INTERNATIONAL FEDERATION OF SURVEYORS

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

INTERNATIONAL CARTOGRAPHIC ASSOCIATION

STANDARDS OF COMPETENCE FOR NAUTICAL CARTOGRAPHERS AND GEOSPATIAL DATA ANALYSTS

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Comments arising from the experience gained in the application of the guidance are welcome. They should be addressed to the Chair of the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers at the above address. This document is published periodically. Please check with IHO for the latest edition, including current amendments.

1. PREFACE

All components of the hydrographic surveying and marine cartography professions face the challenge of how best to ensure the maintenance of high standards and best practices based on minimum standards of competence worldwide.
To achieve these objectives, standards of competence have been developed by the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC).
The IBSC is composed of members of known competence in the civil, governmental or educational sectors of hydrographic surveying and nautical cartography, selected to provide as wide as possible a spectrum of knowledge and experience in educational practices, hydrography and nautical cartography, from different geographical areas. The members of the IBSC belong to three international organizations: International Federation of Surveyors (FIG), International Hydrographic Organization (IHO) and International Cartographic Association (ICA).
The latest edition of the standards of competence for nautical cartographers (S-8) and hydrographic surveyors (S-5) was published in June 2018.
Since May 2024, IBSC has been working to update these standards to keep pace with new technologies, methodologies, specifications and the concept of data centricity, which prioritizes data as a highly valuable resource. In developing this new edition, the IBSC liaised with the hydrographic and cartographic community and received input from many stakeholders: hydrographic offices, academies, universities, industries, private companies, professional associations and individuals. The input was crucial in expressing the needs of the community and guiding the Board in updating the standards S-8/S-5, while remaining committed to its mandate.

For this publication, the words:

- **must**: indicates a mandatory requirement;
- **should**: indicates a recommended requirement;
- **may**: indicates an optional requirement

The IHO will release changes to S-8 and S-5 standards as a New Edition, Revision, or Clarification as per the IHO Resolution 02/2007.
The associated version control numbering to identify changes (n) to the S-8 and S-5 Standards must be as follows:

- **New Editions** denoted as **n**.0.0
- **Revisions** denoted as n.**n**.0
- **Clarifications** denoted as n.n.**n**

2. INTRODUCTION

The IBSC can recognize two different categories of *programmes*: Category “A” and Category “B”. A Category “A” programme provides a comprehensive and broad-based knowledge in all aspects of the theory and practice of hydrography, nautical cartography and allied disciplines. A Category “B” programme provides a practical comprehension of hydrographic surveying, nautical cartography and related subjects.
Institutions and professional bodies must use the Standards when submitting their education/training programmes and competence schemes for IBSC Recognition.
In addition, even if they are not applying for Recognition, education and training providers should adopt the Standards for planning, scheduling and delivering their programmes.

Publication S-8 aims to provide a set of minimum competencies required for nautical cartographers and geospatial data analysts.
The intention is that a Category "A" individual with appropriate experience and education, would be a senior professional in their chosen field (government, industry, academia). Category "B" individuals with appropriate experience would be technical practitioners leading and delivering products and services to meet specifications and outcomes.

This document is structured to enable students to acquire knowledge incrementally, preparing them to be competent cartographers and geospatial data analyst at the Category "A"/Category "B" level.
Each programme is made up of a series of lectures, tutorials, practical exercises, self-study/self-guided hours, laboratories and project work in the cartographic field. More specifically, the sequence of the subjects is designed so that any new subject builds upon the content and the knowledge of the preparatory subjects.
The theoretical subjects are complemented with a final cartographic project (respectively called *Comprehensive Final Cartographic Project* (CFCP) for a Category B programme and *Complex Multi-disciplinary Cartographic Project* (CMCP) for a Category "A" programme) that includes all those items required to enable the student to solve efficiently and effectively, at different levels of knowledge, problems associated with the planning and production of modern nautical charts, S-57 ENCs, S-101 ENCs, and special purpose charts according to internationally adopted specifications.
Successful completion of the theoretical subjects and the final cartographic project will enable the student to obtain the appropriate Category "A" or Category "B" educational certification on **Nautical Cartography and Geospatial Data Analytics**.

3. DEFINITIONS

3.1 Subjects, topics and elements

The S8-A standard contains the following list of ***B**asic subjects, **F**oundation subjects and **C**artographic Science subjects*:

B1 Mathematics, Statistics, Theory of Errors	9
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Topics and Elements:

- Each **Basic, Foundation** or **Cartographic Science** *subject* comprises a list of *topics* which are denoted by Bx.y, Fx.y or Cx.y;
- Some of the *topics* contain *elements* which are denoted by Bx.y<c>, Fx.y<c> or Cx.y<c> .

For example, the *subject* C4 "Nautical Cartography" contains the *topic* C4.1 "The Nautical Chart" that has the *element* C4.1a "Evolution of nautical charts".

3.2 List of content and Learning outcomes

It is important to understand that each *topic* and/or *element* is associated with:

- a *content* list. This list is associated with one or more *learning outcomes* and describes the theoretical knowledge or practical/technical context which the course syllabi should address to meet a particular *learning outcome*.
- one or more intended *learning outcomes* that a student should be able to achieve on completion of the programme.

A level of knowledge has been defined for each *topic/element*. It is indicated in italics in the left column, by a letter (*B*=Basic, *I*=Intermediate, *A*=Advanced) that complements the learning outcome description associated with each element.
All *learning outcomes* must be assessed. This may be done through one of, or a combination of, the following: examination, assessed exercise or presentation, laboratory report, before commencement of the final project.

3.3 Final Cartographic Project

The Programme must include a supervised and evaluated final Cartographic Project that reflects the level of knowledge outlined in the programme.
For students of S-8 Category "A" Programme, a *Complex Multi-disciplinary Cartographic Project* (CMCP) is required, which will include analytical reasoning, decision making and development of solutions to non-routine problems. The instruction for the CMCP must include a composite cartographic scenario from which the students must develop the cartographic solution, the process for its implementation and the production of the resulting nautical chart/ENC.

4. PROGRAMME PREPARATION AND SUBMISSION

The preparation of a programme submission to the IBSC must be in accordance with the document entitled "Guidelines for the implementation of the standards of competence for hydrographic surveyors and nautical cartographers," Ed.XX.XX.XX This document is available from the IHO website: https://iho.int/en/standards-and-specifications
The cross-reference table is a mandatory requirement for a programme submission and must be completed.
A template is specified and is available from the IHO website: https://iho.int/en/ibsc-templates

LIST OF ACRONYMS AND INITIALISMS USED IN THIS DOCUMENT

1D	One-Dimensional
2D	Two-Dimensional
3D	Three-Dimensional
A	Advanced (level of knowledge)
AI	Artificial Intelligence – a form of Expert System
AIS	Automatic Identification System
B	Basic (level of knowledge)
B/W	Black and White
CATZOC	Category of Zones Of Confidence
CIE	International Commission on Illumination
CFCP	Comprehensive Final Cartographic Project
CCP	Comprehensive Cartographic Project
CPU	Central Processing Unit
CRS	Coordinate Reference Systems
DBMS	Data Base Management System
DEM	Digital Elevation Model
DIGEST	Digital Geographic Exchange Standard
DXF	Digital Exchange Format
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
ENC	Electronic Navigational Chart
EPSG	European Petroleum Survey Group (part of the IOGP)
EROS	Earth Resources Observation and Science
ETRS89	European Terrestrial Reference System 1989
FAIR	Findable, Accessible, Interoperable, Reusable
FIG	International Federation of Surveyors
GeoTIFF	Geographic Tag Image File Format
GIS	Geographic Information System
GISc	Geographic Information Science
GML	Geography Markup Language
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference System (1980)
GUI	Graphical User Interface
HSL	Hue, Saturation, Lightness
I	Intermediate (level of knowledge)
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IBSC	International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers
ICA	International Cartographic Association
IHO	International Hydrographic Organization
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
INT	International
IOGP	International Oil & Gas Producers
ISO	International Standards Organization

ITRF	International Terrestrial Reference Frame
JPEG	Joint Photographic Experts Group
LAN	Local Area Network
LiDAR	Light Detection And Ranging
MatLab	Mathematics Laboratory software
ML	Machine Learning – a form of Expert System
MSDIs	Marine Spatial Data Infrastructures
OGC	Open Geospatial Consortium
P	Practicals (fieldwork and/or laboratories)
QA	Quality Assurance
QC	Quality Control
RADAR	RAdio Detection And Ranging
RENC	Regional ENC Coordinating Centre
RGB	Red, Green, Blue
RHC	Regional Hydrographic Commissions
RIP	Raster Image Processing
RMSE	Root Mean Square Error
S-4	IHO Publication S-4 *Regulations for International (INT) Charts and Chart Specifications of the IHO*
S-11	IHO Publication S-11 *INTernational Chart Web Catalog*
S-52	IHO Publication S-*52 Specifications for Chart Content and Display Aspects of ECDIS*
S-57	IHO Publication S-57 IHO *Transfer Standard for Digital Hydrographic Data*
S-58	IHO Publication S-58 *ENC Validation Checks*
S-65	IHO Publication S-65 *ENCs: Production, Maintenance and Distribution Guidance*
S-67	IHO Publication S-67 Mariners guide to accuracy of Electronic Navigational Charts (ENC)
S-99	IHO Publication S-99 *Operational Procedures for the Organization and Management of the S-100 Geospatial Information Registry*
S-100	IHO Publication S-100 *IHO Universal Hydrographic Data Model*
S-101	IHO Publication S-101 *ENC Product Specification*
S-102	IHO Publication S-102 *Bathymetric Surface Product Specification*
SDIs	Spatial Data Infrastructures
SDTS	Spatial Data Transfer Standard
SENC	System Electronic Navigation Chart
SG	Self-Guided exercises (or student's personal independent work)
SOLAS	Safety Of Life At Sea
SSDM	Seabed Survey Data Model
SVG	Scalable Vector Graphics
T	Theoretical (theory through lectures)
TIN	Triangulated Irregular Network
UKOOA	UK Offshore Operators Association
UNCLOS	United Nations Convention on the Law Of the Sea
UTM	Universal Transverse Mercator
WGS84	World Geodetic System (1984)
XML	eXtensible Markup Language
ZOC	Zones Of Confidence

S-8A STANDARDS

CONTENT
AND
INTENDED LEARNING OUTCOMES

1. **BASIC SUBJECTS**

B1 Mathematics, Statistics, Theory of Errors		
Topic/Element	**Content**	**Learning outcomes**
B1.1 Coordinate geometry *(I)*	(i) Coordinate systems (ii) Linear and quadratic functions (iii) Functions in plane geometry for lines and planes (iv) Parametric equations of curves and surfaces (v) Geometry of the ellipse.	Describe and use coordinate systems. Describe and use equations for lines and planes. Calculate distances between points, the intersection between lines and planes and the distance from a point to a plane. Compute lengths and coordinates on an ellipse.
B1.2 Linear Algebra *(I)*	(i) Vector and affine spaces, vector and inner products, norms. (ii) Linear equations, determinants (iii) Analytical geometry, line and plane equations (iv) Linear operators, matrix representation, composition, inverse, transpose (v) Translations, rotations, coordinate transformations.	Describe and apply 2D and 3D transformations involved in mapping. Solve linear equations using matrix methods.
B1.3 Differential and integral calculus *(I)*	(i) Real and vector-valued functions (ii) Series, Taylor expressions (iii) Gradient of real-valued functions and their discrete approximations (iv) Integrals of real-valued functions (v) Numerical integration methods.	Compute the gradient of a vector-valued function. Apply differential calculus to real and vector-valued functions from a n-dimensional vector space. Calculate the integral of classical functions and approximate numerical values.
B1.4 Trigonometry *(I)*	(i) Basic trigonometry (ii) Spherical trigonometry (sphere, great circle, rhumb lines, spherical angles, spherical triangles, and spherical excess).	Apply plane and spherical trigonometry to cartography problems.

B1.5 Statistics and sources of uncertainties *(I)*	(i) Statistics of samples and populations (ii) Sources of uncertainties and their classification (iii) Level of Confidence (iv) Random variables, mean, variance, standard deviation. (v) Covariance and correlation (vi) Estimation of mean, variance, and co-variance (vii) Normal distribution.	Identify and assess possible sources of error as a result of the utilization of a map/chart/data set (e.g., digitization). Estimate and interpret the mean, variance, covariance, and standard deviation from data sets.
B1.6 Least squares *(I)*	(i) Least squares principle (ii) Solution of problems using least squares estimation (iii) Definition and use of Root Mean Square Error (RMSE).	Solve problems by least squares estimation. Evaluate uncertainty in measurements from the use of least squares.
B1.7 1D & 2D Interpolation *(I)*	(i) 1D and 2D interpolation.	Describe and apply 1D and 2D spatial interpolation methods.
B2 Information and Communication Technology		
Topic/Element	**Content**	**Learning outcomes**
B2.1 Computer systems *(I)*	(i) Computer systems and peripherals (ii) Communication board, serial links, communication ports buffers, Ethernet links, data transmission rates (iii) Communication protocols and Remote Desktop Protocol (iv) Operating systems (v) Device drivers (vi) Input/output devices (scanners, digitizers, printers, plotters) and associated technical characteristics/specifications. (vii) Data storage: device types (viii) Cloud computing: Overview ● Essential characteristics, ● Cloud infrastructure concepts ● Infrastructure as a Service (IaaS) ● Platform as a Service (PaaS) ● Software as a Service (SaaS) ● Deployment models ● Advantages, limitations ● Adoption and suitability	Describe the different components of a computer system and the alternative ways of communication between systems and peripheral devices. Describe the role of a device driver and its relation to data transfer. Prepare technical specifications for input/output devices used in cartographic operations. Describe and interact with the most used data storage devices and the cloud. Describe the characteristics of a cloud computing environment, its advantages/ limitations, and advice on its suitability for adoption by an organization.

B2.2 Programming *(I)*	(i) Basic operations of a computer program or script (ii) File types (binary, text, XML) (iii) Algorithms (loops, conditional instructions) (iv) Programming languages (Visual Basic, Visual C++, Python, Java, Lua, XSLT) (v) Scripts and scripting languages (vi) Scientific computation environments (e.g., Matlab) (vii) Application to data exchange, file, and format conversion.	Write software programs and scripts for data format conversion and basic algorithmic computation. Perform computations using common scientific application environments.
B2.3 Databases and Database Management Systems (DBMSs) *(I)*	(i) Database Management Systems and query languages (ii) Overview of Geospatial Data, Types of Geospatial Data (iii) Relational databases (iv) Importance of Data Management and Metadata, Overview of Metadata Standards (ISO 19115, Dublin Core, etc.) (v) Data Stores, Workspaces, GeoDB, Projects (vi) Adding and Managing Layers, Introduction to Style Descriptors, Creating and Applying Styles (vii) User Roles and Permissions, Data Security Best Practices, Caching Strategies, Load Balancing, and Clustering (viii) Tools for Creating and Editing Metadata Records, Conducting Metadata Searches, Advanced Metadata Search Techniques, Using Controlled Vocabularies and Thesauri (ix) Linking Geospatial Data with Metadata, Configuring Integrated Systems, Managing Geospatial Data Effectively, Maintaining Comprehensive Metadata Records (x) Open-source software and Database management	Describe and design a geospatial database. Create/populate a geospatial database and query its content. Identify and differentiate between distinct types of geospatial data. Explain the importance of metadata and data management in geospatial contexts. Understand and apply metadata standards in geospatial data management. Organize geospatial data in Data stores, workspaces, GeoDB, Projects, etc., effectively. Add and manage layers within geospatial datasets. Create and apply styles to geospatial data for visual portrayal. Implement user roles and permissions to secure geospatial data. Develop caching strategies to enhance geospatial data performance. Create and edit comprehensive metadata records. Conduct advanced metadata searches using various techniques. Link geospatial data with metadata for integrated management. Implement best practices for managing geospatial data and maintaining metadata records. Use open-source software to create, populate, modify, and query a database.
B2.4 Web and network communications *(I)*	(i) Networks (LANs) (ii) Network and cloud storage file sharing (iii) Internet (iv) Network integrity (v) Communication protocols. .	Use various network communication configurations and associated protocols utilized in data transfer/exchange applications.

B3 Earth Sciences		
Topic/Element	**Content**	**Learning outcomes**
B3.1 Marine geomorphology and marine geographic features *(B)*	(i) Marine Geomorphology ● concepts ● features ● processes	Explain the concept of marine geomorphology. Describe and identify marine geographic features, such as coastline, bays, inlets, capes, oceans, seas, channels, etc. Describe processes of deposition and erosion in coastal, fluvial, and glacial environments.
B3.2 Marine geophysics *(B)*	(i) Gravity (ii) Magnetics (iii) Seismic profiles.	Describe the geophysical properties of undersea features. Describe the data acquired by gravity, magnetic, and seismic surveys.
B3.3 Ocean properties and dynamics *(B)*	(i) Seawater properties (ii) Ocean Dynamics ● nature ● motion ● tides ● currents.	List the main properties of seawater. Describe ocean dynamics in terms of currents and tidal variations.
B3.4 Seafloor characteristics *(B)*	(i) Sediment types (ii) Submerged aquatic vegetation (iii) Corals (iv) Outcropping rocks.	Distinguish common seafloor characteristics.

2. **FOUNDATION SUBJECTS**

F1 General Geodesy		
Topic/Element	**Content**	**Learning outcomes**
F1.1 Introduction to Geodesy *(A)*	(i) Shape and size of the Earth as a geoid, spheroid, and sphere (ii) The authalic sphere as a model of the Earth (iii) Traditional geodetic datums (iv) Terrestrial reference systems and reference frames. (v) Local and global Cartesian coordinate systems. (vi) Modern Coordinate Reference Systems (CRSs) and Geodetic Datums [GRS80, WGS84, ETRS89, ITRF], (vii) The EPSG Geodetic Parameter Catalogue and its use (viii) Datums and datum transformation techniques, including similarity transformations and grid-based approaches. (ix) Computations on the sphere (x) Computations on the ellipsoid (xi) Vertical datums and associated transformations.	Describe in detail the figure of the Earth as a geoid, a spheroid, and a sphere. Analyze the characteristics of loxodrome and orthodrome and compute positions on these lines using appropriate applications.
F1.2 Coordinate systems, frames, and datums *(A)*		Define and specify geodetic reference systems (GRSs) and associated reference frames.
F1.3 Geodetic transformations and associated computations *(I)*		Describe, select, and apply transformations between horizontal and vertical datums
F1.4 Spherical and ellipsoidal computations *(I)*		Perform grid, spherical, and ellipsoidal computations on spherical and ellipsoidal surfaces and evaluate the results.
F2 Hydrography and Nautical Products		
Topic/Element	**Content**	**Learning outcomes**
F2.1 Hydrography, nautical cartography, and navigation *(I)*	(i) Rationale for hydrographic and other surveys (ii) Relationship between hydrography, nautical cartography, and navigation (iii) Hydrographic and other data for map/chart purposes.	Define hydrography, nautical cartography, and types of navigation, explaining their relationships. Identify and select hydrographic and other data for map/chart purposes.
F2.2 Navigational hazards and aids to navigation *(I)*	(i) Navigational hazards (ii) Types of buoys and beacons (iii) The IALA system (iv) Automatic Identification Systems (AISs).	Identify and describe navigational hazards. Classify the principal fixed and floating aids to navigation and their significance for nautical charting. Describe AIS and elaborate on its use.

F2.3 Nautical data sources *(I)*	(i) Hydrographic surveys (ii) Shoreline surveys (iii) Navigational hazards (iv) Aids to navigation updates (v) Geographic names (including undersea features) (vi) Overhead obstruction clearances (vii) Offshore installations (viii) Regulatory publications	Describe the components of different nautical data source deliverables. Outline the ATON update process. List the authoritative sources for various chart features. Describe the monitoring and update process through international regulatory publications.
F2.4 Navigational publications *(I)*	(i) Notices to Mariners (ii) Sailing directions (iii) Light and radio lists (iv) Tides and current tables.	Describe and use content derived from nautical publications in a charting context.
F2.5 Hydrographic surveys *(I)*	(i) Types and scales of hydrographic surveys (ii) Hydrographic survey operations (former and modern methods) (iii) Special-purpose surveys (iv) Data sources, formats, accuracy, and applications.	Differentiate the type and purpose of different hydrographic surveys. Evaluate and select the hydrographic survey and associated data essential to ensure nautical charting integrity.
F2.6 Positioning *(I)*	(i) Evolution of technology in positioning (ii) Satellite (GNSS...), radio and other systems for positioning (iii) Relative accuracy of commonly available and former systems (iv) Error sources in positioning.	Classify various methods and systems used for positioning based on their accuracy. Describe the principal characteristics of Global Navigation Satellite Systems (GNSS). Examine data for positional consistency with the positional method employed.
F2.7 Depth measurement *(I)*	(i) Evolution of technology and methodologies for depth measurement (ii) Hydrographic vs. bathymetric data measurement (iii) Influence of the environmental factors on depth measurement (iv) Error sources in depth measurement.	Classify different methods and systems used for depth measurement concerning their accuracy. Assess the suitability of various depth measurement methods to achieve specific charting objectives. Examine data for depth measurement uncertainty in relation to the measurement methods employed.
F2.8 Hydrographic data management *(I)*	(i) Management of hydrographic data in the chart compilation process (ii) Databases for hydrographic data.	Specify hydrographic data management processes in the chart compilation procedure. Specify the content and use of a hydrographic source database.

F3 Photogrammetry and Remote Sensing		
Topic/Element	**Content**	**Learning outcomes**
F3.1 Photogrammetry and Remote Sensing – Application to mapping and charting *(I)*	(i) Equipment types: sensors and formats of aerial photographs, remotely sensed data, and imagery (ii) Photogrammetric and remote sensing geometry in the context of adjustment and application: ● Image scale, relief, and radial displacement ● Theory and implementation of spatial rectification (iii) Positional control, including use of aerial GPS. (iv) Satellite-derived bathymetry (SDB)	Analyze the geometrical principles applicable to aerial photography and imaging. Analyze the quality of photogrammetric and remotely sensed data types. Select photogrammetric and remotely sensed data sources to define topographic features. Classify remotely sensed techniques applicable to depth measurement. Apply rectification and control methods to photogrammetric and remotely sensed data sources. Analyze and perform data extraction from SDB.
F3.2 Sensor data sources *(I)*	(i) Characteristics of commonly available photogrammetric and satellite sensors (e.g., EROS; IKONOS; SPOT; Landsat; WorldView, GeoEye-1, QuickBird panchromatic, Sentinel, …) and associated data (ii) Pan sharpening techniques (iii) RADAR altimetry.	Evaluate the characteristics of commonly available photogrammetric, satellite sensors, and specify data sources for use in mapping/charting. Merge high-resolution panchromatic and lower-resolution multispectral imagery to create a single high-resolution colour image. Process and use RADAR altimetry data.
F3.3 Geometric modeling *(I)*	(i) Utilization of different imagery: panchromatic, multi-spectral bands; colour, laser, and altimetry (ii) Image geo-referencing (iii) Ortho-image production and utilization (iv) Establishment of the requirements for mapping/ charting (v) Setting up spatial control parameters with a variety of data sets (vi) Guidelines and methodologies for data extraction (vii) Guidelines and methods for automated feature extraction (viii) Identification of different levels of detail. (ix) Methods of change detection	Classify photogrammetric and remotely sensed imagery for feature extraction. Explain and apply a suitable approach to use for the effective extraction of distinctive features for mapping/charting.
F3.4 Data management, processing, and analysis *(I)*		Apply geo-reference procedures for photogrammetric and remotely sensed imagery. Identify changes to existing mapping products' content regarding more recent imagery sources.
F3.5 Shoreline delineation, feature extraction, and satellite bathymetry *(I)*		Evaluate source data and perform shoreline extraction about the state of the tide at the time of imagery. Determine intertidal areas. Utilize remotely sensed images for bathymetry. Extract hydrographic features: reefs, rocks, hazards, and sea-bed features. Use specific applications for automated feature extraction.

F3.6 Airborne topographic and bathymetric LiDAR systems and data products *(I)*	(i) Airborne topographic and bathymetric LiDAR systems and their capabilities (ii) Sensor data, formats and standards (iii) Modeling land and sea-bed features and topography (iv) Water surface mapping techniques (v) Environmental mapping techniques (vi) Temporal mapping techniques (vii) Integrating airborne and terrestrial data. (viii) Calibration of topographic and bathymetric LIDAR data after sea-truthing. (ix) Methods of Change detection	Classify commonly available LiDAR systems and assess their capabilities and uses. Evaluate and apply LiDAR sensor data for determining coastal features and changes over time. Identify appropriate bathymetric LiDAR data and use associated techniques to derive products for use in mapping/charting. Integrate topographic and bathymetric LIDAR data after calibration.

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F4 Data Analytics for Marine Cartography		
Topic/Element	**Content**	**Learning outcomes**
F4.1 Introduction to Data Analytics in Marine Sciences *(B)*	(i) Importance of data analytics in marine cartography (ii) Introduction to big data and real-time data in marine environments (iii) Introduction to spatial and spatiotemporal data analysis	Describe the role of data analytics in modern marine cartography. Explain the importance of spatial and spatiotemporal considerations. Prepare data for input into machine learning pipelines.
F4.2 Applied Machine Learning for Marine Cartography *(I)*	(i) Data normalization and scaling for Machine Learning - ML models (ii) Supervised vs. unsupervised learning (iii) Regression models for geospatial data (iv) Model evaluation and cross-validation in spatial contexts (v) Practical use of open-source libraries	Apply classification and clustering algorithms to marine datasets. Train and validate regression models for predictive tasks. Analyze the performance and reliability of ML models. Use standard ML libraries for marine geospatial data.
F4.3 Deep Learning for Feature Detection *(I)*	(i) Convolutional Neural Networks (CNNs) basics (ii) CNNs for feature extraction in satellite imagery (iii) Deep learning applied to cartographic raster and vector data	Implement deep learning models for geospatial data. Use CNNs for feature detection and classification. Apply deep learning methods to recognize and extract cartographic features from validated vector and raster data.

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1 3. CARTOGRAPHIC SCIENCE SUBJECTS

C1 General Cartography		
Topic/Element	**Content**	**Learning outcomes**
C1.1 Elements of Cartography *(A)*	(i) Maps, charts, and their characteristics (ii) The scale of maps/charts and their categorization in relation to their use (iii) Representing the figure of the Earth on a flat surface (iv) Cartographic design (v) Abstract representation and generalization (vi) Symbolization (vii) Static & dynamic maps/charts.	Detail the fundamental cartographic elements and analyze associated characteristics of maps and charts. Assess the importance of cartographic design, symbolization, and dynamic representation.
C1.2a Map projections *(A)*	(i) Map/chart projections, their properties, and associated distortions (ii) Categories of map/chart projections (cylindrical, conical, azimuthal) (iii) Properties of map/chart projections (conformal, equivalent, equidistant) (iv) Methodology for the selection of a cartographic projection (v) Projection formulae and planimetric coordinates (vi) Projection systems (vii) Worldwide cartographic systems such as Universal Transverse Mercator - UTM, Gauss-Krüger - GK and Universal Polar Stereographic - UPS.	Specify the properties and distortions in various categories of projections used for maps and charts. Analyze the procedure for selecting a specific projection and apply appropriate projection formulae. Analyze the characteristics of prevailing worldwide cartographic systems and specify their use. Analyze the projections used for nautical charts and ENCs
C1.2b Study of map distortions *(A)*	(i) Definition of Scale Factor (ii) Tissot's theorem (iii) Principal directions (iv) Tissot's indicatrix (v) Distortions in distances, areas and angles associated with map projections (vi) Selection of the appropriate cartographic projection.	Define and compute scale factor at various locations on different projections. Calculate the parameters of Tissot's indicatrix and classify a projection according to the results. Calculate bearings, distances and areas on projections used in cartography. Evaluate distortions and apply the process for the selection of the appropriate projection and associated parameters for specific use.
C1.3 Abstract representation and generalization *(A)*	(i) Rationale for abstract representation and generalization (ii) Model, semantic, and cartographic generalization (iii) Elements of generalization	Detail the rationale for abstract representation and generalization. Distinguish between model, semantic, and cartographic generalization. Specify and detail the processes of generalization.

	(iv) Controls of generalization (v) Rules for semantic generalization (vi) Cartographic generalization of point, line, and area features (vii) Cartographic generalization algorithms and associated parameters. (viii) Guidelines and methodologies for the automated generalization process	Perform model, semantic, and cartographic generalization of cartographic features, selecting appropriate generalization algorithms and the values of associated parameters. Perform procedures aimed at describing automation challenges, defining rules, recognizing patterns, mitigating overprints, and deriving multiple scale products.
C1.4 Relief representation *(A)*	(i) Rationale for terrain and sea bottom representation (ii) Methods for terrain and sea bottom representation (contouring, zoning, shading, etc.) (iii) Relative and absolute accuracy in contouring (iv) Digital representation of the relief – Digital Elevation Models [DEMs] and methods of interpolation: • Inverse distance • TIN • GRID • Kriging (v) Methods for accuracy assessment of digital relief. (vi) Extraction of DEM by-products (slope, aspect, volume…) (vii) Dynamic relief representation.	Analyze the need and evaluate methods used for terrain and sea-bottom representation. Select and apply the appropriate interpolation method for DEM creation for a specific purpose and assess the results. Extract by-products from a created DEM. Create a dynamic relief representation using appropriate software.
C1.5 Scales of measurement of cartographic and geospatial variables *(I)*	(i) Scales of measurement of cartographic and geographical variables: • Nominal scale • Ordinal scale • Interval scale.	Classify cartographic and geospatial variables according to their scale of measurement.
C1.6 Symbolization *(I)*	(i) Rationale for symbolization (ii) Concepts of symbolization (iii) Graphical elements of symbols (point, line, area) (iv) Visual variables (shape, size, orientation, colour, pattern, etc.) (v) Scales of cartographic data measurement and associated visual variables (vi) Symbol design and use (vii) Symbol libraries, their content, and use.	Explain the rationale for symbolization. Analyze and use visual variables with respect to the scale of cartographic data measurement. Design cartographic symbols for spatial features with respect to their scale of measurement. Classify and use types of symbols according to cartographic design rules. Select and use symbols from symbol libraries.
C1.7 Colour	(i) Rationale for the use of colour (ii) The nature of colour (spectral colours vs. reflected colours)	Explain the rationale, role, and importance of the use of colour in mapping and charting.

(I)	(iii) The dimensions of colour (iv) Systems of colour modeling/ specification, including transformation between systems (CIE, Munsell, ...) (v) Electronic display colour models (RGB, HLS…) (vi) Colour conventions (vii) Colours for maps/charts and their features (viii) Patterns (B/W – colour) (ix) Colour in computer graphics (screens, plotters, printers) (x) Colour in printing	Classify the principal colour conventions for maps/charts and their features. Differentiate and specify colour for various computer graphics and printing applications.
C1.8 Map/chart lettering, toponymy and labeling *(I)*	(i) Rationale of toponymy (ii) Structure of toponyms (iii) Translation and transliteration of toponyms (iv) Lettering and its functionality (v) Lettering style, size, and colour (vi) Relationship between toponyms and the use of lettering (vii) Naming conventions (viii) Position guidelines for toponyms of point, line, and area features (ix) Placement of toponyms with respect to the scale/graticule. (x) Automatic placement of toponyms and text.	Explain the rationale, structure, and functionality of toponyms. Apply lettering in relation to the inherent characteristics of cartographic features. Describe and apply placement rules for toponyms and associated features on maps/charts at various scales. Use software for automatic placement of toponyms and text.
C1.9 Cartographic design *(I)*	(i) Principles of good and efficient cartographic design (ii) Design requirements for different map/chart categories and scales (iii) Scale selection (iv) Graphic organization (map/chart layout) (v) Visual balance (vi) Types of data (point, linear, areal, 3D) (vii) Representation (of reality) (viii) Visual hierarchy (ix) Presentation (x) Use of colour/figure-ground/contrast.	Describe, specify, and apply the principles and characteristics underpinning good and efficient cartographic design at various scales and different map/chart categories. Identify selected maps/charts in terms of the principles of good cartographic design (with proper justification).
C1.10 Map/chart compilation and composition *(A)*	(i) The cartographic compilation and composition process (ii) Compilation planning and scheduling (iii) Source data and map/chart scale (iv) Map/Chart data quality elements	Describe and apply the map/chart compilation process, identifying discrete stages. Differentiate between the appropriate compilation processes for maps and

	• Accuracy (positional, thematic, temporal) • Resolution (spatial, temporal) • Consistency (logical, domain) • Currency • Completeness • Clarity (v) Data quality standards (vi) Assessment of appropriateness of source data for map or chart compilation (vii) Source data homogenization (viii) Quality control process within a quality management system (ix) Digital compilation worksheet.	nautical charts of different themes and scales. Specify and apply cartographic data quality assessment processes and evaluate the results for map and chart compilation. Specify and analyze the advantages and disadvantages of analog and digital compilation processes. Create a digital compilation worksheet covering a complex region and utilize it for map/chart composition and symbolization.
C2 Data for Nautical and Special Purpose Charting		
Topic/Element	**Content**	**Learning outcomes**
C2.1 Coastline and topographic data *(A)*	(i) Data sources appropriate for inclusion in nautical charting for coastline and topography (ii) Categories and corresponding definitions of coastline (iii) Scale and accuracy requirements for selecting appropriate data sources (iv) Principles of selection and depiction of topography (v) Principles of selection and depiction of bathymetry (vi) Bathymetric data quality (vii) The concept and use of CATZOC (viii) Bathymetric data products, e.g., GEBCO, crowd sourced bathymetric data (Refer to IHO publication B-12)	Specify categories of coastline and their depiction. Evaluate and homogenize topographic data from various data sources for depiction on charts with regard to scale
C2.2 Bathymetric data and associated products *(A)*		Evaluate bathymetric data sources and resolve conflicts for use in nautical and special-purpose charts. Define and use CATZOC. Evaluate and homogenize hydrographic/bathymetric data from various data sources and utilize them for depiction on charts/maps, with regard to scale/purpose.
C2.3 Encoding and portrayal of nautical data *(A)*	(i) Natural features (skin of the earth) (ii) Hazards to navigation (iii) Aids to navigation (iv) Routing measures (v) Regulated areas (vi) Administrative areas (vii) Offshore installations	Evaluate selected data sources for encoding, portrayal, and critical updates. Demonstrate the ability to encode nautical data features according to documented standards. Understand and apply the relationship between feature attribution and portrayal on ENC and the automated chart products. Analyze the automatic INT1 portrayal of S-57/S-101 ENCs.
C2.4 Sailing directions, nautical publications,	(i) Identification of textual and administrative data suitable for graphic presentation (boundaries, environmental	Analyze the relationship between nautical charts and textual data sources and their use (sailing directions and

and special-purpose reports *(A)*	areas, traffic routing, special purpose sources, etc.) (ii) Symbiotic relationship between textual and graphic data. (iii) E-publications.	other nautical publications, including reports, lists, and tabular data). Evaluate available administrative data for consistency in its graphical depiction and/or textual promulgation. Analyze the relationship between special-purpose data and associated reports and documents.
C2.5 Source data adjustment *(I)*	(i) Chart datums: horizontal and vertical (ii) Principles of horizontal and vertical datums (iii) Methodologies for adjusting data against various datums (iv) Adjusting data by use of software.	Define horizontal and vertical datums. Identify horizontal and vertical datums commonly used in cartographic data sources. Perform horizontal and vertical adjustments of data referred to various datums using appropriate software applications.
C2.6 Oceanographic information *(I)*	(i) Identification of appropriate oceanographic information and associated sources (ii) Depiction of oceanographic information (iii) Tidal and current data (selection, evaluation, depiction).	Evaluate the sources and characteristics of oceanographic information. Specify oceanographic data and associated sources for depiction on nautical charts. Select and depict oceanographic, current, and tidal information on nautical and special-purpose charts.
C2.7 Magnetic data *(I)*	(i) Magnetic variation and anomalies, computation and appropriateness for charting. (ii) Magnetic data sources, utilization, computations, encoding practices and portrayal.	Define the Earth's magnetic components and secular variation. Compute magnetic variation for specific positions, elevations, and times. Identify, encode, and portray magnetic anomalies.
C2.8 Metadata *(I)*	(i) Metadata and associated standards (ISO 19115) for digital data and chart products.	Explain the scope and importance of creating and utilizing metadata according to appropriate standards. Create, structure, and utilize metadata for digital chart products.
C2.9 Quality Management System(s) for chart production *(A)*	(i) Nautical chart production processes and their content (ii) Quality Management System(s), Quality Control (QC), and Quality Assurance (QA) processes for the compilation and production of nautical and special-purpose charts (iii) Data quality implications relevant to scales, density, accuracy, time, different datums, technologies, etc.	Specify and evaluate nautical chart production processes. Specify and apply QC and QA processes applied to nautical chart and special-purpose chart production. Evaluate and classify data quality implications arising from variability of source data characteristics. Apply automated quality validation checks in chart production.
C2.10 Data for special-purpose charting	(i) Requirement, use, and design of special-purpose charts (ii) Data types:	Classify special-purpose charts categories and their uses.

(I)	• Subsurface • Imagery • Geotechnical • Environmental • Engineering and assets.	Identify and assess data types for particular special-purpose charts.
C3 Geospatial Information and Processing		
Topic/Element	**Content**	**Learning outcomes**
C3.1 Overview of Geospatial Information Science and systems *(A)*	(i) Geospatial Information Science and data (ii) Geographic Information Systems [GIS] and applications (iii) Graphical User Interface (GUI).	Define Geospatial Information Science and analyze its role in spatial data processing and utilization. Analyze the characteristics and the functionality of a GIS with emphasis on the charting process.
C3.2 Geospatial data modeling *(A)*	(i) Vector data models (ii) Raster data models (iii) Representation of point, line, and area data in vector and raster models (iv) Geospatial data structures (v) The Seabed Survey Data Model (SSDM) as an industry standard data model (vi) Spatial resolution and scale (vii) Model suitability criteria (viii) Topology: definition, levels, and topological relationships. (ix) Open data formats: XML, GML, SVG, and their use.	Analyze the characteristics of vector and raster data models. Select and apply the appropriate data model and structure for a specific purpose and scale, considering the spatial resolution required. Define and encode topological relationships in spatial data files using available software tools. Select and apply an open data format to encode and portray geospatial data.
C3.3 Geospatial data input and editing *(I)*	(i) Feature and attribute data encoding and standards (ii) Data entry: • manual • semi-automatic • automatic (iii) Data editing.	Select a GIS environment to encode and edit spatial data derived from manual, semi-automatic, and automatic digitization. Select and apply the appropriate scanning parameters with respect to a specific application and scale, and utilize the resulting file.
C3.4 Geospatial data transformations *(A)*	(i) Affine transformation (ii) Projection transformations (iii) Problems associated with geospatial data transformations.	Assess and apply commonly used spatial data transformations, selecting appropriate software. Analyze and evaluate the results of spatial data transformations.
C3.5 Raster to Vector Conversion *(A)*	(i) Raster to Vector and Vector to Raster conversions and associated algorithms.	Apply Raster to Vector and Vector to Raster conversions using available software and assess the results.

C3.6 Geospatial and cartographic databases *(A)*	(i) Geospatial vs. cartographic databases (ii) Geospatial/Cartographic database: • design • integrity • operations (iii) Adding and Managing Layers, Introduction to Style Descriptors, Creating and Applying Styles (iv) Open-source geospatial databases and standards.	Specify distinct types of geospatial data and their representation in a DBMS environment. Describe a geospatial database on a conceptual, logical, and physical level. Design, create, and populate a geospatial or cartographic database and use it in cartographic composition. Add and manage layers within geospatial datasets. Create and apply styles to geospatial data for visual portrayal.
C3.7 Geospatial data analysis and modeling *(I)*	(i) Single and multiple layer operations in a GIS environment (ii) Geospatial data analysis and tools (iii) Geospatial modeling and tools. (iv) Machine learning tools for data processing (v) Digital twins	Use the functionality of a GIS/SDI in geospatial data analysis and modeling. Geospatial processing with machine learning tools Integrate available data sets to design and create a digital twin model.
C3.8 Raster data compression *(I)*	(i) Raster data compression methods, e.g.: • Run-length encoding • Freeman chain codes • Quadtree encoding	Specify and apply the various raster data compression methods.
C3.9 Geospatial data transfer standards *(I)*	(i) Geospatial data transfer standards (e.g. S-57, S-100, DXF, SDTS, DIGEST, OGC……) (ii) Geospatial data transfer process	Select appropriate geospatial data transfer standards for different applications. Specify and apply the process for importing/exporting data between different standards.
C3.10a Spatial Data Infrastructures (SDIs) *(I)*	(i) Spatial Data Infrastructures: overview, benefits, and hierarchy (ii) Quantitative and qualitative benefits (iii) Authoritative and Open data in SDIs (iv) FAIR data principles	Describe the requirement for structured geospatial data from government, industry, academia, and citizens. Identify economic, social, scientific, and environmental benefits of SDIs Classify distinct types of SDI at various organizational levels. Analyze and classify several types of Data. Explain the rationale for data sharing and the use of FAIR data principles.

C3.10b Marine Spatial Data Infrastructures (MSDIs) *(I)*	(i) MSDI: the Spatial Data Infrastructures [SDI] for the marine environment (ii) Interoperability as a vital aspect for the development of MSDIs (Refer to IHO Publication C-17) (iii) Tools and technologies used in building MSDIs: ● GIS, DBMS ● Web Services and APIs ● Data Visualization Tools ● Metadata Standards and Catalogs ● Satellite Remote Sensing and Imagery Processing Software ● Data Conversion and Transformation Tools ● Geospatial Analytics and Modeling Software and use of Expert Systems ● Cloud Computing Services ● Data Quality Assurance and Validation Tools ● Open-Source Software ● Cybersecurity and Data Protection Tools (iv) Types of marine data of an MSDI: ● Hydrographic Data ● Bathymetric Data ● Oceanographic Data ● Remotely sensed data ● International, national, and regional boundaries and limits. ● Any other marine spatial information	Specify the structure and the content of an MSDI. Evaluate the need for efficient collaboration between the various spatial stakeholders Utilize interoperability as an enabler for seamless operation of data systems and services in an MSDI environment Analyze and apply the technologies and tools used in building MSDIs Specify the types of marine data relevant to an MSDI Data analytics with Expert Systems (ML, AI, etc.)

C3.10c Spatial analysis techniques used with MSDIs *(I)*	(x) Spatial analysis techniques commonly used with MSDIs: ● Buffer analysis ● Overlay analysis ● Distance analysis ● Spatial Join ● Hotspot analysis ● Network analysis ● Density analysis ● Multicriteria decision analysis ● Statistical analysis ● Time series analysis ● Use of Expert Systems (AI and ML) and tools.	Classify and apply the techniques used with MSDIs on vector and raster data. Use of Expert Systems in Geospatial Data Analysis Tasks
C3.11 Web services *(I)*	(i) Communication protocols (TCP/IP, HTTP) (ii) Hyper Text Markup Language (HTML) (iii) Client-server (architecture, software, and communication) (iv) Web browsers and web servers for geospatial data (v) Web services and associated functionalities: • Web Feature Services (WFS) • Web Coverage Services (WCS) • Web Processing Services (WPS) • Web Map Services (WMS) (vi) Map and chart compilation, composition, and publication on the Web.	Describe the functionality of communication protocols. Describe client-server architecture. Analyze the functions of web browsers and web servers. Analyze the capabilities and limitations of available web services. Utilize web services and data for map/chart composition and for publication on the web.
C3.12 Visualization with mobile devices *(I)*	(i) Map and chart functions on mobile devices (ii) Security of data (iii) Tracking and visualizing routes and locations (iv) Mobile services, products, and updates (v) Mobile Networks, 4G, 5G, Iridium (vi) Limitations and benefits of mobile devices for navigation.	Detail the limits of mobile devices for nautical use Elaborate on the different data transmission technologies to mobile devices and their characteristics.

C4 Nautical Cartography		
C4.1 The Nautical Chart		
Topic/Element	**Content**	**Learning outcomes**
C4.1a Evolution of nautical charts *(I)*	(i) Paper (national and INT) (ii) ENCs (ECDIS) (iii) ECS (iv) Nautical charts and ENCs derived from encoded data through automated/semi-automated processes	Outline the evolution of nautical charts and chart systems.
C4.1b Nautical charts and ENCs *(I)*	(i) Planning/scheming (ii) The use of charts in navigation (iii) Types of charts (iv) Chart reading.	Analyze and classify the various types of nautical charts and ENCs and their content according to their primary purpose.
C4.1c Nautical chart and ENC design *(A)*	(i) Design principles for nautical charts and ENCs (ii) Characteristics (iii) Content (iv) Terminology (v) Symbolization.	Specify present-day characteristics and design principles of nautical charts and ENCs Analyze the impact of technology on nautical charts and ENC design and production.
C4.1d Nautical chart reference framework *(A)*	(i) Chart graticule (ii) Chart grid.	Specify, compute, and prepare chart graticules and chart grids using appropriate software.
C4.2 International Organizations and the Nautical Charting Products		
C4.2a Role and structure of the IHO *(I)*	(i) IHO roles and structure • Assembly • Committees and Working Groups (ii) Regional Hydrographic Commissions (iii) IMO and the SOLAS convention (iv) IALA guidelines and recommendations.	Outline and distinguish the roles of IHO, IMO, and IALA for the development and use of nautical charts and ENCs for safe navigation.
C4.2b Role of the IMO *(I)*		
C4.2c Role of the IALA *(I)*		
C4.3 Nautical chart compilation and production		
C4.3a Planning and scheming *(A)*	(i) Geographical area and scale (ii) Chart scheming (iii) Overlapping and nesting principles.	Specify the planning processes adopted internationally for the scheming and production of (official) nautical charts and ENCs. Design chart and ENC schemes.
C4.3b Data sources *(I)*	(i) Metadata considerations (ii) Source data selection and evaluation (iii) Source data homogenization (iv) Source data registration.	Analyze methods applied for the appropriate selection, evaluation, and homogenization of source data, data collected from uncrewed survey platforms and crowd-sourced data.

C4.3c Content, Symbology and Encoding *(A)*	(i) Coastlines ● Natural ● Constructed ● Approximate (ii) Bathymetry ● Soundings ● Sounding pattern selection ● Principles ● Automated techniques ● Channel depiction ● Sea floor descriptions (iii) Bathymetric contours (iv) Dangers to navigation ● Rocks ● Wrecks ● Reefs ● Shoals ● Offshore constructions ● Submarine pipelines and cables ● Obstructions ● Sea floor descriptions (v) Topography ● Depiction using the seaward view principle ● Natural features • Landmarks • Constructed features ● Conspicuous objects (vi) Boundaries and limits ● Dredged areas ● Controlled areas ● Controlled routes ● Baselines ● International boundaries and maritime zones ● Ocean limits (vii)Navigation aids ● Lights, beacons, buoys, marks ● Light sectors ● Leads ● Radio beacons ● Radar reflectors ● Recommended tracks ● Recommended routes (viii)Source data and data quality diagrams – depiction (ix) ZOC diagrams (x) Titles and chart notes (xi) Graphic scales	Specify the various categories of features portrayed in nautical charts and ENCs, apply and use them in their production. Determine the appropriate symbol for depiction for each feature to ensure usefulness and legibility at compilation scale. Define and select critical and controlling depths.

	(xii)Feature names including undersea features, e.g., gazetteers.	
C4.3d Chart compilation and composition *(A)*	(i) The chart compilation and composition processes. • Element selection • Database extraction • Synthesis and homogenization • Conflict resolution • Validation. (ii) AI in chart compilation and composition • Automatic sounding selection and generalization	Specify and analyze the processes required for chart compilation and composition from a geospatial database and implement them using standalone software systems or integrated cartographic production systems. Analyze and apply the workflow adopted to produce ENCs and paper charts. Analyze advanced dynamic portrayal capabilities to convert S-57/S-101 ENCs to INT1 paper charts. Employ AI tools in chart compilation and composition Implement sounding selection algorithms based on bathymetric models, cartographic rules, and deep learning inference.
C4.3e IHO Standards and Chart Specifications *(I)*	(i) IHO standards and chart specifications (ii) INT chart specifications a) INT 1 b) INT 2 c) INT 3 (iii) IHO S-4 (iv) IHO S-11 (v) IHO S-57 (vi) IHO S-58 (vii) IHO S-65 (viii)IHO S-100 overview (ix) Feature attribution (x) Text (Styles as symbols) (xi) Notes, legends.	Describe the processes of the IHO Member States for the development of international charts, ENC standards, and schemes Identify the relevant international standards and specifications and apply them appropriately to nautical charts.
C4.3f Updating *(I)*	(i) Procedures for updating nautical charts (ii) Notices to mariners (iii) New editions and reprints	Specify the requirement for updating nautical charts. Analyze and apply the workflow adopted to update ENCs and paper charts. Undertake a complete chart updating task, including editing, updating, and publishing.

C4.3g Mapping on demand *(I)*	(i) Customized mapping from existing databases. (ii) Printing up-to-date official nautical charts from an existing catalog	Identify and apply the processes required for mapping and printing on demand.
C4.4 Map/chart production systems		
C4.4a Commercial Systems *(I)*	(i) Commercial systems for map/chart production (ii) Graphics and image processing software for cartographic applications. (iii) Open standards and public domain systems (iv) Open Geospatial Consortium (OGC).	Identify common commercial systems and analyze their functionality. Use a commercial system for map/chart composition and production. Identify and use commercial graphics and image processing systems.
C4.4b Public domain systems *(I)*		Analyze the characteristics of commercial and public domain systems. Identify key open geospatial standards, their content, and the organizations developing them.
C4.4c Map/chart production systems evaluation *(I)*		Analyze the benefits and/or limitations of the use of commercial and/or public domain systems, including those employing AI-based methodologies for data analytics. Chart production using machine learning software tools Evaluate the qualitative requirements for a chart production system in the procurement process
C4.5 Electronic chart production		
C4.5a Introduction to Electronic Navigational Charts (ENCs) *(I)*	(i) Definition of ENC, SENC, and ECDIS (ii) IMO carriage requirements (iii) ENC as product (iv) Production conventions • Issuance • Numbering • Cell structure • Updating • Official status • Security protection • SENC	Define and differentiate ENC and SENC. Describe ECDIS and its functional characteristics. Analyze the product characteristics of ENCs.
C4.5b ENC production and IHO Standards *(I)*	(i) IHO S-57 • Contents including appendices • Data model • Topology (ii) Object Catalogue	Identify and analyze international standards and specifications relating to ENCs.

	• Object, attribute, and master/slave classes • Spatial objects • Feature objects • Relationships • Special cases (iii) IHO S-52 • Presentation Library (iv) IHO S-65 • ENC production • Quality control • Quality assurance • Quality management systems (v) Designing workflow (vi) IHO S-58 • Validation process • Spatial accuracy • Feature completeness • Logical consistency • Vertical and horizontal consistency • ECDIS display consistency • Software validation tools • False warnings • Errors and warnings (vii) IHO S-99 (viii) IHO S-100 data model ● S-100 Registry and Registers ● S-101 ENC product specification ● S-102 Bathymetry surface product specification. (ix) S-57 ENC to S-101 Conversion (x) ENC distribution system ● IHO S-63 ● IHO WEND principles and RENCS	Analyze the content of the ENC standards and explain the relationships between them. Use of the object catalogue for ENC Analyze the rationale underpinning the development of S-100 and understand the real time dynamic data integration and interoperability concepts. Analyze the S-57 and S-100 data models, including their differences. Analyze the benefits of S-100 and understand the dynamic data integration and interoperability concept. Classify the general principles underpinning electronic chart data visualization. Describe and use the content of the Presentation Library. Describe recommended production procedures for ENCs and utilize a software environment to produce an ENC. Implement the paper and ENC synchronization process Identify and use best practice approaches and validation software for the QC/QA of an ENC. Describe the ENC distribution system. Analyze and use the product specifications relating to the S-100 universal hydrographic data model, focusing on the S-101. Analyze how to adapt S-57 ENC to optimize the automated conversion to S-101 ENC. Apply and assess automated conversion processes. Load and test the ENC on an ECDIS simulator.

C4.6 Rasterized products		
C4.6 Raster charts *(I)*	(i) The rasterization process (ii) Scanning processes (iii) Advantages and limitations of rasterized chart products (iv) Raster data structures (v) Raster chart formats (vi) Raster chart products (vii) Raster chart images and tiles (viii) Raster chart images are used within GIS and other environments.	Analyze the characteristics of rasterized chart products and assess their advantages and limitations. Perform rasterizing processes. Analyze the use of rasterized chart images within navigation systems.
C5 Legal aspects (Relating to nautical cartography)		
Topic/Element	**Content**	**Learning outcomes**
C5.1 Liability and responsibility *(I)*	(i) The IMO SOLAS Convention (ii) The status of an official nautical chart • General status under IMO carriage requirements • Legal document • Status post maritime incident (iii) The role of national hydrographic agencies (iv) Potential legal issues: • Duty of care • Product liability • Fitness for purpose • Defectiveness (v) Professional responsibilities (vi) Best practices (vii) Role of professional associations	Describe and assess the role and responsibilities of national hydrographic agencies as required under the Safety of Life at Sea Convention. Analyze the status of the nautical chart as both an operational and legal entity. Analyze the organizational structure, departmental responsibilities, and duties involved in the production of nautical products and services. Explain the role of the nautical cartographer in terms of liability and ethical practices. Assess potential issues of legal liability relating to nautical charts and ENCs.
C5.2 Intellectual property and copyright *(B)*	(i) Definition (ii) Protection (iii) Permission/License and fees (iv) Disclaimers (v) Penalties.	Define intellectual property and copyright in the framework of nautical charting. Compare how copyright issues are managed within different map and chart production agencies.
C5.3 Law of the Sea *(I)*	(i) Historical development of the Law of the Sea (ii) The United Nations Convention on the Law of the Sea (UNCLOS) • General provisions • Base points	Describe the historical evolution of the Law of the Sea. Specify and analyze the types of lines and areas defined under UNCLOS, their delimitation, and apply them on charts.

	• Baselines – normal (including bay closing lines), straight, and archipelagic • Internal waters • Territorial sea • Contiguous zones • Exclusive Economic Zone • Continental Shelf and Extended Continental Shelf. (iii) Status of the nautical chart for portrayal of boundaries and maritime zones (iv) Delimitation of boundaries and maritime zones.	Describe and assess the status of the official nautical chart as a reference to the depiction of boundaries and maritime zones.
C6 Special Purpose Charting		
C6.1 Industrial and Engineering Survey Chart Production		
Topic/Element	**Content**	**Learning outcomes**
C6.1a Introduction to industrial and engineering surveys *(B)*	(i) Types of Industrial and Engineering Surveys. (ii) Remotely operated and autonomous vehicles (iii) Additional sensors (iv) Unexploded ordnance, archaeological and artefact detection, and representation. (v) Expert Systems in data analytics (including ML and AI) for industrial and engineering surveys. (vi) General requirements and forms for cartographic presentation. (vii) Applicable standards (e.g., IOGP, UKOOA, IMCA, …).	Differentiate the representation of industrial and engineering survey data from nautical charting data Describe and assess specific requirements and standards for charting engineering surveys. Describe the use of Expert Systems in industrial and engineering data analytics.
C6.1b Route surveys charting *(B)*	(i) Rationale of charts and graphics for route surveys (ii) Forms of presentation for route survey data (iii) Vertical exaggeration in DEMs and profiles.	Describe the requirements for charting route survey data.
C6.1c Dredging surveys charting *(B)*	(i) Rationale of charts and graphics for dredging surveys (ii) Forms of presentation for dredging survey data (iii) Presentation techniques for volumetrics.	Describe specific requirements for the charting of dredging surveys.

C6.1d Shallow geophysical site surveys charting *(B)*	(i) Rationale of charts and graphics for Geophysical Site surveys. (ii) Use of Data Analytics and Expert Systems. (iii) Forms of presentation for Geophysical Site survey data. (iv) Presentation techniques for Geophysical Site survey data, including the depiction of multiple layers.	Describe specific requirements for charting shallow geophysical survey data.
C6.1e Still photographs and video surveys charting *(B)*	(i) Rationale for the use of still photographs and video surveys (ii) Photographic and video formats (iii) Video eventing (iv) Relating video surveys to other relevant charts and graphics. (v) Positional considerations. (vi) Use of Data Analytics and Expert Systems.	Describe specific requirements for charting photographic and/or video survey data.
C6.1f Geo-technical surveys charting *(B)*	(i) Rationale of charts and graphics for geotechnical data • Engineering • Ground structure (ii) Forms of presentation for geotechnical data, including written reporting.	Describe specific requirements for charting engineering and foundation survey data.
C6.1g Environmental surveys charting *(B)*	(i) Rationale of charts and graphics for environmental data (ii) Forms of presentation for environmental data.	Assess specific requirements and use guidelines for charting environmental surveys.
C7 Map/Chart Reproduction		
Topic/Element	**Content**	**Learning outcomes**
C7.1 Output options and formats *(I)*	(i) Soft copies, hard copies. (ii) Page description language (Postscript)	Differentiate and use available output options.
C7.2 Raster processing techniques *(I)*	(i) Raster Image Processing (RIP) • Stages of RIP (ii) Parameters associated with the product.	Define product parameters and apply raster processing techniques.

C7.3 Output devices *(I)*	(i) Electrostatic printers/plotters (ii) Ink-jet printers/plotters (iii) Laser printers/plotters (iv) Thermal printers (v) Image setters.	Describe the technical characteristics of the various output devices used in cartographic production. Develop device specifications for particular tasks.
C7.4 Colour management *(I)*	(i) Standards for Colour Matching (ii) Colour profiles (iii) Gamut mapping.	Explain the need for the use of colour standards and create colour profiles as required. Describe and use the gamut mapping process.
C7.5 Colour separation *(I)*	(i) Colour separation (ii) Image Setters (iii) Compositing separations	Describe and analyze colour separation in digital environments. Create colour separation files for a map or chart utilizing an image setter.

CMCP – COMPLEX MULTI-DISCIPLINARY CARTOGRAPHIC PROJECT

Programmes must include a supervised and evaluated COMPLEX MULTI-DISCIPLINARY CARTOGRAPHIC PROJECT - CMCP – with a minimum aggregate period of **at least four weeks**; see "GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS AND NAUTICAL CARTOGRAPHERS".

Notes:

a. The COMPLEX MULTI-DISCIPLINARY CARTOGRAPHIC PROJECT does not include practical exercises, which form a part of the course modules' syllabi and are designed to complement the theory component, see "GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS AND NAUTICAL CARTOGRAPHERS".

b. The COMPLEX MULTI-DISCIPLINARY CARTOGRAPHIC PROJECT must contain all those items that will enable the student to compile and compose a modern nautical chart, ENCs, and special-purpose charts according to international specifications.

c. The COMPLEX MULTI-DISCIPLINARY CARTOGRAPHIC PROJECT must be divided into phases, representing the distinct processes involved in cartographic composition and production, i.e., planning, preparation, acquisition & processing, composition, deliverables (paper charts, ENCs, special purpose charts), and reports.

d. Each phase will be further divided into tasks that will:
   - result in specific outcome(s)
   - require specific equipment, software, data sources, etc.
   - be carried out in a specific number of hours and
   - be related to specific S-B elements.

THE TABLE -AS SPECIFIED IN THE GUIDELINES- **MUST** BE COMPLETED AND SUBMITTED IN ADDITION TO A DETAILED AND COMPREHENSIVE NARRATIVE DESCRIPTION OF THE COMPLEX MULTI-DISCIPLINARY CARTOGRAPHIC PROJECT MODULE FOLLOWING THE GUIDELINES.