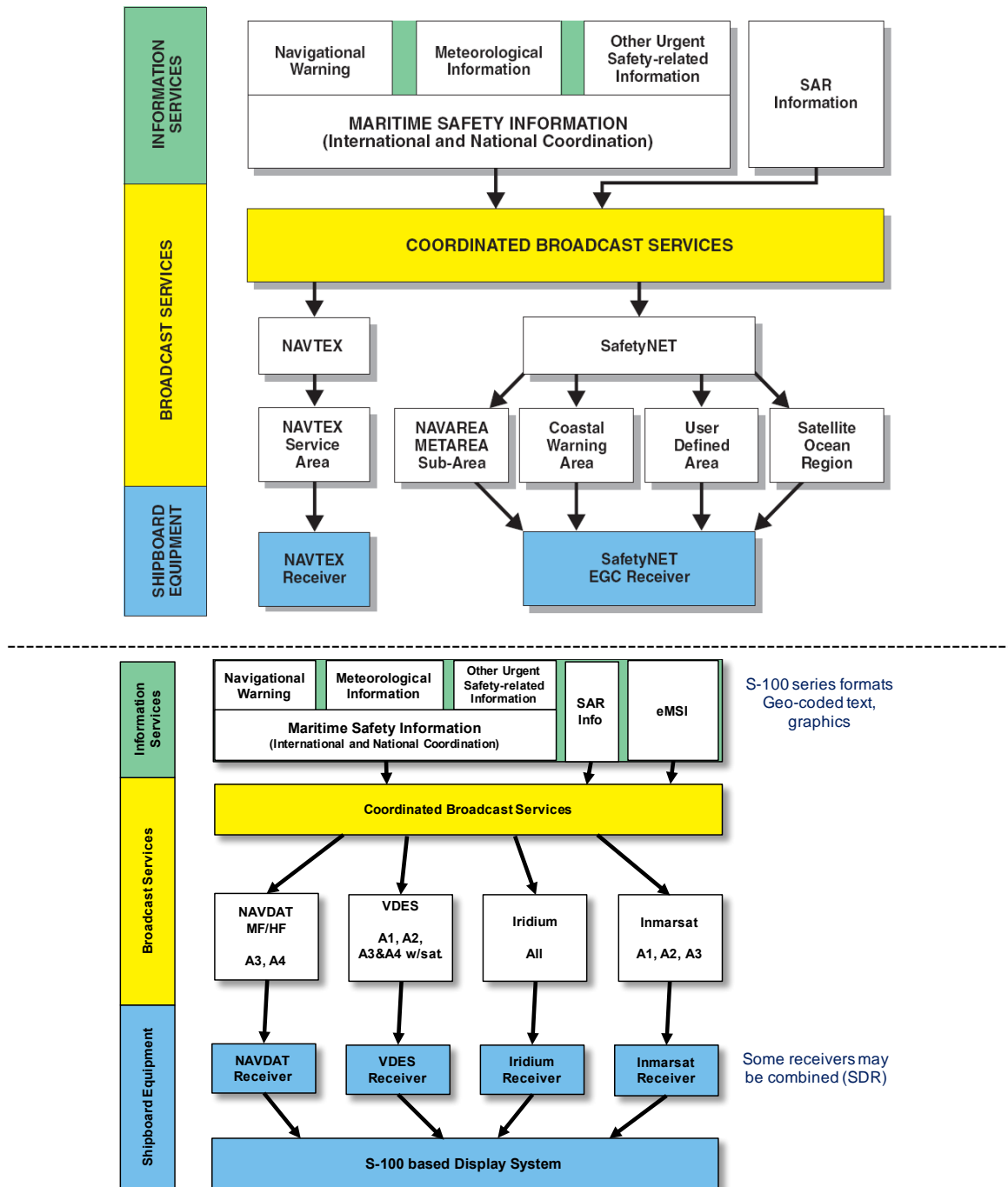


Figure ES-1. (Top) The maritime safety information service of the GMDSS (Figure 1 from [1, 2]) and (Bottom) Potential Future MSI Architecture.

¹ Physical Oceanographic Real-Time System, see <https://tidesandcurrents.noaa.gov/ports.html>.



The USCG will need to stay on top of these developments over the next few years to ensure that it is ready for modernization. Some effort should be expended to assess the performance and usefulness of the various VDES components (ASM1 and 2, VDE terrestrial, VDE satellite). This will help make the decision whether to implement the system or not. If the USCG decides to implement the system, it will need to determine how to best configure the system for operations. The USCG will need to track the progress of Iridium being approved as a GMDSS provider and potentially conduct some prototyping in order to be ready to use the service upon commissioning. There may be some operational considerations that need to be resolved for the USCG to make the best use of multiple satellite services simultaneously. The use of Iridium Short Burst Data (SBD) for moving AIS messages (NMEA sentences) has been tested by RDC with some success. If the service improves with the Iridium NEXT constellation, then this may be a viable option for eMSI transmissions in the Polar Regions. This will need to be tested and if viable, operational considerations resolved. The use of High Frequency – Digital Radio Mondiale (HF-DRM) or NAVDAT HF has been successfully demonstrated by RDC. As a follow-on, it may be beneficial to prototype and demonstrate NAVDAT Medium Frequency (MF), ideally in conjunction to show the benefits of a single Content Server feeding modulators for both MF and HF simultaneously. The S-100 series of standards will be the framework for the entire modernized GMDSS and eNavigation. It is thus important for the USCG to stay abreast of developments and be involved in the process so that USCG requirements can be included in the standards. As standards become solidified, they will need to be prototyped and tested, and MSI creation and dissemination processes revised to make use of the new standards.



(This page intentionally left blank.)



TABLE OF CONTENTS

EXECUTIVE SUMMARY	v
LIST OF FIGURES	x
LIST OF TABLES	x
LIST OF ACRONYMS AND ABBREVIATIONS	xi
1 INTRODUCTION.....	13
2 CURRENT STATUS OF MARITIME SAFETY INFORMATION	13
2.1 Navigational Warnings	14
2.2 Meteorological Warnings.....	16
2.3 NAVTEX	17
2.4 SafetyNET.....	18
2.5 Enhanced MSI.....	19
3 AGENCIES RESPONSIBLE FOR MSI.....	19
3.1 IMO.....	19
3.2 IALA	20
3.3 IHO	21
3.4 ITU.....	22
3.5 IEC	22
4 FUTURE MSI.....	22
4.1 IHO S-100 Universal Hydrographic Data Model	23
4.1.1 S-124 Navigational Warnings Product Specification	25
4.2 VHF Data Exchange System (VDES)	25
4.3 Iridium for Space-based GMDSS Services Including MSI Broadcasts.....	29
4.4 MSI over HF	30
5 CONCLUSIONS/RECOMMENDATIONS	31
5.1 VDES	34
5.2 Iridium.....	34
5.3 HF	34
5.4 S-100	34
6 REFERENCES.....	35
APPENDIX A. DEFINITIONS.....	A-1



LIST OF FIGURES

Figure ES-1. (Top) The maritime safety information service of the GMDSS (Figure 1 from [1, 2]) and (Bottom) Potential Future MSI Architecture.	vi
Figure 1. The maritime safety information service of the GMDSS (Figure 1 from [1, 2]).	14
Figure 2. NAVAREAs for coordinating and promulgating navigational warnings within the GMDSS, Figure 3 from [4].	15
Figure 3. METAREAs for coordinating and promulgating meteorological warnings within the GMDSS, Figure 2 from [4].	17
Figure 4. Some examples of the data types supported by S-100. Figure 1 from [16].	23
Figure 5. S-100 within the ISO-19100 Data Framework (from [17]).	24
Figure 6. NavWarning model (from [18]).	25
Figure 7. Frequency arrangement for RR Appendix 18.	27
Figure 8. Channel Plan A.	28
Figure 9. Potential Future MSI architecture.	32
Figure 10. The present maritime safety information architecture of the GMDSS on the top and additional potential future MSI architecture on the bottom.	33

LIST OF TABLES

Table 1. Subjects suitable for NAVAREA warnings.	16
Table 2. NAVTEX subject indicator characters and definitions.	18
Table 3. SafetyNET EGC ocean region, priority, and service codes.	18
Table 4. IHO working groups and sub-committees relevant to MSI and eNavigation.	21
Table 5. S-100 product specifications under development.	24
Table 6. RR Appendix 18 channels for VDES applications: AIS, ASMs, VDES. Table A1-1 from [24]. ...	28



LIST OF ACRONYMS AND ABBREVIATIONS

AIS	Automatic Identification System
ARM	Aids to Navigation Requirements and Management
ASM	Application Specific Message
AtoN	Aids to Navigation
COMSAR	Sub-Committee on Search and Rescue (Subcommittee of IMO – now Sub-Committee on Navigation, Communications and Search and Rescue (NCSR))
DGPS	Differential Global Positioning System
DPSK	Differential Phase Shift Keying
DRM	Digital Radio Mondiale
EGC	Enhanced Group Call
EMC	Electromagnetic Compatibility
eMSI	Enhanced MSI
ENAV	Enhanced Navigation
ENC	Electronic Navigational Chart
ENG	Aids to Navigation Engineering and Sustainability
HF	High Frequency
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organization
IMC	Industrial Members Committee
IMO	International Maritime Organization
ISO	International Organization for Standardization
ITU	International Telecommunications Union
ITU-R	ITU Radiocommunications Sector
kbps	kilobits per second
kHz	kilo-Hertz
km	kilometer
LW	Long Wave
GES	Ground Earth Stations
GMDSS	Global Maritime Distress and Safety System
GML	Geography Markup Language
GMSK	Gaussian Minimum Shift Keying
METAREA	Meteorological Area
MF	Medium Frequency
MHz	Mega-Hertz
MSC	Maritime Safety Committee (of IMO)
MSI	Maritime Safety Information
MW	Medium Wave
NAVAREA	Navigation Area
NAVDAT	Navigational Data
NAVTEX	Navigational Text
NBDP	Narrowband Direct Printing
NCSR	Navigation Communications and SAR (IMO subcommittee)



LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

NMEA	National Marine Electronics Association
NIPWG	Nautical Information Provision Working Group
NW	Navigational Warnings
OFDM	Orthogonal Frequency Division Multiplexing
OTH	Over the Horizon
PNT	Positioning Navigation Timing
PS	Product Specifications
QAM	Quadrature Amplitude Modulation
RDC	USCG Research and Development Center
RR	Radio Regulations
SAR	Search and Rescue
SBD	Small Burst Data
SDR	Software Defined Radio
SOLAS	Safety Of Life At Sea
SW	Short Wave
TETRA	Terrestrial Trunked Radio
TX	Transmit
TWCWG	Tides, Water Level and Currents Working Group
UK	United Kingdom
UN	United Nations
US	United States
USCG	US Coast Guard
VDE	VHF Data Exchange
VDES	VHF Data Exchange System
VDL	VHF Data Link
VHF	Very High Frequency
VTs	Vessel Traffic Services
WHO	World Health Organization
WMO	World Meteorological Organization
WRC	World Radiocommunication Conference
WWMIWS	World-wide Met-ocean Information and Warnings Service
WWNWS	World-Wide Navigational Warning Service
WWNWS-SC	World-Wide Navigational Warning Service Sub-Committee
XML	Extensible Markup Language



1 INTRODUCTION

Maritime Safety Information (MSI) is data and information pushed out from shore authorities to mariners at sea to improve safety and efficiency of navigation. The details of what is MSI and how it is disseminated are covered in various international resolutions and standards. They are described in detail in the succeeding sections. Much of this is codified as part of the Global Maritime Distress and Safety System (GMDSS). The international maritime community is in the midst of a modernization effort for the GMDSS which will bring about major changes in both how MSI is disseminated and what format will be used for MSI.

This report provides a synopsis of the current state of MSI and the existing distribution mechanisms in Section 2. Section 3 gives an overview of the various agencies involved with MSI. A discussion of the new technologies being pursued as part of the GMDSS modernization effort is in Section 4. Recommendations for action by the USCG and RDC are in Section 5.

2 CURRENT STATUS OF MARITIME SAFETY INFORMATION

Maritime Safety Information (MSI) has a very specific international definition as promulgated by the International Maritime Organization (IMO) in Resolution A.705(17) [1]. This circular includes a number of relevant definitions that are reproduced in Appendix A. The most recent guidance on MSI as part of the Global Maritime Distress and Safety System (GMDSS) is contained in MSC.1/Circ.1310 [2]. MSI consists of navigational warnings, meteorological information, and urgent safety-related information that is broadcast to ships (currently) via Navigation Text (NAVTEX) and SafetyNET (see Figure 1) and by High Frequency (HF) Narrowband Direct Printing (NBDP) in areas outside of SafetyNET coverage.



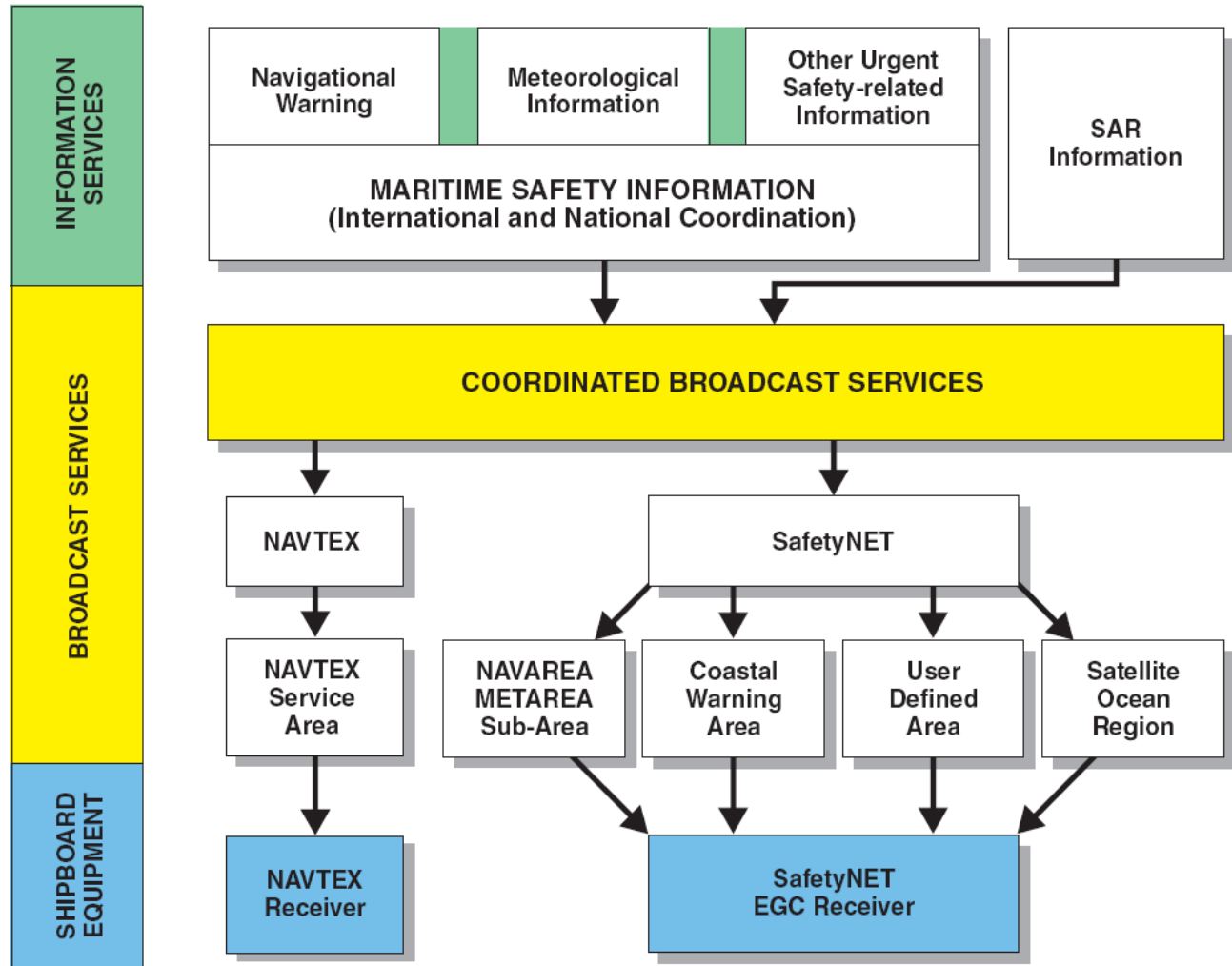


Figure 1. The maritime safety information service of the GMDSS (Figure 1 from [1, 2]).

2.1 Navigational Warnings

The World-Wide Navigational Warning Service (WWNWS) is the internationally and nationally coordinated service for the promulgation of navigational warnings [3]. This service is part of the International Hydrographic Organization (IHO), but guidance is jointly approved by IHO and IMO. There are three types of navigational warnings covered under the WWNWS: Navigation Area (NAVAREA) warnings, sub-area warnings, and coastal warnings. NAVAREA warnings are broadcast to one or more of the areas defined in Figure 2. Sub-area warnings are intended for only part of a NAVAREA and coastal warnings are for coastal (near-shore) regions. Table 1 contains the information subjects suitable for broadcast as NAVAREA warnings (from [3]).

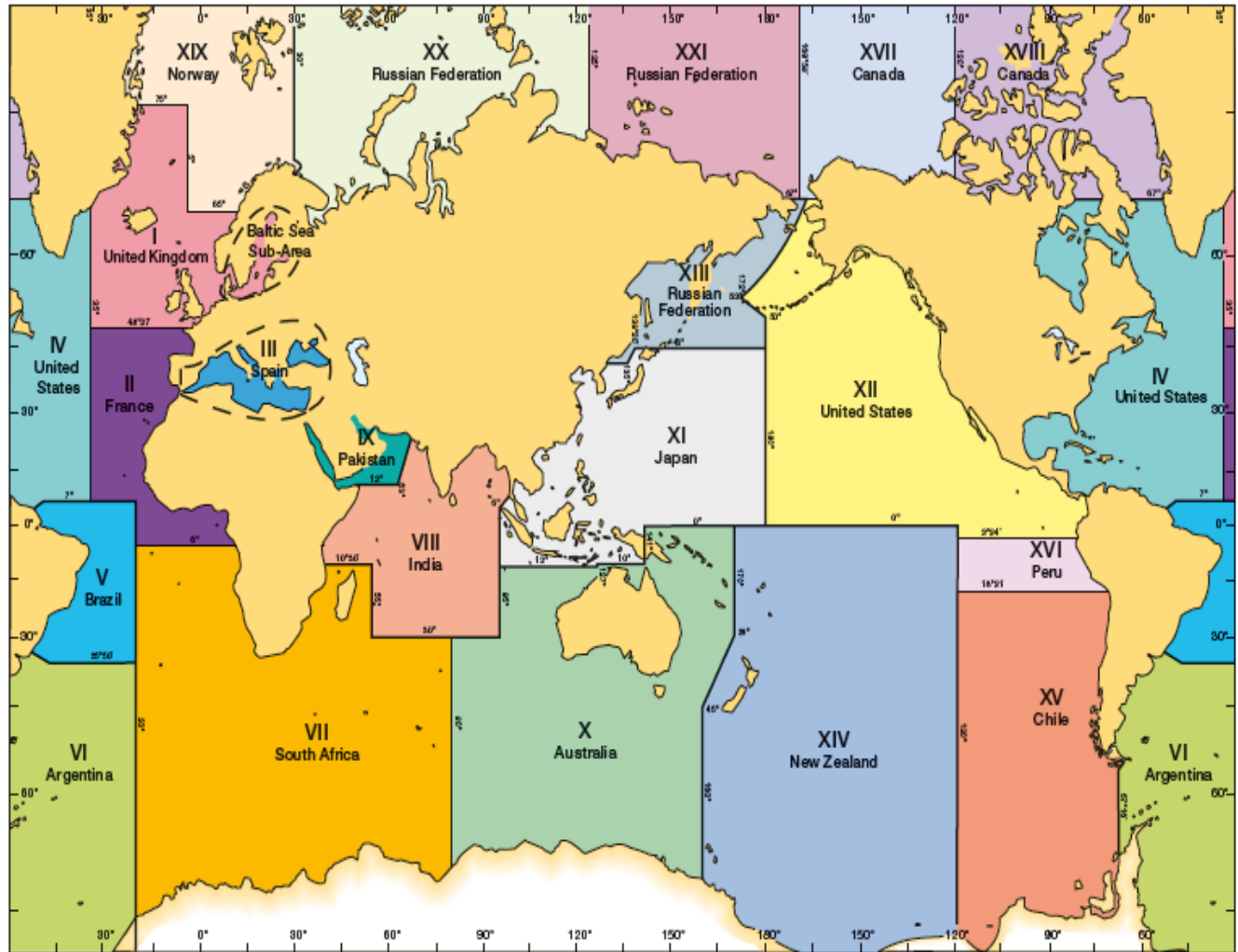


Figure 2. NAVAREAs for coordinating and promulgating navigational warnings within the GMDSS, Figure 3 from [4].

Table 1. Subjects suitable for NAVAREA warnings.

<ul style="list-style-type: none">• Casualties to lights, fog signals, buoys and other aids to navigation affecting main shipping lanes.• Establishment of major new aids to navigation or significant changes to existing ones, when such establishment or change might be misleading to shipping.• The presence of large unwieldy tows in congested waters.• Areas where search and rescue (SAR) and anti-pollution operations are being conducted (for avoidance of such areas).• The presence of newly discovered rocks, shoals, reefs and wrecks likely to constitute a danger to shipping, and, if relevant, their marking.• Unexpected alteration or suspension of established routes.• Cable or pipe-laying activities, the towing of large submerged objects for research or exploration purposes, the employment of manned or unmanned submersibles, or other underwater operations constituting potential dangers in or near shipping lanes.• The establishment of research or scientific instruments in or near shipping lanes.	<ul style="list-style-type: none">• The presence of dangerous wrecks in or near main shipping lanes and, if relevant, their marking.• Tsunamis and other natural phenomena, such as abnormal changes to sea level.• Significant malfunctioning of radionavigation services and shore-based maritime safety information radio or satellite services.• Drifting hazards (including derelict ships, ice, mines, containers, other large items over 6 meters in length, etc.).• Acts of piracy and armed robbery against ships.• Information concerning events which might affect the safety of shipping, sometimes over wide areas, e.g. naval exercises, missile firings, space missions, nuclear tests, ordnance dumping zones, etc. It is important that when the degree of hazard is known, this information is included in the relevant warning. Whenever possible such warnings should be originated not less than five days in advance of the scheduled event and reference may be made to relevant national publications in the warning.• World Health Organization (WHO) health advisory information.• The establishment of offshore structures in or near shipping lanes.• Security-related requirements.
--	--

2.2 Meteorological Warnings

Meteorological forecasts and warnings are issued by the World Meteorological Organization (WMO) World-wide Met-ocean Information and Warnings Service (WWMIWS). This is covered under IMO resolution A.1051(27) [5]. There are two types of information covered under the WWMIWS guidance: High Seas and Coastal. High Seas services consist of gale and storm warnings and weather and sea bulletins. Coastal services consist of warnings, synopses, and forecasts. The world is divided into geographical sea areas called Meteorological Areas (METAREAs) (see Figure 3) for coordination purposes.





Figure 3. METAREAs for coordinating and promulgating meteorological warnings within the GMDSS, Figure 2 from [4].

2.3 NAVTEX

NAVTEX broadcasts are for coastal waters and are defined in the NAVTEX Manual [4]:

NAVTEX is an international automated direct-printing service for promulgation of MSI, navigational and meteorological warnings, meteorological forecasts and other urgent safety-related messages to ships. It was developed to provide a low-cost, simple and automated means of receiving MSI on board ships at sea in coastal waters. The information transmitted may be relevant to all sizes and types of vessel and the selective message-rejection feature ensures that mariners can receive MSI broadcasts which are tailored to their particular needs.

NAVTEX can be used for MSI as listed in Table 2.

Table 2. NAVTEX subject indicator characters and definitions.

A	Navigational warnings
B	Meteorological warnings
C	Ice reports
D	SAR information, acts of piracy warnings, tsunamis and other natural phenomena
E	Meteorological forecasts
F	Pilot and VTS service messages
G	AIS service messages (non-navigational aid)
H	LORAN messages
I	Not used
J	GNSS messages regarding PRN status
K	Other electronic navigational aid system messages
L	Other navigational warnings (add on to category A)

HF NBDP as an expansion of NAVTEX to HF; specifically on 4,209.5 kHz, was codified by the International Telecommunications Union (ITU) in 1990 [6] with technical details in [7]. HF NBDP is the alternative to NAVTEX and SafetyNET in Sea Area A4 (polar regions).

2.4 SafetyNET

SafetyNET broadcasts are for the entire globe except for Sea Area A4 and are defined in the International SafetyNET manual [8]:

SafetyNET is an international automatic direct-printing satellite-based service for the promulgation of MSI, navigational and meteorological warnings, meteorological forecasts, SAR information and other urgent safety-related messages to ships. It has been developed as a safety service of the Inmarsat C Enhanced Group Call (EGC) system to provide a simple and automated means of receiving MSI on board ships at sea. The message-selection features of SafetyNET receivers enable mariners to receive safety information broadcasts that are tailored to their particular needs. Transmission area, priority and type of service are defined for SafetyNET messages as per Table 3.

Table 3. SafetyNET EGC ocean region, priority, and service codes.

Ocean Region (OR)	Priority	Service
Atlantic Ocean Region – West 0 – AOR-W	1 – Safety	00 – All ships (general call)
	2 – Urgency	04 – Navigational, meteorological, piracy warning or meteorological forecast to a rectangular area
Atlantic Ocean Region – East 1 – AOR-E	3 - Distress	13 - Navigational, meteorological, coastal, piracy warning or meteorological forecast to a coastal warning area
		14 – Shore-to-ship distress alert to a circular area
Pacific Ocean Region 2 – POR		24 - Navigational, meteorological, piracy warning or meteorological forecast to a circular area
Indian Ocean Region 3 – IOR 9 - All		31 – NAVAREA / METAREA, piracy warning or meteorological forecast to a NAVAREA/METAREA
		34 – SAR coordination to a rectangular area
		44 – SAR coordination to a circular area



2.5 Enhanced MSI

RDC has been working on transmitting enhanced MSI (eMSI) over AIS for many years. eMSI is a term coined by the general international maritime community that describes additional information beyond NAVAREA and METAREA warnings that improves safety and efficiency of navigation. At this time, the term eMSI is not officially approved by IMO, IHO and WMO, but it is building traction and fits within the intent of IMO Res A.705 as amended [1]: “Other urgent safety-related information should be provided by the relevant national or international authority responsible for managing the system or scheme.” The use of AIS to transmit eMSI also fits within Res A.705: “Administrations may also provide maritime safety information by other means.”

RDC started gathering requirements and developing the processes and procedures for the use of AIS to transmit eMSI back in 2007. This work has continued to date and has included several test beds: Tampa Bay, Stellwagen Bank, Columbia River, and most recently the Ohio River and Marine Exchange Alaska (MXAK). Over the course of the testing, RDC has identified the processes required for the efficient use of AIS for transmission of eMSI and has developed software to implement those processes. This work has been documented in several papers [9-12].

3 AGENCIES RESPONSIBLE FOR MSI

There are several international organizations that are involved with the development of standards and guidance for MSI and e-Navigation.

3.1 IMO

The IMO is an United Nations (UN)-chartered body with official representation from national authorities. Specifically, “the IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships.”² “The Organization consists of an Assembly, a Council and five main Committees: the Maritime Safety Committee; the Marine Environment Protection Committee; the Legal Committee; the Technical Cooperation Committee; the Facilitation Committee; and a number of Sub-Committees that support the work of the main technical committees.”³ Of relevance here is the Maritime Safety Committee (MSC) which is responsible for safety at sea; specifically, to “consider any matter within the scope of the Organization concerned with aids to navigation, construction and equipment of vessels, manning from a safety standpoint, rules for the prevention of collisions, handling of dangerous cargoes, maritime safety procedures and requirements, hydrographic information, log-books and navigational records, marine casualty investigations, salvage and rescue, and any other matters directly affecting maritime safety.”⁴ Falling within this charter are amendments to conventions such as Safety Of Life At Sea (SOLAS).

IMO’s e-Navigation interest comes from SOLAS, which means the focus is primarily on safety (i.e., not efficiency, cost savings, reliability, etc.). IMO is a mandated body- it requires carriage of equipment,

² <http://www.imo.org/en/About/Pages/Default.aspx>

³ <http://www.imo.org/en/About/Pages/Structure.aspx>

⁴ <http://www.imo.org/en/About/Pages/Structure.aspx#3>



compliance with regulations, etc.⁵ IMO mainly focuses on shipboard requirements; personnel, equipment, vessel standards, but less on shore-side requirements (although Vessel Traffic Services [VTS] is an exception, but most of the details of VTS are left to the International Association of Marine Aids to Navigation and Lighthouse Authorities [IALA]). IMO is the body that identifies and sets high-level requirements, then other bodies work on the details.

3.2 IALA

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is a big player in e-Navigation, primarily from the shore-side perspective. IALA is a non-profit international technical association established in 1957 whose purpose is “to ensure that seafarers are provided with effective and harmonized marine Aids to Navigation (AtoN) services worldwide to assist in safe navigation of shipping and protection of the environment.”⁶ IALA's mandate is to support provision of aids to navigation services - physical and electronic AtoN, VTS, etc. IALA is a membership organization - they have national members (Government AtoN authorities or competent authorities), industrial members (equipment manufacturers) and associate members. IALA has several committees (Aids to Navigation Requirements and Management (ARM), Enhanced Navigation (ENAV), Aids to Navigation Engineering and Sustainability (ENG), VTS, and Industrial Members Committee (IMC)) that develop 4-year work plans and then have working groups that work on specific parts of the work plan. The IALA Committee in e-Navigation is the ENAV Committee, which consists of five technical areas (though much of the technical work is performed by more specific bodies such as ITU and IHO⁷):

- 1) Technical Domain 1 – Data modeling and message systems
 - AtoN data information structure, exchange, presentation
 - S-100 Registry and Product Specifications
 - S-100 Registry – coordination of work by all Committees
 - Message structure for e-Navigation including VDES
- 2) Technical Domain 2 – e-Navigation communications
 - VDES, satellite, WRCP
 - AIS technology
 - ASM coordination and web hosting
 - ITU planning and liaison, World Radiocommunication Conference (WRC) preparation and national coordination
- 3) Technical Domain 3 – Shore technical infrastructure
 - Resilient Positioning Navigation Timing (PNT) shore services – Differential Global Positioning System (DGPS), eLoran, other
 - Virtual AtoN technology
 - Sharing of shore data
- 4) Technical Domain 4 – e-Navigation test beds
 - Data gathering and analysis
 - Participation in and harmonization of results of test beds
 - Harmonization policy and planning

⁵ Technically, IMO develops resolution, individual countries then become signatories to the resolutions. If the resolution meets the ratification requirement then it becomes a convention which member states pass their own regulations to enforce.

⁶ <http://www.iala-aism.org/about-iala/>

⁷ <http://www.iala-aism.org/meetings-events/committees/enav/>



- Monitoring of developments nationally and regionally, and effect on competent authorities
- 5) Technical Domain 5 – Maritime Service Portfolios
 - Maritime Service Portfolios, design, content, and implementation

3.3 IHO

IHO plays a major role in charting and navigation information (publications, notices, etc.). IHO “is an intergovernmental consultative and technical organization that was established in 1921 to support safety of navigation and the protection of the marine environment.”⁸ “The official representative of each Member Government within the IHO is normally the national Hydrographer, or Director of Hydrography, who, together with their technical staff, meet at 3-yearly intervals in Monaco for an IHO Assembly. The Assembly reviews the progress achieved by the organization through its committees, sub committees and working groups, and adopts the programs to be pursued during the ensuing 3-year period.”⁹ IHO consists of two committees (Hydrographic Services and Standards and Inter-Regional Coordination) and numerous working groups and sub-committees focused on various aspects of the IHO.

The group of primary relevance to MSI is the World-Wide Navigational Warning Service Sub-Committee (WWNWS-SC). Two other important groups that contribute significantly to eNavigation are; the S-124 Correspondence Group, the Nautical Information Provision Working Group (NIPWG), and the Tides, Water Level and Currents Working Group (TWCWG). Their objectives are listed in Table 4.

Table 4. IHO working groups and sub-committees relevant to MSI and eNavigation.

Group	Objectives
WWNWS-SC	To monitor and guide the IHO/IMO WWNWS which includes NAVAREA and coastal warnings. The WWNWS-SC is responsible for studying and proposing new methods to enhance the provision of navigational warnings to mariners at sea, facilitating the implementation of the major changes in procedures for dissemination of navigational warnings and providing appropriate guidance to concerned IHO Member State Representatives to further the evolution of the WWNWS.
S-124 Correspondence Group	To develop an S-100 product specification for navigational warnings. The product specification is expected to contribute to the technical infrastructure of e-navigation as designed by IMO and to the modernization of the GMDSS.
NIPWG	To develop and maintain guidance, resolutions, and specifications in order to provide shipboard users the necessary and up-to-date information in a timely manner to allow for the planning of a safe route for the intended voyage and the safeguarding of the ship's navigation throughout the voyage.
TWCWG	To provide technical advice and coordination on matters related to tides, water levels, currents and vertical datum, including integrated water level/current data models. To support the development and maintenance of related specifications in liaison with the relevant IHO bodies and non-IHO entities. To develop and maintain the IHO publications for which the WG is responsible. Working on three S-100 product specifications: S-104 (Tidal Information for Surface Navigation), S-111 (Surface Currents), and S-112 (Dynamic Water Level Data Transfer).

⁸ https://www.iho.int/srv1/index.php?option=com_content&view=article&id=298&Itemid=297&lang=en

⁹ *ibid.*

With the development of e-Navigation, electronic charts are a critical piece. The IHO S-100 Maritime Data Framework is shaping up to be the backbone of e-Navigation data management infrastructure.

3.4 ITU

The ITU “is the United Nations’ specialized agency for information and communication technologies (ICTs).”¹⁰ ITU membership consists of the 193 UN member states plus experts from regulatory bodies, industry and academia. Their mandate is to manage the use of the radio spectrum and satellite orbits and develop technical standards. ITU is organized into three Sectors: Radiocommunications, Standardization, and Development with the actual technical work being done in study groups under the Sectors. The main output of the Study Groups is the technical standards, called Recommendations. The Sector most relevant to MSI is the Radiocommunications Sector. Most of the relevant standards are ITU-R Recommendations, for example ITU-R M.1371-5, the AIS technical standard. Primarily the ITU Recommendations deal with defining technical interfaces and protocols to ensure devices and networks can communicate and interconnect.

3.5 IEC

The International Electrotechnical Commission (IEC) is “the world’s leading organization that prepares and publishes International Standards for all electrical, electronic and related technologies.”¹¹ Founded in 1906, it is not-for-profit quasi-governmental organization that is a sister organization to ITU and the International Organization for Standardization (ISO). IEC cooperates with the other organizations to ensure the Standards all work together. IEC is responsible for test procedures to evaluate performance standards, which are the documents referenced when a manufacturer of equipment wants to get it certified (e.g., to prove it meets the standards required for equipment carriage by IMO, or a national authority). Performance standards have two parts: (1) technical requirements and (2) procedures to ensure the equipment under test meets each requirement. IEC membership is on a national basis, and each National Committee can choose who they want to represent them at IEC meetings, technical committees, and working groups either as delegates or experts.

4 FUTURE MSI

In 1993, the IMO adopted the GMDSS as part of the 1988 Amendments to SOLAS 1974. The driving impetus was to modernize distress and safety systems from the existing 500 kHz Morse telegraphy to new systems with more bandwidth, taking advantage of emerging maritime satellite systems (Inmarsat). This led to the institution of NAVTEX and SafetyNET. After twenty years, IMO is in the midst of a modernization plan for GMDSS as there is once again a desire for increased bandwidth to allow for new services and better dissemination of information. The expansion of shipping in the Arctic is also driving the need for better communications in the Polar Regions.

The NCSR sub-committee released a detailed review of the system in 2016 [13] which will set the agenda for the modernization plan. Korcz’s 2017 paper [14] provides an updated status on this and includes a timeline for adoption. The modernization includes several elements: VHF Data Exchange System (VDES), Iridium’s application to IMO to provide space-based GMDSS services including MSI broadcasts,

¹⁰ <https://www.itu.int/en/about/Pages/overview.aspx>

¹¹ <http://www.iec.ch/about/?ref=menu>

NAVDAT, HF-DRM, and the IHO S-100 universal hydrographic data model for the graphical presentation of navigation safety information. Many of these elements will allow for the support of additional information (eMSI) to back the e-Navigation concept.

4.1 IHO S-100 Universal Hydrographic Data Model

S-100, The Universal Hydrographic Data Model, was adopted by IHO as an official standard in January 2010. It was developed as the replacement to the existing S-57 standard for Digital Hydrographic Data. It was designed to overcome the limitations of S-57 by being flexible and able to support a wider range of hydrographic data such as imagery, gridded data and time-varying data. The current version of S-100 (version 3) was published in 2017 [15].

S-100 is a data model; specific Product Specifications (PS) are then defined under the model, with a numbering of S-10x (Table 5). For example, S-101 is the new Electronic Nautical Chart (ENC) PS being developed by IHO (see Figure 4). S-100 thus “provides a framework of components that can be used by interested communities to develop their own maritime geospatial products and services” [15]. In order to achieve more worldwide harmonization of geographic data standards, IHO developed S-100 within the framework of the ISO 19100 series of geographic information standards (see Figure 5). S-100 is intended by IMO to be the data standard for e-Navigation developments. It is a key enabling technology for the GMDSS modernization.

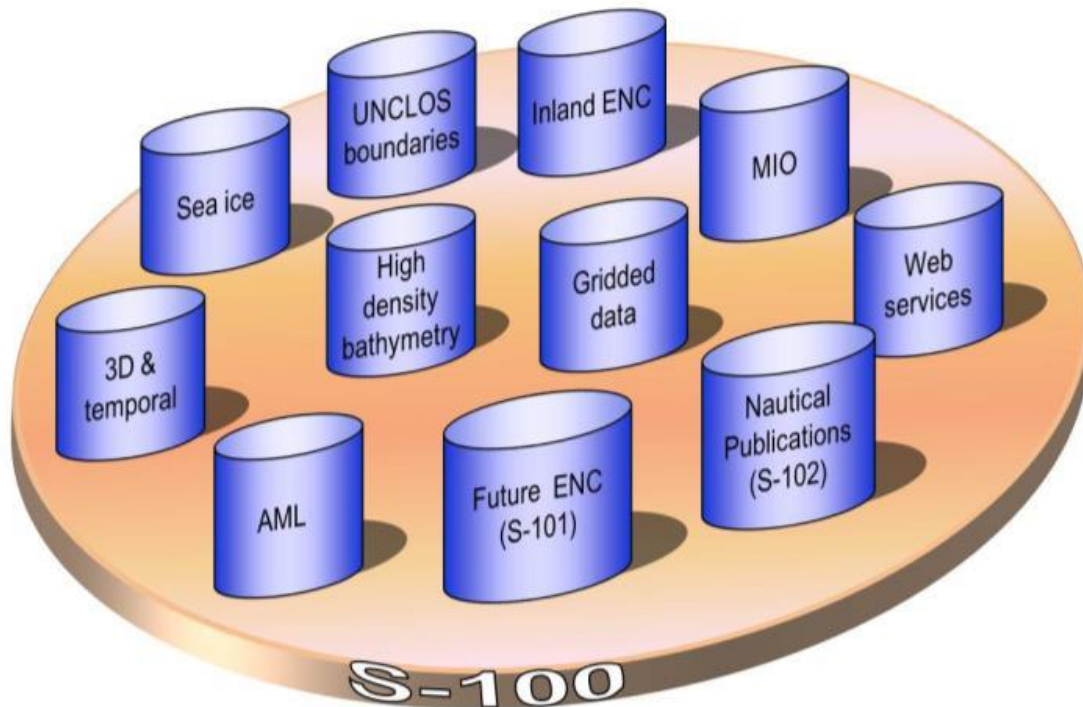


Figure 4. Some examples of the data types supported by S-100. Figure 1 from [16].

The S-100 model “comprises twelve related parts that give the user the appropriate tools and framework to develop and maintain hydrographic related data, products and registers. These standards specify, for

RDC Review/Status of IMO MSI Systems

hydrographic and related information, methods and tools for data management, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. By following this set of geospatial hydrographic standards, users will be able to build constituent parts of an S-100 compliant product specification” [15].

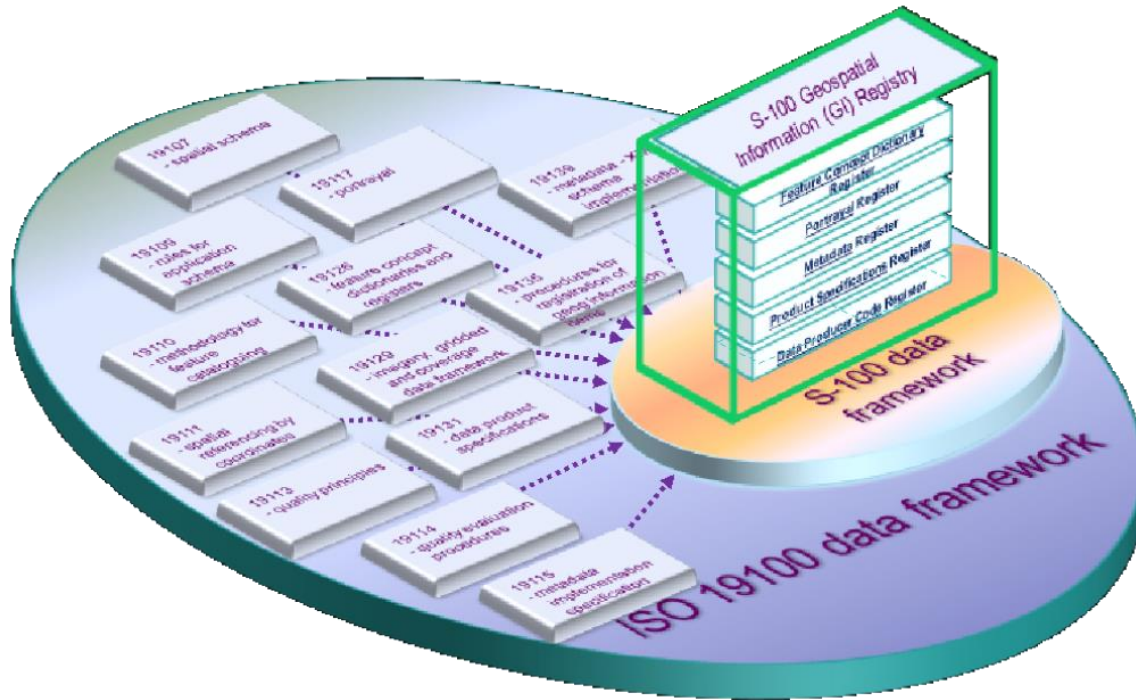


Figure 5. S-100 within the ISO-19100 Data Framework (from [17]).

Table 5. S-100 product specifications under development.

PS Number	Description
S-101	Electronic Navigational Chart (ENC)
S-104	Tidal Information for Surface Navigation
S-111	Surface Currents
S-112	Dynamic Water Level Data
S-121	Maritime Limits and Boundaries
S-122	Marine Protected Areas
S-123	Radio Services
S-124	Navigational Warnings
S-125	Navigational Services
S-126	Physical Environment
S-127	Traffic Management

4.1.1 S-124 Navigational Warnings Product Specification

One of the PSs under development by IHO of direct relevance to MSI is the S-124 PS, for Navigational Warnings (NW). This is being developed by the S-124 Correspondence Group under the WWNWS-SC. The goal is to develop a NW model (see Figure 6) that can be used to generate NWs that can then be sent out in TELEX format (joint manual S-53) over NAVTEX or SafetyNET, and in the future in Geography Markup Language (GML) format (S-124) for distribution over NAVDAT, VDES or HF-DRM.

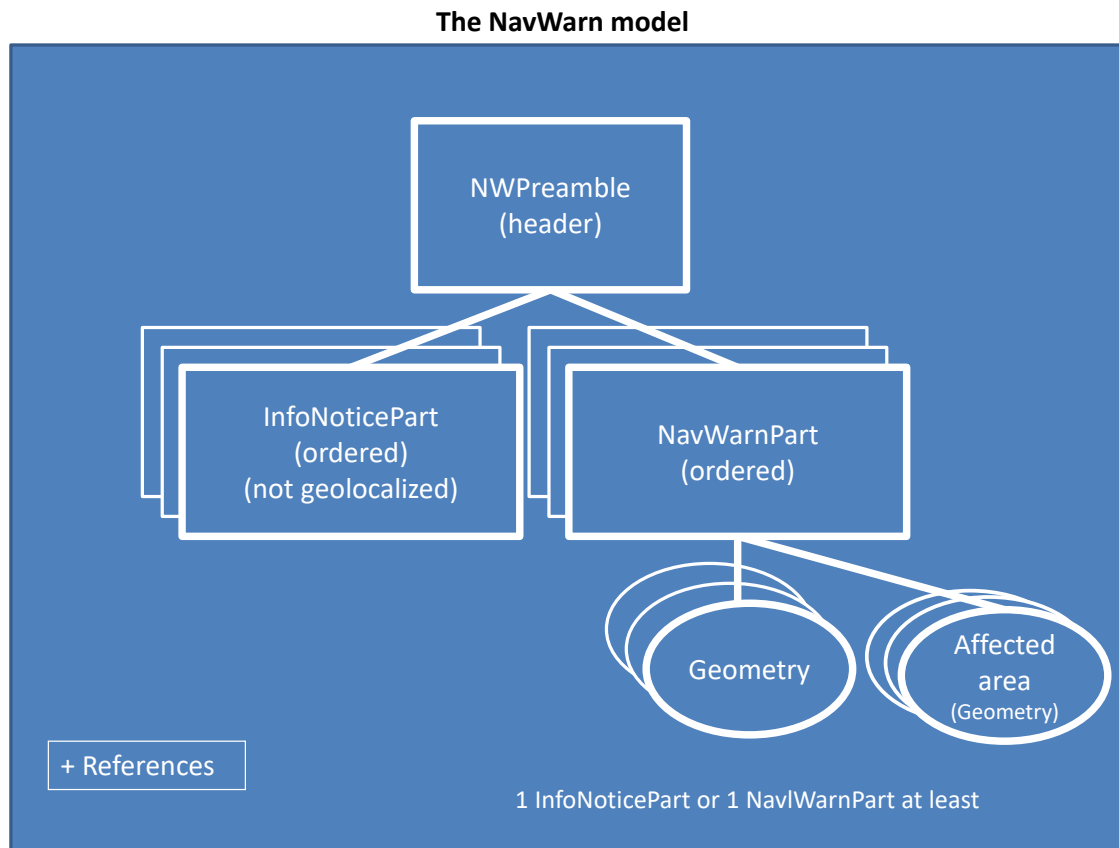


Figure 6. NavWarning model (from [18]).

4.2 VHF Data Exchange System (VDES)

The “VDES is a technological concept developed by the IALA e-NAV Committee and now widely discussed at ITU, IMO, and other organizations. VDES was originally developed to address emerging indications of overload to the VHF Data Link (VDL) of AIS and simultaneously enabling a wider seamless data exchange for the maritime community” [19]. This concept has been in development over the past decade; originally as a terrestrial system aimed as an extension or alternative to AIS. The addition of a satellite component was proposed in 2012 by IMO Sub-Committee on Radiocommunications and Search and Rescue (COMSAR) [20]. The COMSAR information paper provided a number of justifications for having a satellite channel such as the ability to extend coverage to ships beyond terrestrial radio range and to efficiently reach a large number of ships simultaneously. Some specific service examples given in [20] include:

- *Broadcast applications that will address the needs of the planned modernization of the GMDSS;*
- *Augment MSI dissemination to Sea Area A4 of severe weather warnings, complementing the maritime safety information service and WWNWS broadcasts via HF NBDP or SafetyNET;*
- *Extend situational awareness by disseminating aggregated situational information to beyond-line-of-sight areas;*
- *Act as an alternative NAVTEX channel, in particular for the Arctic and Antarctic NAVAREA's/METAREA's;*
- *Possible integration with future use of long range AIS reception by satellite, as such, implementing future two-way applications; and*
- *Allow a broadcast overlay for current VHF data networks.*

A good summary of the proposed VDES, which is comprised of AIS + ASM + VDE + Satellite, is contained in Bober's paper [21], and his presentation at the 2014 Tokyo VDES Workshop [22]. Some of the technical details may have changed but the overall concept has not. The VDES concept addresses the need for additional capacity for digital data exchange. It provides for high capacity data transmission using different message structures and modulations. The idea is that most of the existing application specific messages (ASMs) and new messages will be moved to new channels called ASM 1 and 2. AIS will remain for the original function of ship identification, position reporting, and tracking. VDE terrestrial service will be for higher volume data exchange and VDE satellite will provide VDE beyond the radio coverage range of a shore infrastructure or where no shore infrastructure exists.

The currently published technical reference is ITU-R M.2092-0 [23]. However, this has already undergone extensive changes such that the published version should not be relied upon for any developmental work. The true purpose of the M.2092-0 version was to lay out the general technical standard in order to get the frequencies authorized; the M.2092-1 version is what people will manufacture to. This new version is slated to be published in May 2019, prior to the WRC meeting. The current draft version [24] is from the June inter-sessional meeting. A new IEC standard for certifying and testing VDES equipment will also need to be developed.

The development of VDE was based on some earlier ITU standards. The 2009 M.1842-1 Standard [25] defined four example VHF data systems which form the basis of the proposed VDES modulations.

1. 25 kHz channel, based on Terrestrial Trunked Radio (TETRA) [26] – $\pi/8$ Differential phase shift keying (DPSK).
2. 25 kHz channel, 4-level Gaussian Minimum Shift Keying (GMSK).
3. 50 kHz channel, 16 subcarriers of 16 Quadrature Amplitude Modulation (QAM), based on TETRA.
4. 100 kHz channel, 32 subcarriers of 16 QAM, based on TETRA.

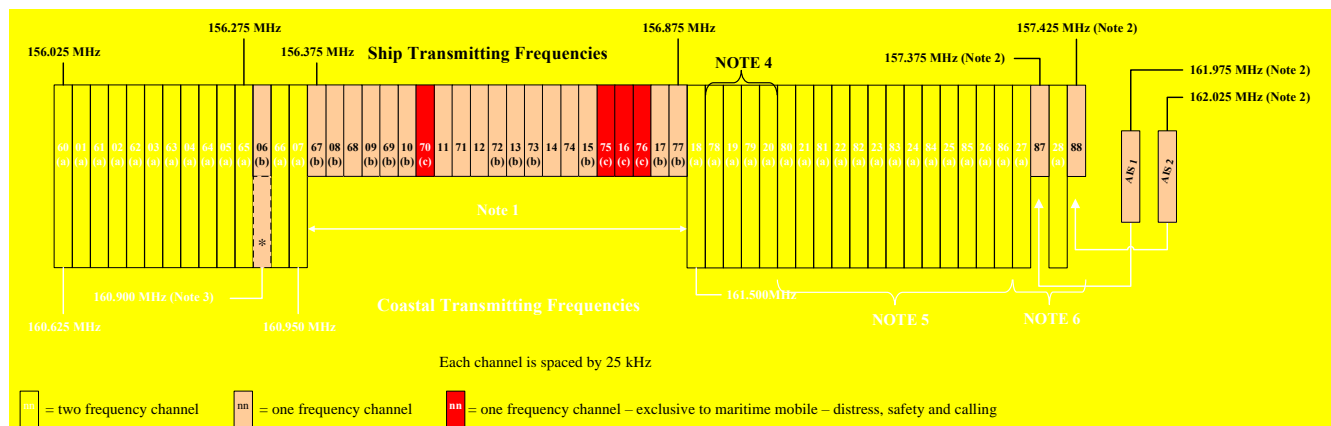
Some of the key features of VDES are:

- VDES has several different modulations and speeds which can be used at different times.
- All radios may not support all possible modulations/speeds. Operationally it is likely that national authorities will limit the options supported on the base stations.
- For the satellite portion of VDES, the cost model is that users pay to access the earth station to send/receive data. Ships do not pay to transmit or receive.
- Within range of a base station, VDES will act as control to support allocation of resources; far from base stations ships will use autonomous self-organizing.



- If within shore station coverage a ship will use terrestrial VDE (ship to shore); satellite VDE will be used outside of terrestrial VDE coverage.
- Intelligence (like a VDE gateway) for deciding (satellite or shore or ship) will be provided (most probably in the transceiver) to support satellite and terrestrial VDE.
- VDES contains AIS, ASM and VDE components (all separate frequency bands and modulations) which can all be in one box or separate – manufacturer choice.
- Radios will be developed to support all different types of modulations on all bands.

One of the key issues in the development of VDES was the channel allocation. The Radio Regulations (RR) Appendix 18 [27] frequencies for maritime mobile use are described in ITU-R M.2231 [28]. Figure 7 copied from this reference shows the VHF channels. M.2231 walks through an analysis of the channel usage in the United States (where some of the channels have been re-allocated). This coupled with information from an electromagnetic compatibility (EMC) assessment carried out by ITU [29] leads to the conclusion that the best channels to use for the VDES are the duplex channels 24, 84, 25, 85, 26, and 86. This is in addition to the assignment of the upper parts of channels 27 and 28 (2027 and 2028) to be used as ASM 1 and ASM 2 (this puts ASM 1 & 2 adjacent to ASI 1 & 2).



Channels: 06, 08, 09, 10, 13, 15, 17, 67, 69, 72, 73 and 77 are identified for inter-ship use (indicated by (b) in the above diagram).

Channel: 01-07 (inclusive), 18-28 (inclusive) and 78-86 (inclusive) are identified for public correspondence (indicated by (a) in the above diagram).

Figure 7. Frequency arrangement for RR Appendix 18.

There have been several proposals and studies conducted to determine the desired arrangement and usage of these six channels. Four options were proposed and then analyzed in ITU Report M.2371 [30]. In this report, the options were first evaluated against a set of criteria developed by the committee (that included implementation, technical, and operational factors) and then against a set of six use cases. The recommendation was to use Channel Plan A (shown in Figure 8). Report M.2371 included the results of a Chinese study on Channel Plan D, a Canadian Study on Plans A, B, and C [31], and the results of a sounding campaign carried out by the United Kingdom (UK) and Australia [32, 33] in making this recommendation.

RDC Review/Status of IMO MSI Systems

1024 157.200	1084 157.225	1025 157.250	1085 157.275	1026 157.300	1086 157.325	2024 161.800	2084 161.825	2025 161.850	2085 161.875	2026 161.900	2086 161.925	2027 161.950	AIS1 161.975	2028 162.000	AIS2 162.025
VDE1 Ship-to-shore						VDE1 Shore-to-ship, ship-to-ship						ASM1		ASM2	
SAT up3						SAT downlink						SAT up1	AIS1 uplink	SAT up2	AIS2 uplink

Figure 8. Channel Plan A.

Some of the desired radio frequencies (VDE and ASM channels) have been allocated worldwide by WRC-15 [34]. These will be available January 2019. The satellite frequencies were not approved; the goal is for them to be approved at WRC-19. However, the US and some other countries have some issues. For instance, some of the frequencies are owned by MariTEL™ in the US. MariTEL's frequencies licensing must be resolved before the US can adopt VDES.

The frequency plan proposed in M.2092 (see Table 6) also may not be final. IALA is trying to shift the satellite frequencies to their own block versus the current plan that has satellite uplink and downlink sharing frequencies. There is 525 kHz of undesignated spectrum that could be used for the satellite downlink – independent of the rest of VDES. The plan is to use spread spectrum modulation for the downlink.

Table 6. RR Appendix 18 channels for VDES applications: AIS, ASMs, VDES. Table A1-1 from [24].

RR Appendix 18 Channel Number		Transmitting Frequencies (MHz)	
		Ship stations (ship-to-shore) (long range AIS) Ship stations (ship-to-satellite)	Coast stations Ship stations (ship-to-ship) Satellite-to-ship
AIS 1		161.975	161.975
AIS 2		162.025	162.025
75 (long range AIS)		156.775 (ships are TX only)	N/A
76 (long range AIS)		156.825 (ships are TX only)	N/A
2027 (ASM 1)		161.950 (2027)	161.950 (2027)
2028 (ASM 2)		162.000 (2028)	162.000 (2028)
24/84/25/85 (VDE 1)	24/84/25/85/26/86 (Ship-to-satellite, satellite-to-ship)	100/150 kHz channel (24/84/25/85, lower legs (VDE1-A) merged) Ship-to-shore (24/84/25/85/26/86) Ship-to-satellite	100/150 kHz channel (24/84/25/85, upper legs (VDE1-B) merged) Ship-to-ship, Shore-to-ship (24/84/25/85/26/86) Satellite-to-ship
24	24	157.200 (1024)	161.800 (2024)
84	84	157.225 (1084)	161.825 (2084)
25	25	157.250 (1025)	161.850 (2025)
85	85	157.275 (1085)	161.875 (2085)
	26	157.300 (1026)	161.900 (2026)
	86	157.325 (1086)	161.925 (2086)



Some early testing of VDES has been done, notably a series of trials conducted in Australia in 2015. These included both lab and field tests [35]. Although these tests were conducted using early specifications for VDES, the results are good indicators of what can be expected within the current specification. The lab results are consistent with what would be expected: the wider bandwidth/higher bit rate modulations require more power / have less predicted range than the narrowband modulations such as 25 kHz Gaussian Minimum Shift Keying (GMSK). The field tests were mixed, some trials showed less range in actuality than that predicted and others more. They also showed the negative impacts of terrain on signal propagation and that there was the possibility of interference between AIS and VDES. Some concerns with interference with existing AIS were also raised [31].

4.3 Iridium for Space-based GMDSS Services Including MSI Broadcasts

The Iridium satellite system was conceived in the late 1980s and the first satellites launched in 1997. It is a low-earth orbit system (at ~780 km) with 66 satellites arranged in 11 planes inclined at 86.4°. It was originally thought that 77 satellites would be needed, hence the name Iridium (the 77th chemical element on the periodic table). Due to the inclination, the system is one of the few that provides high-latitude coverage. The satellites provide true global coverage, with each satellite in view for about 10 minutes. It is also an unique system in that there are inter-satellite links so that messages may be routed from satellite to satellite. This allows the system to operate in real-time (vice store-and-forward) with very few ground earth stations (GES). Iridium provides voice and data services in the 1618.85 to 1626.5 MHz band. For more information see [The Global Network: Ground Infrastructure [36] and Satellite Constellation [37].

Iridium is in the midst of launching new satellites and upgrading their system to what is called Iridium NEXT [38]. The upgraded constellation will provide higher speed/higher bandwidth services. Under the moniker of Iridium Certus, the plan is for a range of services with bit rates of 22 kbps to 1408 kbps [39].

RDC used Iridium voice and data services on projects in the past. More recently RDC studied the Iridium Small Burst Data (SBD) service [40] in 2014-2015 and recommended using AIS over Iridium SBD as a solution for high latitude communications including the transfer of eMSI over AIS [41]. RDC is working on testing this as part of the Over the Horizon (OTH) Cutter Boat project as one of the communications links for the Intelligent Gateway concept. It does work, but is not as quick or reliable as expected. Signal penetration indoors is virtually non-existent and satellite availability outdoors is not 100%, leading to message delays that are at times measured in minutes rather than seconds. There is insufficient published details on the SBD system to determine whether the difficulties are due to a weak link budget or insufficient bandwidth allocated to the SBD service. Perhaps this will improve with the Iridium NEXT constellation.

The IMO Subcommittee on Navigation Communications and SAR (NCSR) established a Correspondence Group to review the modernization of the GMDSS and tasked the group with providing recommendations. One of the areas reviewed was the use of additional satellite systems to provide Enhanced Group Calling (ECG) services, similar to SafetyNET. In their review, the Correspondence Group did identify several concerns relating to interoperability and cost. However, they did recommend that additional systems be allowed assuming they could meet the criteria. Specifically, their recommendations [Completion of the Detailed Review of the Global Maritime Distress And Safety System (GMDSS)[13]] include the following:

- SOLAS chapter IV should be revised to provide for other GMDSS satellite service providers in addition to Inmarsat.



- Possible ways for MSI providers to provide and monitor MSI broadcasts over multiple GMDSS satellite service providers should be identified, with a view to minimizing the costs, or at least the cost increases for MSI providers. Resolution A.707(17) could be revised to provide for shore-to-ship MSI broadcasts without charge to the originator.
- Formatting of Enhanced Group Calling (EGC) should be standardized if possible to minimize delays, and if possible, a way should be found to transmit EGC simultaneously on all GMDSS satellite service providers.
- IMO instruments applying to Inmarsat should be reviewed and should be revised, if appropriate, to apply to all GMDSS satellite service providers.

Iridium Communications, Inc. proposed in 2013 that their satellite system be accepted as a GMDSS provider. The rules and requirements for this are documented in IMO Resolution A.1001(25) [42] and Circular 1414 [43]. An update on the status of this process is contained in [44]. They are currently working with NCSR and WWNWS subcommittees to resolve remaining issues and concerns, demonstrate feasibility, and update necessary documentation and standards. They are on a path for approval in the 2020 timeframe. Iridium in conjunction with the IHO WWNWS-SC has also been working on a draft of an Iridium EGC manual [45] (comparable to the Inmarsat SafetyNET manual [8]).

It appears that within the next few years Iridium will be approved as an authorized GMDSS provider. This will benefit both mariners and national authorities, as Iridium provides coverage in the polar regions that is not possible with Inmarsat's geostationary satellites. Also, increased competition should improve service and drive costs down in the long run. In the short term, there are likely to be some increased costs and complexity for national authorities as MSI will need to be transmitted via both systems.

4.4 MSI over HF

NCSR is considering the option to require future NAVTEX receivers include NAVDAT capability for the reception of MSI on the designated HF frequencies in addition to the MF frequencies. NAVDAT (MF in 495-505 kHz band) is the proposed improvement to NAVTEX, providing data rates up to 18 kbps versus 50 bps for NAVTEX. If widely adopted, NAVDAT could replace NAVTEX. Since the global architecture of NAVDAT is similar to NAVTEX, this reduces cost and facilitates the evolution from NAVTEX to NAVDAT. In addition, as described below, the existing NW distribution architecture could be re-used.

The MF NAVDAT system is described in Recommendation M.2010 [46] that was published in 2012. After this Recommendation was approved, France proposed extending this to the HF band, six frequencies (4.226, 6.3375, 8.443, 12.6635, 16.9095, and 22.45054 MHz) have been proposed and the complementary HF NAVDAT described in Recommendation M.2058 [47] was published in 2015.

MF NAVDAT is proposed to use Orthogonal Frequency Division Multiplexing (OFDM) in a 10 kHz bandwidth with the subcarriers modulated using 4,16, or 64-QAM to achieve overall useful data rates of between 12 and 18 kbps. This is essentially Digital Radio Mondiale™ (DRM) at 500 kHz. DRM is a universal, openly standardized digital broadcasting system for all frequencies below and above 30 MHz (above 30 MHz is coined DRM+), including Long Wave (LW), Medium Wave (MW), Short Wave (SW) and VHF (see [48] for a good description of the system). HF NAVDAT is proposed using the same modulation techniques and bandwidth, after error correction coding is applied it is expected to provide useful data rates of 10 to 15 kbps.



The proposed NAVDAT (MF and HF) would allow for MSI to be broadcast at much higher rates (more than 300x) than the current NAVTEX system. This significantly higher data rate would allow transmission of more detailed weather, ice edge, and notice to mariner's information, as well as electronic chart updates. The bandwidth would also support the delivery of MSI in S-100 formats (Extensible Markup Language-XML, binary data, and graphics) vice text only. The use of HF in addition to MF allows for wider geographic coverage than MF alone. With higher data rates and the ability to support more than just text, encryption and authentication services would also be possible.

The proposed NAVDAT (MF & HF) system also benefits from its use of DRM. One of the key components of DRM is the Content Server. It serves to aggregate the data to be transmitted and provide it to the modulator in a constant stream. The data may be of various types (text, graphics, binary) from a variety of sources and at different update rates. The Content Server organizes it all and provides the data stream to the modulator at a constant rate. The available bandwidth can be divided up amongst the various services according to user preference. This has been demonstrated by RDC in a year-long test using a Content Server, DRM Modulator, and HF transmitter in Kodiak, AK. The final report on this will be forthcoming in March 2018; the initial results are that the system performed well, and included a demonstration of broadcasting NAVAREA Warnings.

HF NBDP will likely become defunct as it is rarely used. HF data exchange (as described in Recommendation M.1798 [49]) could be a replacement although it has not been put to operational use. This would provide a ship-to-ship capability on MF/HF for the exchange of information over longer distances than VHF.

5 CONCLUSIONS/RECOMMENDATIONS

The ongoing GMDSS modernization plan will result in big changes in the way that MSI is delivered and in the type of information that can be delivered by 2024. The current state is shown in Figure 1 and reflects the delivery of text information at a low bit rate. The developments being considered as part of the GMDSS modernization, discussed in Section 4, have been mapped into the same framework in Figure 9. In this new potential architecture the information being delivered is not limited to text only but can include geo-coded text, graphics, and binary data all defined by S-100 series standards. The information sources can also be expanded to include other local MSI such as PORTS¹² data and other information relevant to the safety and efficiency of navigation. The USCG will need to stay on top of these developments over the next few years to ensure that it is ready for modernization. Figure 10 shows views of Figure 1 (the present MSI architecture) and Figure 9 (potential future MSI architecture).

¹² Physical Oceanographic Real-Time System, see <https://tidesandcurrents.noaa.gov/ports.html>.



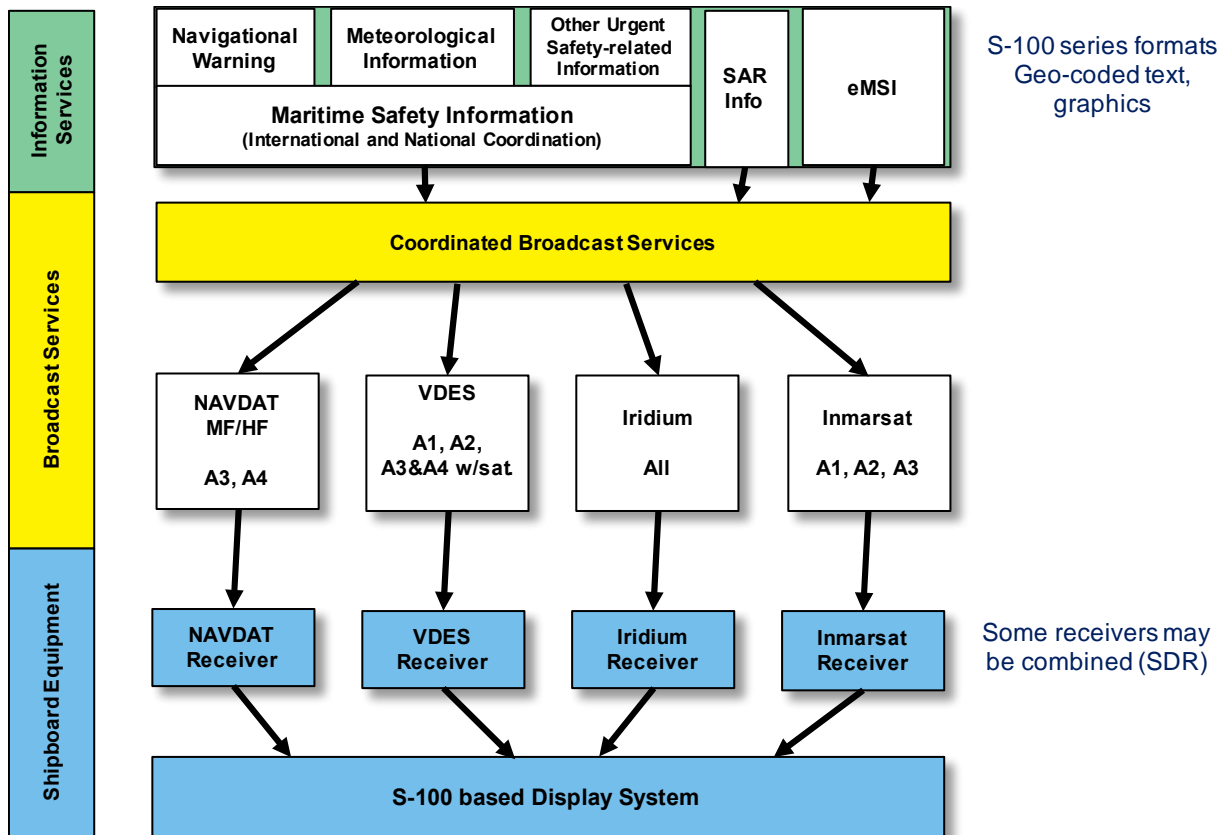


Figure 9. Potential Future MSI architecture.

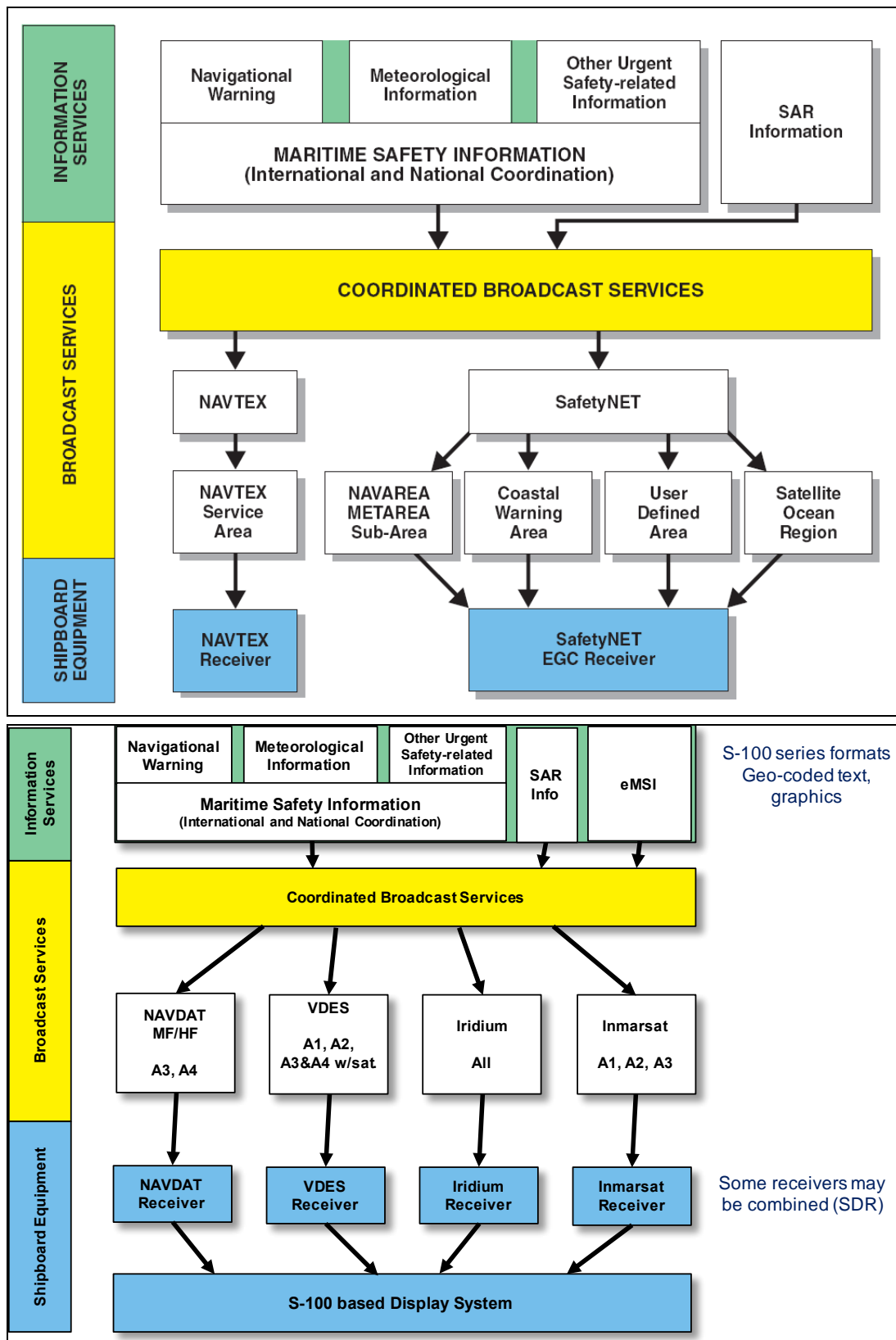


Figure 10. The present maritime safety information architecture of the GMDSS on the top and additional potential future MSI architecture on the bottom.

5.1 VDES

Going forward there is still a large amount of research and development work that needs to be done before VDES can be an operational system. However, the technical specification (committee draft not the published version) is probably sufficiently mature at this time to do some hardware and software development and testing such as:

- Prototype installations to assess range and message throughput of ASM 1 and 2 versus AIS 1 and 2 as well as frequency interference and coordination issues.
- Prototype installations of VDE terrestrial to assess performance and identify and resolve operational usage issues.
- Track development of satellite VDE as this may be extremely useful for meeting Arctic communications needs, though this would need to be compared against other options for both cost and performance.

The results of this testing will guide both the system development and enable the USCG to answer operational implementation questions. How ASM 1 & 2 and VDES might be used to transmit MSI (and eMSI) also needs to be considered and prototyped (this is also noted in [13]). The US also needs to resolve the MariTEL™ channel ownership issues prior to any system implementation.

5.2 Iridium

The USCG will need to track the progress of Iridium being approved as a GMDSS provider and potentially conduct some research and development in order to be ready to use the service once it is approved. Although IMO is considering ways to standardize MSI delivery formats to facilitate delivery to multiple service providers, this is not assured. There may be some operational considerations that need to be resolved for the USCG to make the best use of multiple satellite services simultaneously.

The use of Iridium SBD service for moving AIS messages (NMEA sentences) has been tested by RDC with some success. If the service improves with the Iridium NEXT constellation, then this may be a viable option for eMSI transmissions in the Polar Regions. This needs to be tested and if viable, operational considerations resolved.

5.3 HF

The use of HF-DRM (NAVDAT HF) has been successfully demonstrated by RDC. As a follow-on, it might be beneficial to prototype and demonstrate NAVDAT MF and perhaps use both in conjunction to show the benefits of a single Content Server feeding modulators for both MF and HF simultaneously.

5.4 S-100

The S-100 series of standards will be the framework for the entire modernized GMDSS system and eNavigation. It is thus important for the USCG to stay abreast of developments and be a part of the development process so that USCG requirements can be included in the standards. As standards become solidified, they will need to be prototyped and tested; and MSI creation and dissemination processes revised to make use of the new standards.



6 REFERENCES

- [1] "Amendments to Resolution A.705(17) - Promulgation of Maritime Safety Information," International Maritime Organization, London, UK, MSC.1/Circ. 1287/Rev.1, 24 June 2013.
- [2] "Revised Joint IMO/IHO/WMO Manual on Maritime Safety Information (MSI)," International Maritime Organization, London, UK, MSC.1/Circ. 1310/Rev. 1, 21 November 2014.
- [3] "Amendments to Resolution A.706(17) - World-Wide Navigational Warning Service," International Maritime Organization, London, UK, MSC.1/Circ. 1288/Rev.1, 24 June 2013.
- [4] "Amendments to the Revised NAVTEX Manual," International Maritime Organization, London, UK, MSC.1/Circ. 1403/Rev.1, 25 November 2016.
- [5] "IMO/WMO Worldwide Met-ocean Information and Warning Service - Guidance Document," International Maritime Organization, London, UK, Resolution A.1051(27), 20 December 2011.
- [6] "Technical Characteristics for a High Frequency Direct-Printing Telegraph System for Promulgation of High Seas and Navtex-type Maritime Safety information," International Telecommunications Union, Geneva, Recommendation ITU-R M.688, 1990.
- [7] "Operational and Technical Characteristics for an Automated Direct-Printing Telegraph System for Promulgation of Navigational and Meteorological Warnings and Urgent Information to Ships," International Telecommunications Union, Geneva, Recommendation ITU-R M.540, 1990.
- [8] "Amendments to the Revised International SAFETYNET Manual," International Maritime Organization, London, UK, MSC.1/Circ. 1364/Rev.1, 25 November 2016.
- [9] G. W. Johnson, M. Winkler, and B. Tetreault, "Dissemination of enhanced Marine Safety Information (eMSI) via AIS," in *Radio Technical Commission for Maritime Services Annual Conference*, St Petersburg, FL, 2016.
- [10] G. W. Johnson and B. Tetreault, "Identification of Standards Needed to Support Robust and Reliable AIS Transmit Operations," in *European Navigation Conference ENC 2016*, Helsinki, Finland, 2016.
- [11] G. W. Johnson, B. J. Tetreault, and I. M. Gonin, "Development of an AIS Transmit Architecture to support the dissemination of electronic Marine Safety Information (eMSI)," presented at the European Navigation Conference (ENC14), Rotterdam, 2014.
- [12] I. Gonin, G. Johnson, R. Shalae, B. Tetreault, and L. Alexander, "USCG Development, Test and Evaluation of AIS Binary Messages for Enhanced VTS Operations," presented at the Institute of Navigation, International Technical Meeting (ION-ITM 09), Anaheim, CA, 2009.
- [13] "Completion of the Detailed Review of the Global Maritime Distress And Safety System (GMDSS) " IMO Subcommittee on Navigation Communications and SAR, Report of the Correspondence Group on the Review of the GMDSS NCSR 3/14, 11 December 2015.
- [14] K. Korcz, "Some Aspects of the Modernization Plan for the GMDSS," *TransNav*, vol. 11, March 2017.
- [15] "S-100 - Universal Hydrographic Data Model," International Hydrographic Organization, Monaco, Publication S-100, April 2017.
- [16] R. Ward and B. Greenslade, "IHO S-100 - The Universal Hydrographic Data Model," International Hydrographic Organization, Monaco, Information Paper January 2011.
- [17] I. H. Organization, "S-100 - Universal Hydrographic Data Model Background Brief," ed, 2016.
- [18] S.-. CG, "S-124 Model Explanations and comments," in *Eighth Meeting of the WNWWS Sub Committee (WWNWS8)*, Ålesund, Norway, 2016.
- [19] "VHF Data Exchange System (VDES)," presented at the 3rd Meeting CPG PTC, Bucharest, 2013.



- [20] "A Satellite VDE Segment as Part of the Future VHF Data Exchange (VDE)," IMO Sub-committee on Radiocommunications and Search and Rescue, London, UK, COMSAR 17/INF.716 November 2012.
- [21] S. Bober, "AIS Next Generation – the development of the VHF Data Exchange System (VDES) for Maritime and Inland Navigation," presented at the Smart Rivers 2015, Buenos Aires, Argentina, 2015.
- [22] S. Bober, "VDES – VHF Data Exchange System Overview," presented at the Second Workshop on VDES, Tokyo, Japan, 2014.
- [23] "Technical Characteristics for a VHF Data Exchange System in the VHF Maritime Mobile Band," International Telecommunications Union, Geneva, Recommendation ITU-R M.2092-0, October 2015.
- [24] "Technical Characteristics for a VHF Data Exchange System in the VHF Maritime Mobile Band," International Telecommunications Union, Geneva, Working Draft Recommendation ITU-R M.092-0+, June 2017.
- [25] "Characteristics of VHF Radio Systems and Equipment for the Exchange of Data and Electronic Mail in the Maritime Mobile Service RR Appendix 18 Channels," International Telecommunications Union Radiocommunication Sector ITU-R Rec. M.1842-1, March 2009.
- [26] "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)," European Telecommunications Standards Institute (ETSI), European Standard ETSI EN 300 392-2 V2.3.2, March 2001.
- [27] "Radio Regulations," International Telecommunications Union Radiocommunication Assembly (ITU-R), Geneva, Volume 2 - Appendices, 2016
- [28] "Use of Appendix 18 to the Radio Regulations for the Maritime Mobile Service," International Telecommunications Union, Geneva, Report ITU-R M.2231-1, November 2014.
- [29] "EMC assessment of Shore-Based Electronic Navigation (eNAV) Infrastructure and New Draft Standards for Data Exchange in the VHF Maritime Mobile Band (156-174 MHz)," International Telecommunications Union, Geneva, Report ITU-R M.2122, November 2014.
- [30] "Selection of the Channel Plan for a VHF Data Exchange System," International Telecommunications Union, Geneva, Report ITU-R M.2371-0, July 2015.
- [31] H. LeBlanc, "Canadian Coast Guard Options and Impacts for VDE and AIS Systems: A Wireless Communications Study," Roche Ltd Consulting Group 21 July 2014.
- [32] "VHF Data Exchange System Channel Sounding Campaign," International Telecommunications Union, Geneva, Report ITU-R M.2317-0, November 2014.
- [33] J. Safar, "VDES Channel Sounding Campaign: Trial Report," GLA Research & Radionavigation Directorate, Harwich, UK RPT-09-JSa-14, 4 March 2014.
- [34] "Provisional Final Acts - World Radiocommunication Conference (WRC-15)," International Telecommunication Union, Geneva, Report 2 - 27 November 2015.
- [35] "Australian Maritime Safety Authority Brisbane VDES trials," Stone Three Venture Technology, IMIS Global Limited, and Australian Maritime Systems, Somerset West, South Africa, VDES Field Trial Report SDR002-D003-1.0, September 2015.
- [36] "The Global Network: Ground Infrastructure," rev 07/12 ed. <http://www.iridium.com/> Iridium Communications Inc., 2012.
- [37] "The Global Network: Satellite Constellation," rev 07/12 ed. <http://www.iridium.com/> Iridium Communications Inc., 2012.
- [38] "Iridium NEXT: Changing the future of satellite communications NOW," 6/16 ed. <http://www.iridium.com/> Iridium Communications Inc., 2016.



- [39] "Iridium CertusSM: The advanced new multi-service platform powered by Iridium NEXT," 10/16 ed. <http://www.iridium.com/> Iridium Communications Inc., 2016.
- [40] "Iridium SBD: Short Burst Data Service," 1/14 ed. <http://www.iridium.com/> Iridium Communications Inc., 2014.
- [41] W. Glidden, O. Akbik, D. Palmer, J. Spalding, and M. Turner, "Feasibility of an Iridium/ Automatic Identification System (AIS) Shipboard System," USCG Research and Development Center, New London, CT, Final Report UDI #1528, June 2015.
- [42] "Criteria for the Provision of Mobile Satellite Communication Systems in The Global Maritime Distress And Safety System (GMDSS)," International Maritime Organization, London, UK, Resolution A.1001(25), 3 January 2008.
- [43] "Guidance to Prospective GMDSS Satellite Service Providers," International Maritime Organization, London, UK, MSC.1/Circ. 1414, 25 May 2012.
- [44] L. Solomon, "Iridium Update," presented at the IHO – WNWNS Sub-Committee Meeting (WWNWS 8), Alesund, Norway, 2016.
- [45] "Iridium Global Satellite EGC System Manual - 2020 Edition," WNWNS-SC, 2 June, DRAFT, unpublished.
- [46] "Characteristics of a digital system, named Navigational Data for broadcasting maritime safety and security related information from shore-to-ship in the 500 kHz band from shore-to-ships," International Telecommunications Union Radiocommunication Sector ITU-R Rec. M.2010, March 2012.
- [47] "Characteristics of a Digital System, Named Navigational Data for Broadcasting Maritime Safety and Security Related Information from Shore-to-Ship in the Maritime HF frequency band," International Telecommunications Union Radiocommunication Sector ITU-R. M.2058-0, February 2014.
- [48] "The DRM Digital Broadcasting System Introduction and Implementation Guide," DRM Consortium, Geneva, Switzerland Revision 2, 13 September 2013.
- [49] "Characteristics of HF Radio Equipment for The Exchange of Digital Data and Electronic Mail in the Maritime Mobile Service," International Telecommunication Union Radiocommunication Sector, Recommendation ITU-R M.1798-1, April 2010.



(This page intentionally left blank.)



APPENDIX A. DEFINITIONS

From [1, 8]

Coastal warning means a navigational warning or in-force bulletin promulgated as part of a numbered series by a National Coordinator. Broadcast should be made by the International NAVTEX service to defined NAVTEX service areas and/or by the International SafetyNET service to coastal warning areas. (In addition, Administrations may issue coastal warnings by other means).

Coastal warning area is a unique and precisely defined sea area within a NAVAREA/METAREA or Sub-area established by a coastal State for the purpose of coordinating the broadcast of coastal maritime safety information through the SafetyNET service.

Enhanced Group Call (EGC) is the system for broadcasting messages via the mobile satellite communications system operated by Inmarsat Global Limited. EGC is a part of the Inmarsat C system and supports two services: SafetyNET and FleetNET.

FleetNET is the commercial service for the broadcasting and automatic reception of fleet management and general public information by means of direct printing through Inmarsat's EGC system. Some receivers for FleetNET may not be able to receive SafetyNET.

Global Maritime Distress and Safety System (GMDSS) means the global communications service based upon automated systems, both satellite and terrestrial, to provide distress alerting and promulgation of maritime safety information for mariners.

HF NBDP means High Frequency narrow-band direct-printing, using radio telegraphy as defined in Recommendation ITU-R M.688, as amended.

In-force bulletin is a list of serial numbers of those NAVAREA, Sub-area or coastal warnings in force issued and broadcast by the NAVAREA Coordinator, Sub-area Coordinator or National Coordinator.

Inmarsat C is the digital satellite communications system for store-and-forward text or data messaging using mobile terminals with omni-directional antennas. Inmarsat C is the only system that allows ships to meet the majority of the satellite communication requirements of the GMDSS including distress alerting, reception of maritime safety information and general communications.

Inmarsat mini-C means smaller terminals, based on the same technical requirements as Inmarsat C terminals. Some models are approved as GMDSS compliant terminals.

Inmarsat Fleet is the digital satellite communication system that provides voice and flexible data communication services, e-mail and secure internet access for maritime users, comprising a family of Fleet F77, F55 and F33 mobile terminals. The Inmarsat Fleet F77 system provides voice distress and safety functionality and meets the requirements of resolution A.1001(25).

Inmarsat FleetBroadband is the communication service that provides voice and high-speed data services, simultaneously, through compact terminals for maritime users.

International NAVTEX service is the coordinated broadcast and automatic reception on 518 kHz of maritime safety information by means of narrow-band direct-printing telegraphy using the English language.



International SafetyNET service is the coordinated broadcast and automatic reception of maritime safety information via the Inmarsat Enhanced Group Call (EGC) system, using the English language, in accordance with the provisions of the International Convention for the Safety of Life at Sea, 1974, as amended.

Issuing Service means a National Meteorological Service which has accepted responsibility for ensuring that meteorological warnings and forecasts for shipping are disseminated through the Inmarsat SafetyNET service to the METAREA for which the Service has accepted responsibility under the broadcast requirements of the GMDSS.

Land Earth Station (LES) is a fixed terrestrial station acting as a gateway between terrestrial communication networks and the Inmarsat satellites in the maritime mobile-satellite service. This may also be referred to as a Coast Earth Station (CES).

Land Earth Station Operator (LESO) means an Inmarsat service provider which owns and operates the LES.

Local warning means a navigational warning which covers inshore waters, often within the limits of jurisdiction of a harbor or port authority.

Maritime safety information (MSI) means navigational and meteorological warnings, meteorological forecasts and other urgent safety-related messages broadcast to ships.

Maritime safety information service means the internationally and nationally coordinated network of broadcasts containing information which is necessary for safe navigation.

METAREA means a geographical sea area established for the purpose of coordinating the broadcast of marine meteorological information. The term METAREA followed by a roman numeral may be used to identify a particular sea area. The delimitation of such areas is not related to and shall not prejudice the delimitation of any boundaries between States.

METAREA Coordinator is the authority charged with coordinating marine meteorological information broadcasts by one or more National Meteorological Services acting as Preparation or Issuing Services within the METAREA.

Meteorological information means the marine meteorological warning and forecast information in accordance with the provisions of the International Convention for the Safety of Life at Sea, 1974, as amended.

Mobile Earth Station (MES) is a mobile user terminal in the Inmarsat maritime mobile-satellite service. This may also be referred to as Ship Earth Station (SES).

National Coordinator is the national authority charged with collating and issuing coastal warnings within a national area of responsibility.

National NAVTEX service means the broadcast and automatic reception of maritime safety information by means of narrow-band direct-printing telegraphy using frequencies other than 518 kHz and languages as decided by the Administration concerned.

National SafetyNET service means the broadcast and automatic reception of maritime safety information via the Inmarsat EGC system, using languages as decided by the Administration concerned.



NAVAREA is a geographical sea area established for the purpose of coordinating the broadcast of navigational warnings. The term NAVAREA followed by a roman numeral may be used to identify a particular sea area. The delimitation of such areas is not related to and shall not prejudice the delimitation of any boundaries between States.

NAVAREA Coordinator is the authority charged with coordinating, collating and issuing NAVAREA warnings for a designated NAVAREA.

NAVAREA warning is a navigational warning or in-force bulletin promulgated as part of a numbered series by a NAVAREA Coordinator.

Navigational warning is a message containing urgent information relevant to safe navigation broadcast to ships in accordance with the provisions of the International Convention for the Safety of Life at Sea, 1974, as amended.

NAVTEX is the system for the broadcast and automatic reception of maritime safety information by means of narrow-band direct-printing telegraphy.

NAVTEX Coordinator is the authority charged with operating and managing one or more NAVTEX stations broadcasting maritime safety information as part of the International NAVTEX service.

NAVTEX coverage area means an area defined by an arc of a circle having a radius from the transmitter calculated according to the method and criteria given in resolution A.801(19), annex 4.

NAVTEX service area is a unique and precisely defined sea area, wholly contained within the NAVTEX coverage area, for which maritime safety information is provided from a particular NAVTEX transmitter. It is normally defined by a line that takes full account of local propagation conditions and the character and volume of information and maritime traffic patterns in the region, as given in resolution A.801(19), annex 4.

Network Coordination Station (NCS) is a fixed land station in the Inmarsat satellite communications system which controls channel assignments and provides the network management functions for each of the four satellite ocean regions. NCSs also transmit EGC messages on the NCS common channel.

Other urgent safety-related information means maritime safety information broadcast to ships that is not defined as a navigational warning or meteorological information. This may include, but is not limited to, significant malfunctions or changes to maritime communications systems, and new or amended mandatory ship reporting systems or maritime regulations affecting ships at sea.

Registered information provider is a maritime safety information provider (MSI provider), authorized in accordance with annex 2 of the International SafetyNET Manual, which has an agreement with one or more LES(s) for providing SafetyNET services.

Rescue Coordination Centre (RCC) is a unit responsible for promoting efficient organization of search and rescue services and for coordinating the conduct of search and rescue operations within a search and rescue region. Note: the term RCC will be used within this Manual to apply to either joint, aeronautical or maritime centres; JRCC, ARCC or MRCC will be used as the context warrants.

SafetyNET is the international service for the broadcast and automatic reception of maritime safety information via the Inmarsat EGC system. SafetyNET receiving capability is part of the mandatory equipment which is required to be carried by certain ships in accordance with the provisions of the International Convention for the Safety of Life at Sea, 1974, as amended.



SAR information means distress alert relays and other urgent search and rescue information broadcast to ships.

Satellite Ocean Region is the area on the earth's surface within which a mobile or fixed antenna can obtain line-of-sight communications with one of the four primary Inmarsat C geostationary satellites. This area may also be referred to as the "footprint":

- Atlantic Ocean Region – East (AOR-E)
- Atlantic Ocean Region – West (AOR-W)
- Indian Ocean Region (IOR)
- Pacific Ocean Region (POR)

Sea Area A1 means an area within the radiotelephone coverage of at least one VHF coast station in which continuous DSC6 alerting is available, as may be defined by a Contracting Government.

Sea Area A2 means an area, excluding sea area A1, within the radiotelephone coverage of at least one MF coast station in which continuous DSC alerting is available, as may be defined by a Contracting Government.

Sea Area A3 means an area, excluding sea areas A1 and A2, within the coverage of an Inmarsat geostationary satellite in which continuous alerting is available.

Sea Area A4 means an area outside sea areas A1, A2 and A3.

Sub-area means a subdivision of a NAVAREA/METAREA in which a number of countries have established a coordinated system for the promulgation of maritime safety information. The delimitation of such areas is not related to and shall not prejudice the delimitation of any boundaries between States.

Sub-area Coordinator means the authority charged with coordinating, collating and issuing Sub-area warnings for a designated Sub-area.

Sub-area warning is a navigational warning or in-force bulletin promulgated as part of a numbered series by a Sub-area Coordinator. Broadcast should be made by the International NAVTEX service to defined NAVTEX service areas or by the International SafetyNET service (through the appropriate NAVAREA Coordinator).

User defined area is a temporary geographic area, either circular or rectangular, to which maritime safety information is addressed.

UTC (Coordinated Universal Time) is equivalent to Greenwich Mean Time (GMT), or ZULU, as the international time standard.

World-Wide Met-ocean Information and Warning Service (WWMIWS) is the internationally coordinated service for the promulgation of meteorological warnings and forecasts.

World-Wide Navigational Warning Service (WWNWS) is the internationally and nationally coordinated service for the promulgation of navigational warnings.

In the operating procedures coordination means that the allocation of the time for data broadcast is centralized, the format and criteria of data transmissions are compliant as described in the Joint IMO/IHO/WMO Manual on Maritime Safety Information and that all services are managed as set out in resolutions A.705(17), as amended, A.706(17), as amended, and A.1051(27).

