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Postgraduate Certificate in Marine Navigation and Nautical Technology

# Marine Cartography and Geographic Information Systems

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## Acoustic Positioning

Concept: Determining the location of underwater objects using sound waves.

Related terms: Long Baseline (LBL), Ultra-Short Baseline (USBL), Short Baseline (SBL).

Explanation: An acoustic transceiver emits a sound pulse that reflects off a target or is received by a responder. By measuring travel time and applying the speed of sound in water, the system calculates distance. Multiple baselines triangulate the position.

Example: A research vessel uses a USBL system to track a deployed sensor package at 2 km depth.

Application: Real-time vessel tracking, subsea construction, marine wildlife tagging.

Challenges: Variability of sound speed due to temperature, salinity, and pressure; signal attenuation; multipath interference.

## Admiralty Chart

Concept: Official nautical charts produced by the United Kingdom Hydrographic Office.

Related terms: Electronic Navigational Chart (ENC), Raster Chart.

Explanation: Printed charts depict depth contours, hazards, and navigation aids using standardized symbols and scales. They are updated through Notices to Mariners.

Example: A mariner consults Admiralty Chart 1475 for navigating the English Channel.

Application: Primary reference for visual navigation, pilotage, and route planning.

Challenges: Keeping paper charts up-to-date; limited detail compared with high-resolution digital charts.

## Albers Equal-Area Conic Projection

Concept: A map projection preserving area, suitable for mid-latitude regions.

Related terms: Lambert Conformal Conic, Transverse Mercator.

Explanation: The projection projects the Earth onto a cone that intersects two standard parallels, ensuring that areas are represented accurately while shape may be distorted.

Example: Coastal management agencies use Albers for mapping large estuarine zones.

Application: Thematic mapping of marine habitats where area comparison is critical.

Challenges: Distortion of shape and direction away from standard parallels; not ideal for polar regions.

## Bathymetric Survey

Concept: Collection of depth data to produce seafloor topography.

Related terms: Multibeam Echo-Sounder (MBES), Sidescan Sonar, Digital Elevation Model (DEM).

Explanation: Vessels tow or mount sonar equipment that emits acoustic pulses; the returned signals are processed to derive depth points (soundings). The data are interpolated into a raster grid.

Example: A hydrographic office conducts a MBES survey of a new offshore wind farm site.

Application: Chart production, hazard identification, habitat mapping, engineering design.

Challenges: Motion compensation, water column sound speed correction, data volume management.

#### Chart Datum

Concept: Reference level from which depths are measured on nautical charts.

Related terms: Mean Sea Level (MSL), Lowest Astronomical Tide (LAT), Charted Depth.

Explanation: Chart datum is a vertical datum, often the LAT, representing the lowest predictable tide. Depths are quoted as positive numbers below this datum.

Example: A vessel's echo-sounder displays a depth of 5 m relative to LAT.

Application: Ensures safe clearance calculations for vessel drafts.

Challenges: Variability of tidal regimes; conversion between local datums and global reference frames.

#### Coastal Zone Management (CZM)

Concept: Integrated approach to managing coastal resources and activities.

Related terms: Integrated Coastal Management (ICM), Marine Spatial Planning (MSP).

Explanation: CZM combines ecological, economic, and social objectives, using spatial data to allocate marine uses while protecting the environment.

Example: A regional authority uses GIS layers of shoreline erosion, shipping lanes, and marine protected areas to guide development permits.

Application: Policy formulation, conflict resolution, sustainability assessments.

Challenges: Balancing competing interests; data interoperability; climate change impacts.

#### Coordinate Reference System (CRS)

Concept: Framework defining how geographic coordinates are mapped to locations on Earth.

Related terms: Geographic Coordinate System (GCS), Projected Coordinate System (PCS), EPSG code.

Explanation: A CRS includes a datum, projection, and unit of measure. Geographic coordinates use latitude/longitude; projected systems convert these to planar X/Y values.

Example: A GIS dataset of seabed habitats uses EPSG:4326 (WGS 84) for latitude/longitude.

Application: Ensures spatial data alignment, distance calculations, and map production.

Challenges: Selecting appropriate CRS for regional vs. global analyses; datum transformation errors.

#### Digital Marine Chart (DMC)

Concept: Electronic representation of nautical chart information.

Related terms: Electronic Navigational Chart (ENC), Raster Chart, Chartplotter.

Explanation: DMCs combine vector and raster data, including depth contours, navigation aids, and attributes. They are stored in standard formats (e.g., S-57, S-101) for use in ECDIS.

Example: A ship's bridge displays a DMC on an ECDIS system, showing real-time vessel position.

Application: Real-time navigation, automated route planning, hazard alerts.

Challenges: Data integrity, update frequency, compliance with IMO regulations.

#### Dynamic Positioning (DP)

Concept: Computer-controlled system that maintains a vessel's position and heading using thrusters.

Related terms: Position Reference System (PRS), DP Class.

Explanation: Sensors (GPS, gyrocompass, wind sensors) feed data to a controller that adjusts thruster output to counteract environmental forces.

Example: Offshore supply vessels use DP2 to hold position over an oil platform.

Application: Precision operations such as drilling, cable laying, and ROV deployment.

Challenges: Reliability of sensor inputs, fuel consumption, redundancy requirements.

#### Electronic Chart Display and Information System (ECDIS)

Concept: Integrated navigation system that displays electronic charts and vessel position.

Related terms: Digital Marine Chart, Chartplotter, Automatic Identification System (AIS).

Explanation: ECDIS receives position data (e.g., GPS) and overlays it on ENC layers, providing route planning, alarms for depth and course deviations, and compliance monitoring.

Example: A container ship follows an ECDIS-generated route from Shanghai to Los Angeles.

Application: Mandatory equipment for IMO-compliant vessels, enhancing situational awareness.

Challenges: User training, data updates, cyber-security vulnerabilities.

#### Environmental Impact Assessment (EIA)

Concept: Process to evaluate potential environmental effects of marine projects.

Related terms: Strategic Environmental Assessment (SEA), Mitigation Measures.

Explanation: GIS is used to overlay project footprints with habitats, migration routes, and protected areas to predict impacts.

Example: An offshore wind farm developer conducts an EIA using GIS layers of seabird colonies.

Application: Regulatory approval, design optimization, stakeholder communication.

Challenges: Data gaps, uncertainty in predictive models, cumulative impact analysis.

#### Feature Extraction

Concept: Deriving meaningful objects (e.g., shoals, wrecks) from raw sonar or imagery data.

Related terms: Object-Based Image Analysis (OBIA), Classification.

Explanation: Algorithms detect edges, textures, and shapes, converting pixel data into vector features with attributes.

Example: Automated detection of sandbanks from multibeam backscatter using a machine-learning classifier.

Application: Accelerating chart updates, habitat mapping, hazard detection.

Challenges: False positives, variability in seabed composition, algorithm tuning.

#### Geodetic Survey

Concept: Precise measurement of Earth's shape and position of points on its surface.

Related terms: Global Navigation Satellite System (GNSS), Datum.

Explanation: Surveyors use GNSS receivers, tide gauges, and leveling to establish control points that anchor hydrographic data to a global reference frame.

Example: Establishing a GNSS-based reference station on a coastal lighthouse for chart datum conversion.

Application: Ensuring spatial accuracy of nautical charts and GIS datasets.

Challenges: Satellite geometry, atmospheric delays, maintaining long-term stability of control networks.

#### Geographic Information System (GIS)

Concept: Computer system for capturing, storing, analyzing, and visualizing spatial data.

Related terms: Spatial Database, Map Projection, Layer.

Explanation: GIS integrates vector (points, lines, polygons) and raster (grids, imagery) data, enabling queries, analyses, and cartographic output.

Example: A maritime authority uses GIS to overlay ship traffic density with marine protected areas.

Application: Decision support, risk assessment, resource management, navigation chart production.

Challenges: Data compatibility, scale issues, user expertise, hardware requirements.

### Georeferencing

Concept: Assigning real-world coordinates to raster or vector data.

Related terms: Control Points, Spatial Reference.

Explanation: By matching known locations in an image to geographic coordinates, the dataset is transformed into a defined CRS.

Example: Scanning historical paper charts and georeferencing them to WGS 84 for integration with modern GIS.

Application: Preservation of legacy data, creation of basemaps, change detection.

Challenges: Distortion in source material, selection of accurate control points, projection choice.

### Hydrographic Survey

Concept: Systematic measurement of water depth and related features.

Related terms: Bathymetry, Charting, Multibeam Echo-Sounder.

Explanation: Combines sonar depth soundings, tide measurements, and positional data to produce navigational charts.

Example: A national hydrographic office conducts a coastal survey using a dual-frequency MBES to capture fine-scale seafloor detail.

Application: Safe navigation, dredging planning, scientific research.

Challenges: Weather constraints, data processing workload, integration of multi-sensor datasets.

### International Hydrographic Organization (IHO)

Concept: Intergovernmental body that sets standards for hydrography and nautical charting.

Related terms: S-57, S-101, Maritime Safety.

Explanation: The IHO develops specifications for ENC formats, chart symbols, and data quality, facilitating worldwide interoperability.

Example: Adoption of the IHO S-101 standard for future ENC updates.

Application: Harmonization of chart products, exchange of hydrographic data, safety of navigation.

Challenges: Keeping standards current with technology, achieving global compliance, balancing legacy systems.

### International Maritime Organization (IMO)

Concept: United Nations agency responsible for maritime safety, security, and environmental protection.

Related terms: SOLAS, STCW, ECDIS.

Explanation: IMO adopts conventions and regulations that shape chart usage, vessel equipment, and navigational practices.

Example: IMO mandates the carriage of ECDIS on vessels of 5,000 GT and above.

Application: Regulatory framework for navigation, crew training, and environmental standards.

Challenges: Enforcement across jurisdictions, updating regulations with emerging tech, aligning with regional bodies.

#### Least-Cost Path Analysis

Concept: GIS method to determine the optimal route minimizing a defined cost (e.g., distance, risk).

Related terms: Cost Surface, Raster Analysis.

Explanation: A raster grid assigns a cost value to each cell; algorithms (e.g., Dijkstra) compute the path with the lowest cumulative cost.

Example: Planning a submarine cable route that avoids steep slopes and protected habitats.

Application: Route planning for navigation, pipeline placement, and habitat connectivity studies.

Challenges: Defining appropriate cost parameters, data resolution, computational intensity.

#### Multibeam Echo-Sounder (MBES)

Concept: Sonar system that emits multiple beams to map seafloor depth across a swath.

Related terms: Bathymetry, Backscatter, Beamforming.

Explanation: Transducers generate fan-shaped acoustic pulses; received echoes are processed to calculate depth for each beam, producing dense point clouds.

Example: An offshore survey vessel collects 1,000 soundings per second with a 400 kHz MBES.

Application: High-resolution charting, habitat classification, obstacle detection.

Challenges: Motion compensation, water column sound speed profiling, data storage demands.

#### Navigation Warning System (NWS)

Concept: System that disseminates alerts about hazards or changes affecting navigation.

Related terms: Notice to Mariners (NTM), Advisory Broadcast.

Explanation: Authorities issue warnings via radio, satellite, or electronic chart updates; ECDIS can automatically display relevant alerts.

Example: A temporary buoy displacement is broadcast through the NWS and appears on the vessel's chart.

Application: Enhances situational awareness, supports compliance with safety regulations.

Challenges: Timeliness of updates, information overload, ensuring reception on all vessels.

#### Oceanographic Data Interpolation

Concept: Estimating values (e.g., temperature, salinity) at unsampled locations.

Related terms: Kriging, Inverse Distance Weighting (IDW), Grid Generation.

Explanation: Spatial interpolation techniques generate continuous fields from discrete measurements, supporting analyses such as sound-speed correction.

Example: Interpolating CTD casts to produce a 3-D temperature model for a navigation area.

Application: Improves accuracy of depth sounding corrections, supports marine research.

Challenges: Selecting appropriate method, handling anisotropy, computational load for large datasets.

#### Open-Source GIS (OSGIS)

Concept: Free, community-developed software for spatial data handling.

Related terms: QGIS, GRASS GIS, Geopackage.

Explanation: OSGIS provides tools for vector editing, raster processing, and plugin extensions, fostering reproducibility and customization.

Example: A university marine lab uses QGIS to visualize bathymetric data and create custom thematic maps.

Application: Cost-effective analysis, education, collaborative research.

Challenges: Variable support, compatibility with proprietary formats, need for technical expertise.

### Photogrammetry

Concept: Deriving measurements from overlapping photographs, often from aerial or UAV platforms.

Related terms: Structure from Motion (SfM), Digital Surface Model (DSM).

Explanation: By matching features across images, 3-D coordinates of surface points are reconstructed, yielding high-resolution terrain models.

Example: UAV images of a tidal flat processed with SfM to map intertidal habitats.

Application: Shoreline change monitoring, habitat mapping, coastal engineering.

Challenges: Water surface reflections, need for accurate ground control, processing time.

### Positional Accuracy

Concept: Measure of closeness between reported coordinates and true positions.

Related terms: Horizontal Accuracy, Vertical Accuracy, Error Ellipse.

Explanation: Determined by sensor precision, datum transformation, and environmental factors; expressed as a confidence radius (e.g., 95% within 5 m).

Example: An AIS transponder provides positions with a horizontal accuracy of  $\pm 3$  m.

Application: Critical for collision avoidance, anchorage planning, and chart verification.

Challenges: Maintaining accuracy in dynamic environments, integrating heterogeneous data sources.

### Raster Data

Concept: Grid-based representation of spatial phenomena, where each cell holds a value.

Related terms: Digital Elevation Model (DEM), Backscatter Image.

Explanation: Raster formats include GeoTIFF, NetCDF, and GRIB; they are suited for continuous data such as bathymetry or satellite imagery.

Example: A 30-m resolution DEM of a coastal region used for flood risk modeling.

Application: Interpolation, surface analysis, thematic mapping.

Challenges: Large file sizes, resolution trade-offs, alignment with vector data.

### Remote Sensing

Concept: Acquisition of information about the Earth's surface without direct contact.

Related terms: Satellite Imagery, LiDAR, Synthetic Aperture Radar (SAR).

Explanation: Sensors capture electromagnetic energy reflected or emitted from the sea surface; data are processed to extract parameters like sea-state, chlorophyll, or oil spills.

Example: Sentinel-1 SAR imagery used to detect oil slicks in a shipping lane.

Application: Monitoring environmental incidents, supporting navigation safety, augmenting chart updates.

Challenges: Atmospheric correction, sensor calibration, temporal resolution constraints.

### Sea-Level Rise (SLR) Projection

Concept: Forecast of future increases in mean sea level due to climate change.

Related terms: Coastal Vulnerability, Adaptation Planning.

Explanation: GIS integrates SLR scenarios with topographic and demographic data to assess potential

inundation zones.

Example: A city's coastal resilience plan uses a 1 m SLR projection for 2100 to prioritize flood defenses.

Application: Long-term navigation infrastructure design, risk mitigation, policy development.

Challenges: Uncertainty in climate models, integrating high-resolution terrain data, socioeconomic considerations.

#### Sidescan Sonar

Concept: Sonar system that produces images of seafloor texture by emitting fan-shaped acoustic pulses.

Related terms: Backscatter, Acoustic Imaging.

Explanation: The intensity of returned echoes is plotted as a grayscale image, revealing features like wrecks, rocks, and sediment types.

Example: A survey vessel maps a shipwreck using high-frequency sidescan to produce a detailed image.

Application: Hazard identification, archaeological surveys, habitat classification.

Challenges: Geometric distortion, limited depth accuracy, interpretation expertise required.

#### Spatial Data Infrastructure (SDI)

Concept: Framework of policies, standards, and technologies enabling sharing of spatial information.

Related terms: GeoPortal, Metadata, Interoperability.

Explanation: SDI provides catalog services, download mechanisms, and web services (WMS, WFS) for marine datasets.

Example: A national hydrographic office publishes ENC updates through an SDI portal.

Application: Facilitates collaboration among agencies, supports decision-making, promotes open data.

Challenges: Data security, standard compliance, sustained funding.

#### Spatial Resolution

Concept: The smallest discernible unit in a raster dataset.

Related terms: Pixel Size, Ground Sample Distance (GSD).

Explanation: High spatial resolution captures fine details (e.g., 1 m), while coarse resolution (e.g., 1 km) is suitable for broad-scale analyses.

Example: A 5 m bathymetric raster is used for detailed harbor charting.

Application: Determines suitability of data for navigation, habitat mapping, and modeling.

Challenges: Balancing detail with data volume, matching resolution to analysis scale.

#### Spatio-Temporal Analysis

Concept: Examination of how spatial patterns evolve over time.

Related terms: Time-Series GIS, Change Detection.

Explanation: GIS tools link datasets with timestamps, enabling trend analysis, forecasting, and event correlation.

Example: Tracking the migration of pelagic fish schools using AIS data over a season.

Application: Fisheries management, environmental monitoring, navigation hazard prediction.

Challenges: Data continuity, handling large temporal datasets, aligning disparate time scales.

#### Standard Navigation Symbols (SNS)

Concept: Set of symbols defined by the IHO for consistent chart representation.

Related terms: Chart Symbol, Annotation.

Explanation: Symbols depict buoys, lights, wrecks, and other features; each has a prescribed shape, color, and meaning.

Example: A red triangular symbol indicates a "danger" buoy on a chart.

Application: Uniform interpretation of charts worldwide, reduces miscommunication.

Challenges: Maintaining symbol libraries in digital systems, user familiarity, updates for new features.

### Submarine Cable Route Planning

Concept: Process of selecting a seafloor path for laying telecommunications cables.

Related terms: Least-Cost Path, Geohazard Mapping.

Explanation: GIS integrates bathymetry, seabed geology, and environmental constraints to identify safe, cost-effective routes.

Example: A telecom operator uses GIS to avoid a known submarine landslide zone when planning a trans-Atlantic cable.

Application: Infrastructure development, risk mitigation, cost optimization.

Challenges: Data scarcity in deep-sea regions, regulatory approvals, dynamic seabed processes.

### Synthetic Aperture Radar (SAR)

Concept: Radar system that creates high-resolution images by processing Doppler shifts.

Related terms: Coastal Monitoring, Sea-State Estimation.

Explanation: SAR operates regardless of daylight or cloud cover, making it valuable for continuous maritime surveillance.

Example: SAR imagery detects ship tracks in remote oceanic areas for illegal fishing enforcement.

Application: Maritime domain awareness, oil spill detection, ice monitoring.

Challenges: Speckle noise, interpretation complexity, large data volumes.

### Survey Control Network

Concept: Network of precisely positioned points serving as references for hydrographic surveys.

Related terms: Reference Station, Geodetic Datum.

Explanation: Control points are established using GNSS and tide measurements; they anchor survey data to a global frame.

Example: A coastal survey utilizes a network of 10 GNSS stations to achieve sub-meter accuracy.

Application: Ensures consistency across surveys, facilitates data integration.

Challenges: Maintaining station stability, periodic re-survey, accessibility of control sites.

### Terrain Analysis

Concept: Evaluation of surface characteristics such as slope, aspect, and curvature.

Related terms: Hillshade, Viewshed.

Explanation: GIS derives terrain attributes from DEMs, aiding in line-of-sight assessments and hazard identification.

Example: Generating a viewshed from a lighthouse to assess potential blind spots for navigation.

Application: Site selection, risk assessment, visual navigation planning.

Challenges: DEM resolution limits, handling marine-land interfaces, computational intensity for large areas.

### Underwater Positioning System (UPS)

Concept: System that provides absolute or relative positions of submerged assets.

Related terms: Acoustic Positioning, Inertial Navigation.

Explanation: Combines acoustic ranging with inertial sensors to track objects when GPS signals cannot penetrate water.

Example: An ROV operating at 1,000 m depth uses a UPS to maintain a precise location relative to a surface vessel.

Application: Subsea construction, scientific sampling, asset tracking.

Challenges: Signal attenuation, latency, integration with surface navigation data.

### Vector Data

Concept: Spatial data represented by points, lines, and polygons.

Related terms: Shapefile, Geodatabase, Topology.

Explanation: Attributes are attached to each feature, enabling queries and analysis (e.g., depth values linked to a seabed contour line).

Example: A GIS layer of maritime navigation aids contains point features with beacon characteristics.

Application: Chart annotation, routing, thematic mapping.

Challenges: Maintaining topological integrity, handling large attribute tables, version control.

### Water Column Sound Speed Profile

Concept: Variation of sound speed with depth, temperature, salinity, and pressure.

Related terms: CTD Cast, Ray Tracing.

Explanation: Accurate sound speed is essential for correcting sonar depth measurements; profiles are collected using Conductivity-Temperature-Depth (CTD) sensors.

Example: A survey vessel updates its MBES processing with a real-time sound speed profile sampled every 30 minutes.

Application: Improves bathymetric accuracy, supports acoustic modeling.

Challenges: Temporal variability, sensor calibration, integration into processing pipelines.

### Yield Mapping

Concept: Spatial representation of resource extraction (e.g., fish catch) or production.

Related terms: Catch Per Unit Effort (CPUE), Spatial Statistics.

Explanation: GIS links catch data with location coordinates to visualize productivity patterns.

Example: A fisheries agency creates a yield map showing high-density tuna catches in the western Pacific.

Application: Management of fishing quotas, identifying over-exploited areas, informing navigation advisories.

Challenges: Data reliability, spatial bias, confidentiality concerns.