INTERNATIONAL FEDERATION OF SURVEYORS

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

INTERNATIONAL CARTOGRAPHIC ASSOCIATION

STANDARDS OF COMPETENCE FOR CATEGORY "A" NAUTICAL CARTOGRAPHERS

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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 for Standards of Competence of 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. INTRODUCTION

All components of the hydrographic surveying and nautical cartography professions face challenges as to how best to ensure the continuation of high standards and how best to ensure the continuation of best practices based on minimum standards of competence world-wide. In order to achieve these objectives, three international organizations (FIG, IHO and ICA) have developed Standards of competence that institutions, or professional bodies, may adopt for their educational/training programmes and competency schemes.

Standards indicate the minimum competences necessary for hydrographic surveyors and/or nautical cartographers. Standards recognize two levels of competence. Category "A" programmes introduce competences from the underlying principles level. Category "B" programmes introduce the competences from a practical level appropriately underpinned by the relevant theoretical content.

The intention is that a Category "A" individual with appropriate experience, would be a senior professional in their chosen field (government, industry, academia). Category "B" individuals with appropriate experience would be technical professionals leading and delivering products and services to meet specifications and outcomes.

The Standards are structured to enable the student to acquire incrementally the knowledge required in order to be a competent cartographer at the Category “A” level. More specifically, the sequence of the subjects is designed so that any new subject builds upon the content and the knowledge of the preceding subjects.

The theoretical subjects are complemented with the Comprehensive Final Cartographic Project (CFCP) that includes all those items required to enable the student to efficiently and effectively resolve problems associated with the planning and production of modern nautical charts, ENCs and special purpose charts based on the underlying theory and according to internationally adopted specifications.

Successful completion of the theoretical subjects and the CFCP will enable the student to attain the appropriate Category “A” professional level of competence in nautical cartography.

2. DEFINITIONS

2.1 Subjects, topics and elements

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

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".

2.2 Learning outcomes and list of content

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

- one or more intended *learning outcomes*, that a student should be able to achieve on completion of the programme. All *learning outcomes* should be assessed. This may be done through one of, or a combination of, the following: examination, assessed exercise or presentation, laboratory report, or final project work.
- 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 in order to meet a particular *learning outcome*.

3. PROGRAMME PREPARATION AND SUBMISSION

The preparation of a programme submission to the IBSC should be in accordance with the document entitled GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS and NAUTICAL CARTOGRAPHERS. This document is available from the IHO website: www.iho.int → Standards & Publications.

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: www.iho.int

LIST OF ACRONYMS AND INITIALISMS USED IN THIS DOCUMENT

1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
A	Advanced (level of knowledge)
AIS	Automatic Identification System
B	Basic (level of knowledge)
B/W	Black and White
CATZOC	CAtegory of Zones Of Confidence
CIE	International Commision on Illumination
CFCP	Comprehensive Final Cartographic Project
CCP	Comprehensive Cartographic Project
CPU	Central Processing Unit
DBMS	DataBase Management System
DEM	Digital Evelation Model
DIGEST	Digital Geographic Exchange Standard
DXF	Digital Exchange Format
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
ENC	Electronic Navigation Chart
EROS	Earth Resources Observation and Science
ETRS89	European Tetrestrial Reference System 1989
FIG	International Federation of Surveyors
GeoTIFF	Geographic Tag Image File Format
GIS	Geographical Information System
GML	Geographical Markup Language
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference System (1980)
GUI	Graphical User Interface
HLS	Hue, Illumination and Spectum
I	Intermediate (level of knowledge)
IALA	International Association of 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 Organisation
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
OGC	Open Geospatial Consortium

P	Practicals (fieldwork and/or laboratories)
QA	Quality Assurance
QC	Quality Control
RADAR	RAdio Detection And Ranging
RAM	Random Access Memory
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-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*
SDI	Spatial Data Infrastructure
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
SVG	Scaleable 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)
WWW	World Wide Web
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 Co-ordinate 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 *(B)*	(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 *(B)*	(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 integral of classical functions and approximate numerical values.
B1.4 Trigonometry *(B)*	(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 errors	(i) Statistics of samples and populations	Identify and assess possible sources of error as a result of utilization of a chart (i.e. measurement, digitization).

(I)	(ii) Sources of error and their classification (iii) Random variables, mean, variance, standard deviation (iv) Covariance and correlation (v) Estimation of mean, variance, co-variance (vi) Normal distribution.	Estimate and interpret the mean, variance, co-variance and standard deviation from data.
B1.6 Least squares *(B)*	(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 Interpolation *(B)*	(i) 1D polynomial interpolation.	Describe 1D polynomial interpolation and differentiate between 1-D and spatial interpolation methods.
B2 Information and Communication Technology		
Topic/Element	**Content**	**Learning outcomes**
B2.1 Computer systems *(B)*	(i) Central Processing Unit (CPU) (ii) RAM, data storage (iii) Communication board, serial links, communication ports buffers, Ethernet links, data transmission rates (iv) Communication protocols (v) Operating systems (vi) Device drivers (vii) Input/output devices (scanners, digitizers, printers, plotters) and associated technical characteristics/specifications (viii) Data storage: device types, the cloud; advantages, limitations.	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 commonly used data storage devices and the cloud. Compare and contrast data storage options in the context of spatial data requirements.
B2.2 Office work software suites *(I)*	(i) Word processors (ii) Spreadsheets (iii) Graphics and image processing software.	Use office work software suites. Describe and use graphics and image processing software.
B2.3 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) (v) Scientific computation environments (e.g. Matlab) (vi) Application to data exchange, file and format conversion.	Write software programs for data format conversion and basic algorithmic computation. Perform computations using common scientific application environments.

B2.4 Databases and Database Management Systems (DBMS) *(I)*	(i) Relational databases (ii) Database Management Systems and query languages	Describe and design a database. Create/populate a database and query its content.
B2.5 Web and network communications *(B)*	(i) Networks (LANs) (ii) Network and cloud storage (iii) Internet (iv) Networks integrity (v) Communication protocols.	Describe the different network communication configurations and associated protocols used in data transfer/exchange applications.
B3 Earth Sciences		
Topic/Element	**Content**	**Learning outcomes**
B3.1 General geography of the Earth *(B)*	(i) Earth as a system of interacting 'zones' (ii) Plate tectonics, earthquake zones (iii) Earth dynamics (iv) Ecosystems.	Describe the major components of the Earth as a system. Identify general categories of land and water masses. Explain the plate tectonic theory.
B3.2 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.
B3.3 Marine geophysics *(B)*	(i) Gravity (ii) Magnetics (iii) Seismic profiles.	Describe geophysical properties of undersea features. Describe the data acquired by gravity, magnetic and seismic surveys.
B3.4 Ocean properties and dynamics *(B)*	(i) Sea water properties (ii) Ocean Dynamics • nature • motion • tides • currents.	List the main properties of sea water. Describe ocean dynamics in terms of currents and tidal variations.
B3.5 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 sphere, ellipsoid of revolution and geoid (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 geodetic datums based on terrestrial reference frames. (vii) Datum transformation techniques including similarity transformations and grid based approaches. (viii) Computations on the sphere (ix) Computations on the ellipsoid (x) Vertical datums and associated transformations.	Describe in detail the figure of the Earth as a geoid, an ellipsoid of revolution and a sphere. Characterize the geometry of lines on the sphere and the ellipsoid.
F1.2 Coordinate systems, frames and datums *(A)*		Define and specify geodetic reference systems and associated reference frames.
F1.3 Geodetic transformations and associated computations *(I)*		Describe, select and apply horizontal and vertical datum transformation methods.
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 *(B)*	(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 *(B)*	(i) Navigational hazards (ii) Types of buoys and beacons (iii) The IALA system (iv) Automatic Identification Systems (AISs).	Identify and describe navigational hazards. Describe the principal fixed and floating aids to navigation and their significance for nautical charting. Describe AIS.
F2.3 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.

F2.4 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, accuracies and applications.	Differentiate the type and purpose of different hydrographic surveys. Evaluate and select hydrographic survey and associated data essential to ensure nautical charting integrity. .
F2.5 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 different methods and systems used for positioning with respect to their accuracy. Describe the principal characteristics of Global Navigation Satellite Systems (GNSS). Examine data for positional consistency in relation to the positional method employed.
F2.6 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 with respect to their accuracy. Assess the suitability of different depth measurement methods to achieve specific surveying and charting objectives. Examine data for depth measurement uncertainty in relation to the measurement methods employed.
F2.7 Hydrographic data management *(I)*	(i) Management of hydrographic data at various stages in the chart compilation process (ii) Databases for hydrographic data.	Specify hydrographic data management processes at the various stages in the chart compilation process. 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/charting *(I)*	(i) Equipment types: sensors and formats of aerial photographs and sensed images (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.	Describe the geometrical principles applicable to aerial photography and imaging. 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.

F3.2 Sensor data sources *(A)*	(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) Pansharpening 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 color image. Process and use RADAR altimetry data.
F3.3 Geometric modelling *(I)*	(i) Utilization of different imagery: panchromatic, multi-spectral bands; color, laser, 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 specifications for data extraction (vii) Identification of different levels of detail.	Classify photogrammetric and remotely sensed imagery for feature extraction. Explain and apply the suitable approach to be taken for effective extraction of different 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 with regard to more recent imagery sources.
F3.5 Shoreline delineation, feature extraction and satellite bathymetry *(I)*		Evaluate source data and perform shoreline extraction with regard to 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, sea-bed features.
F3.6 Airborne and terrestrial LiDAR systems and data products *(I)*	(i) Airborne and terrestrial 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.	Classify commonly available LiDAR systems and assess their capabilities and uses. Evaluate and apply terrestrial LiDAR sensor data for determining coastal features and changes over time. Identify appropriate LiDAR data and use associated techniques to derive products for use in mapping/charting.

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.
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 UTM, GK and UPS.	Specify the properties and distortions in different 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.
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 (iv) Controls of generalization (v) Rules for semantic generalization	Detail the rationale for abstract representation and generalization. Distinguish between model, semantic and cartographic generalization. Analyze and detail the processes of generalization. Perform model, semantic and cartographic generalization of cartographic features selecting appropriate generalization

	(vi) Cartographic generalization of point, line and area features (vii) Cartographic generalization algorithms and associated parameters.	algorithms and the values of associated parameters.
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…..) (vii) Dynamic relief representation.	Analyze the need and compare 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 Cartographic data scales of measurement *(I)*	(i) Scales of cartographic data measurement: • Nominal scale • Ordinal scale • Interval scale.	Differentiate cartographic data 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, color, pattern, etc.) (v) Scales of cartographic data measurement and associated visual variables (vi) Symbol design and use (vii) Symbol libraries and their content.	Explain the rationale for symbolization. Analyze and use visual variables with respect to 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 Color *(I)*	(i) Rationale for the use of color (ii) The nature of color (spectral colors vs. reflected colors) (iii) The dimensions of color (iv) Systems of color modeling/ specification including transformation between systems (CIE, Munsell, ...) (v) Electronic display color models (RGB, HLS…)	Explain the rationale, role and importance of the use of color in mapping and charting. Classify the principal color conventions for maps/charts and their features. Differentiate and specify color for various computer graphics and lithographic applications.

	(vi) Color conventions (vii) Colors for maps/charts and their features (viii) Patterns (B/W – color) (ix) Color in computer graphics (screens, plotters, printers) (x) Color in lithographic printing	
C1.8 Map/chart lettering and toponymy *(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 color (vi) Electronic typesetting (vii) Relationship between toponyms and the use of lettering (viii) Naming conventions (ix) Positioning guidelines for toponyms of point, line and area features (x) Placement of toponyms with respect to the scale/graticule.	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 different scales.
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) Composition (ix) Visual hierarchy (x) Presentation (xi) Use of color/figure-ground/contrast.	Describe, specify and apply the principles and characteristics underpinning good and efficient cartographic design at various scales and different map/charts 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 • Accuracy (positional, thematic, temporal) • Resolution (spatial, temporal) • Consistency (logical, domain) • Currency	Describe and apply the map/chart compilation process identifying discrete stages. Differentiate between the appropriate compilation processes for maps and 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.

	• 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) Analog compilation worksheet (x) Digital compilation worksheet.	Develop a digital and an analog 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, ...	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 for depiction on charts with regard to scale.
C2.3 Navigational hazards and aids to navigation *(A)*	(i) Cartographic representations of hazards to navigation (ii) Cartographic representations of aids to navigation.	Evaluate selected data sources for hazards and aids to navigation. Specify and apply the appropriate depiction of identified navigational hazards and aids to navigation on nautical charts.
C2.4 Sailing directions, nautical publications and special purpose reports *(A)*	(i) Identification of textual and administrative data suitable for graphic presentation (boundaries, environmental areas, traffic routing, special purpose sources, etc.) (ii) Symbiotic relationship between textual and graphic data. (iii) E-publications.	Explain the relationship between nautical charts and textual data sources and their use (sailing directions and other nautical publications including reports, lists and tabular data). Evaluate available administrative data for consistency in its graphical depiction and/or textual promulgation. Explain 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	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

	(iv) Adjusting data by use of software.	datums specifying 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 and depiction.	Define "magnetic variation". Compute magnetic variation for specific positions and times. Identify and depict magnetic anomalies.
C2.8 Metadata *(I)*	(i) Metadata and associated standards for analog and 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 analog and 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.
C2.10 Data for special purpose charting *(I)*	(i) Requirement, use and design of special purpose charts (ii) Data types: • Subsurface • Imagery • Geotechnical • Environmental • Engineering and asset.	Classify special purpose charts categories and their uses. 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. Specify 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) Spatial resolution and scale (vi) Model suitability criteria (vii) Topology: definition, levels and topological relationships. (viii) 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 taking into account the spatial resolution required. Define and encode topological relationships in spatial data files using available software tools. Use 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) Digitization and scanning (iii) Data entry: • manual • semi-automatic • automatic (iv) Data editing.	Use 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 the 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) Open geospatial databases and standards.	Describe different types of geospatial data and their representation in a DBMS environment. Describe a spatial database on a conceptual, logical and physical level. Design, build and populate a geospatial or cartographic database and use it in cartographic composition.
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.	Use the functionality of a GIS in geospatial data analysis and modeling.
C3.8 Raster data compression *(I)*	(i) Raster data compression methods, e.g.: • Run-length encoding • Freeman chain codes • Quad tree encoding • JPEG compression.	Describe and use 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, ISO….) (ii) Geospatial data transfer process.	Select appropriate geospatial data transfer standards for different applications. Specify the process for import/export data between different standards.
C3.10 Marine Spatial Data Infrastructures (MSDI) *(I)*	(i) Spatial Data Infrastructures [SDI] for the marine environment (ii) The content of a SDI for the marine environment as a means of: • facilitating and coordinating the exchange of spatial data among providers and users • compilation and production of nautical charts. • marine spatial planning.	Define the structure and the content of a MSDI. Describe the context of collaborative MSDI development.
C3.11 Web services *(I)*	(i) Communication protocols (TCP/IP, HTTP) (ii) HyperText 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 composition and publication on the web.	Describe the functionality of communication protocols. Describe client server architecture. Define the functions of web browsers and web servers. Describe the capabilities of available web services. Utilize web services and data for map/chart composition and for publication on the web.
C4 Nautical Cartography		
C4.1 The Nautical Chart		
Element	**Content**	**Learning outcomes**
C4.1a Evolution of nautical charts *(I)*	(i) Paper (national and INT) (ii) ENC (ECDIS) (iii) ECS.	Outline the evolution of nautical charts and chart systems.
C4.1b Nautical charts *(I)*	(i) Planning/scheming (ii) The use of charts in navigation (iii) Types of charts (iv) Chart reading.	Identify and classify various types of nautical charts and their content according to their primary purpose.

C4.1c Nautical chart design *(A)*	(i) Design principles for nautical charts (ii) Characteristics (iii) Content (iv) Terminology (v) Symbolization.	Specify present day characteristics and design principles of nautical charts. Analyze the impact of technology on nautical chart 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 Chart		
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 with respect to the development and use of nautical charts 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. Design chart schemes.
C4.3b Data sources *(I)*	(i) Metadata considerations (ii) Source data selection (iii) Source data homogenization (iv) Source data registration.	Analyze methods applied for the appropriate selection and homogenization of source data.
C4.3c Content and Symbology *(A)*	(i) Coastlines • Natural • Constructed • Approximate (ii) Bathymetry • Soundings • Italicized • Upright • Special (e.g. Swept) • Sounding pattern selection • Principles • Automated techniques • Channel depiction (iii) Bathymetric contours (iv) Dangers to navigation • Rocks • Wrecks • Reefs • Shoals	Specify the various categories of features portrayed in nautical charts, apply and use them in nautical chart production. Select appropriate symbology for each feature and/or data category and apply them in nautical chart production. Identify sources for names of features, including undersea features.

	• Offshore constructions • Submarine pipelines and cables • Obstructions • Sea floor descriptions (v) Topography • Depiction using 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 diagrams – depiction (ix) ZOC (x) Titles and chart notes (xi) Graphic scales (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.	Specify and analyze the processes required for chart compilation and composition from a geospatial data base and implement using standalone software systems or integrated cartographic production systems.

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) Feature attribution (vi) Text (Styles as symbols) (vii) Notes, legends.	Describe the processes of the IHO Member States for the development of international chart and ENC standards. 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.	Specify the requirement for updating specific nautical charts. Undertake a complete chart updating task including editing, updating and publishing.
C4.3g Mapping on demand *(I)*	(i) Customized mapping from existing databases.	Identify and apply the processes required for mapping 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 open source systems (iv) Open Geospatial Consortium (OGC).	Identify common commercial systems and describe their functionality. Use a commercial system for map/chart composition and production. Identify and use commercial graphics and image processing systems.
C4.4b Open source systems *(I)*		Differentiate between commercial and open systems. Identify key open geospatial standards, their content and the organizations developing them. Identify and assess the benefits and limitations of open systems.
C4.4c Map/chart production systems evaluation *(I)*		Identify the benefits and/or limitations of the use of commercial and/or open source systems.
C4.5 Electronic chart production		
C4.5a Introduction to electronic charts *(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	Define and differentiate ENC and SENC Describe ECDIS and its characteristics Identify the product characteristics of ENCs.

	• SENC.	
C4.5b ENC production and IHO Standards *(I)*	(i) IHO S-57 • Contents including appendices • Data model • Topology (ii) Object Catalogue • 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) 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 (vi) ENC distribution system (vii) IHO S-100 (viii) IHO S-99 • S-100 Registry and Registers • S-101 ENC product specification • S-102 Bathymetry surface product specification.	Identify the international standards and specifications relating to ENCs. Describe the content of ENC standards and explain the relationships between them. Describe and use Object Based Data Bases. Describe the S-57 data model. Classify the general principles underpinning electronic chart data visualization. Describe and use the content of Presentation Library. Describe recommended production procedures for ENCs and utilize a software environment to produce an ENC. Identify and use best practice approaches and validation software for the QC/QA of an ENC. Describe the ENC distribution system. Explain the rationale underpinning the development of S-100. Explain and use the product specifications relating to the S-100 universal hydrographic data model.
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 – use within GIS and other environments.	Describe the characteristics of rasterized chart products and assess their advantages and limitations. Perform rasterizing processes. Describe 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) Contracts • Nature of contracts • Contractual obligation (vi) Professional standards • Competency • Professional ethics • Due diligence • Best practices • 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 Describe the status of the nautical chart as both an operational and legal entity. Explain the role of the nautical cartographer in terms of liability and ethical practices. Assess potential issues of legal liability relating to nautical charts.
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 • 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	Describe the historical evolution of the Law of the Sea. Specify and analyze the types of lines and areas defined under UNCLOS and their delimitation and apply them on charts. Describe and assess the status of the official nautical chart as a reference in relation to the depiction of boundaries and maritime zones.

	(iv) Delimitation 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 charting *(I)*	(i) Types of Industrial and Engineering Surveys. (ii) Remotely operated and autonomous vehicles (iii) Unexploded ordnance, archaeological and artefact detection and representation (iv) Requirement for cartographic presentation. (v) Applicable standards (e.g. IOGP, UKOOA, IMCA, …).	Describe and assess specific requirements, equipment and standards for charting engineering surveys. Identify the coverage areas for the various survey requirements in alignment with the overall project task.
C6.1b Route surveys charting *(I)*	(i) Rationale of charts and graphics for route surveys (ii) Forms of presentation for route survey data (iii) Use of vertical exaggeration in DEMs and profiles.	Assess requirements and use appropriate guidelines for charting route survey data.
C6.1c Dredging surveys charting *(I)*	(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 and apply guidelines for the charting of dredging surveys.
C6.1d Shallow geophysical site surveys charting *(I)*	(i) Rationale of charts and graphics for Geophysical Site surveys. (ii) Forms of presentation for Geophysical Site survey data. (iii) Presentation techniques for Geophysical Site survey data including the depiction of multiple layers.	Identify specific requirements and apply guidelines for charting shallow geophysical survey data.
C6.1e Still photograph and video surveys charting *(B)*	(i) Rationale for the use of still photograph and video surveys (ii) Photographic and video formats (iii) Video eventing (iv) Relating video survey to other relevant charts and graphics (v) Positional considerations.	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 • Foundation analysis (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 *(I)*	(i) Rationale of charts and graphics for environmental data (ii) Forms of presentation for environmental data.	Assess specific requirements and guidelines for charting environmental surveys.
C6.1h Industrial and engineering survey data representation *(I)*	(i) Forms of presentation for industrial and engineering survey data.	Differentiate the representation of industrial and engineering survey data from nautical charting data. Use industrial survey data to generate a special use chart.
C7 Map/Chart Reproduction		
Topic/Element	**Content**	**Learning outcomes**
C7.1 Forms of map/chart artwork *(I)*	(i) Positive artwork (ii) Negative artwork.	Differentiate the forms of map/chart artwork in terms of their characteristics.
C7.2 Output options *(I)*	(i) Soft copies (ii) Hard copies.	Differentiate and use available output options.
C7.3 Raster processing techniques *(I)*	(i) Page description language (Adobe postscript) (ii) Raster Image Processing (RIP) (iii) Parameters associated with the product.	Define product parameters and apply raster processing techniques.
C7.4 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 and specify appropriate devices for particular tasks.
C7.5 Color management *(I)*	(i) Standards for Color Matching (ii) Color profiles (iii) Gamut mapping.	Explain the need for the use of color standards and create color profiles as required. Describe and use gamut mapping process.
C7.6 Color separation *(I)*	(i) Color separation (ii) Image Setters (iii) Compositing separations (iv) Composite to film (v) Composite to plate.	Describe and analyze color separation in analogue and digital environments. Create color separation files for a map or chart utilizing an image setter.
C7.7 Proofing *(I)*	(i) Pre-press proofing (ii) Photo-mechanical proofs (iii) Digital proofs (iv) Inspecting proofs.	Explain the need for proofing. Differentiate between photo-mechanical and digital color proofs. Examine and assess proofs for integrity and subsequent printing.
C7.8 Lithography *(I)*	(i) Single color lithography (ii) Multiple color lithography.	Explain the processes involved in single and multi-color lithography.

C7.9 Plate making *(B)*	(i) Plate making process.	Describe the plate making process.
C7.10 Press work *(B)*	(i) Offset lithography (ii) Printing units (iii) Printed output quality check.	Describe the offset lithographic process. Describe map/chart quality checks in offset printing
C7.11 Printing papers *(I)*	(i) Printing paper specifications.	Explain the need for and prescribe suitable printing paper specifications for various chart uses.

CFCP - COMPREHENSIVE FINAL CARTOGRAPHIC PROJECT

Programmes must include a supervised and evaluated Comprehensive Final Cartographic Project (CFCP) 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 Comprehensive Final 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 Comprehensive Final 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 Comprehensive Final Cartographic Project must be divided in 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 in tasks that will:
    - result in specific outcome(s)
    - require specific equipment, software, data sources, etc.
    - be carried out in 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 COMPREHENSIVE FINAL CARTOGRAPHIC PROJECT MODULE IN ACCORDANCE WITH THE GUIDELINES.