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Contents

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Editorial

This edition comprises two articles and three notes. The first article is a collaborative effort from the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC). The article provides the rationale behind the new format adopted for presentation of the standards and offers information useful to institutions in development of programs with the intention of gaining recognition. Edition 1.0.0 of IHO Publications S-8A and S-8B (Standards of Competence for Category "A" and "B" Nautical Cartographers) and Edition 1.0.1 of IHO Publications S-5A and S-5B (Standards of Competence for Category "A" and "B" Hydrographic Surveyors) have been adopted (IHO CL 54/2017). The Board Members are to be congratulated on their efforts.

The second article from China outlines data quality issues with collecting and processing bathymetric data. The authors describe the various gross and systematic errors and have devised quality control plans covering multibeam sounding data collection and the processing stages including pre-production, data evaluation, checking and final acceptance.

The Japan Hydrographic and Oceanographic Department (JHOD) contributed a note that describes the use of Airborne Lidar Bathymetry (ALB) in their surveys over the past 14 years across a wide ranging number of survey purposes.

A second note from the Korea Hydrographic and Oceanographic Agency (KHOA) discusses the delivery of Phase 3 of their Category B Marine Geospatial Information Programme. The programme was run by the Capacity Building Fund of the International Hydrographic Organization (IHO) sponsored by the RoK from 2015 to 2017.

Finally, in the third note, the Suriname Aids to Navigation Academy (SAA) provided a brief description of their first IALA Aids to Navigation level 1 Manager Course run over May 2017. The Academy is the only training organization for the North & South America, Latin & Caribbean Region that is accredited to deliver aids to navigation training based on the IALA recommendation E-141.

I would also like to take the opportunity to congratulate the new Secretary-General of the IHO, Dr Mathias Jonas and the IHO Directors' Abri Kampfer and Mustafa Iptes upon their appointments (IHO CL52/2017). My thanks also to past Secretary-General Robert Ward and Director Gilles Bessero for their commitment to the IHO and the profession.

On behalf of the Editorial Board, I hope that this edition is of interest to you and may inspire you to submit a future paper on the work that you have done or are currently engaged in.

Thank you to the authors for your contributions and to my colleagues who provided peer reviews for the Articles in this edition.

Ian W. Halls
Editor

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Article

MAINTAINING THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS AND NAUTICAL CARTOGRAPHERS: A MODERN APPROACH

By K. Miller [1], A. Armstrong [2], R. Furness [3], A. Greenland [4], G. Johnston [5], R. Nairn [6], N. Roscher [7], N. Seube [8], S. Syawie [9] and L. Tsoulos [10]

Abstract

The International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers maintains standards in these disciplines and awards recognition to programs of education found to be compliant. Standards have been fully revised and updated, both in terms of expectations of stakeholders and in nomenclature used in education. This paper provides the rationale behind the new format adopted for presentation of the standards and offers information useful to institutions in development of programs with the intention of gaining recognition. In the broader scope of education, the principles adopted in development of the standards offer a novel approach; expressing core requirements in professional education and training while allowing flexibility for further specialization.

Résumé

Le comité international sur les normes de compétence pour les hydrographes et les spécialistes en cartographie marine assure la tenue à jour des normes dans ces disciplines et accorde une homologation aux programmes d'enseignement qui sont jugés conformes. Les normes ont été entièrement révisées et mises à jour, à la fois sous l'angle des attentes des parties prenantes et en ce qui concerne la nomenclature utilisée dans l'enseignement. Cet article explique la raison d'être du nouveau format adopté pour la présentation des normes et offre des informations utiles aux établissements qui développent des programmes en vue d'obtenir une homologation. Dans la perspective plus large de l'enseignement, les principes adoptés au cours de l'élaboration des normes offrent une approche novatrice, en ce sens que les exigences fondamentales en matière d'enseignement et de formation professionnels y sont formulées tout en laissant une certaine souplesse dans l'optique d'une spécialisation plus poussée.

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Article

Resumen

El Comité Internacional sobre las Normas de Competencia para Hidrógrafos y Cartógrafos Náuticos mantiene normas en estas disciplinas y otorga reconocimiento a los programas de enseñanza que se consideran conformes. Las Normas han sido totalmente revisadas y actualizadas, tanto en términos de expectativas de las partes interesadas como en la nomenclatura utilizada en la enseñanza. Este artículo proporciona la razón que inspira el nuevo formato adoptado para la presentación de las normas y ofrece información útil a las instituciones para el desarrollo de programas cuya finalidad sea la obtención de reconocimiento. En el ámbito más amplio de la enseñanza, los principios adoptados en el desarrollo de las normas proponen un nuevo enfoque, expresando los requisitos fundamentales en la enseñanza profesional y en la formación, permitiendo flexibilidad para una especialización adicional.

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1. Introduction

Hydrography and nautical cartography can be used for many disparate purposes, but irrespective of their application, the disciplines of hydrography and nautical cartography are necessarily international. For navigational purposes, watch-keeping officers are required to operate within international protocols, using nautical charts that comply with international standards. There must, then, be a requirement for hydrographers and cartographers responsible for producing those charts to work within a framework of international standards. Similarly, hydrographers and cartographers working in the offshore and construction sectors are expected to adopt professional practices compliant with standards that lead to competent operations and, ultimately, security of the environment. Trinder (2008) offers a partial review of how competency standards are adopted by professional bodies associated with surveying. These typically relate to a professional body within a particular state, sometimes based on legislation, and some states award licenses for surveyors to practice within that state while others have an international membership component. Membership status, or a regional license, is obtained through education, by successful completion of an accredited program of study, together with supervised experience. The individual then operates based on recognized professional status and experience accumulated. As individuals, members of these professional bodies are required to maintain ethical practices and undertake continuous professional development to maintain their membership status. Kapoor (1980) identified the need for international standards of competence for hydrographic surveyors in both the governmental and industrial sectors and reported on the origins of such standards that were first considered in 1972 with the first standards released in 1978. Standards for nautical cartographers were introduced in 2003. Both standards are highly detailed in comparison with those typically adopted by professional bodies and are endorsed by the International Federation of Surveyors (FIG), the International Hydrographic Organization (IHO) and the International Cartographic Association (ICA); they have undergone major revisions through time with details to 2002 reported by Astermo and Gorziglia (2002). Overarching professional authorities of the FIG, the IHO and the ICA represent agencies and professional institutions within their respective membership at an international level rather than individuals, who are able to claim within their professional portfolio that they have completed a FIG/IHO/ICA recognized program. There is, however, an allowance for recognition through schemes whereby a professional body adopts the FIG/IHO/ICA competencies and makes enhancement through requirements for professional practice that then offers membership status. Nairn and Randhawa (2010) explain how such a scheme operates within the Surveying and Spatial Sciences Institute (SSSI) in Australia and the New Zealand Institute of Surveyors (NZIS). A comparable scheme exists through the Association of Canada Lands Surveyors (ACLS). Competencies provided within the standards are common to both program recognition and to schemes and form the basis for this paper.

The standards are drafted by the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (the Board) which, following rigorous assessment, awards recognition to programs that meet the relevant Standard. The Board comprises ten representatives, four nominated by the IHO, four by the FIG and two by the ICA. The IHO provides the Secretary and secretarial support to the Board. Members come from a mixture of academic institutions, government agencies and industry. At its annual meeting the Board consolidates its prior preliminary reviews of programs submitted for recognition. A program submission is normally supported by a presentation to the full Board by the submitting organization after which the Board makes its decision concerning the award of recognition. A program may be awarded recognition, conditionally recognized subject to an inter-sessional resubmission that addresses deficiencies, or, not recognized, in which case reasons are given and the applicants may return with a suitably modified submission the following year.

Maintaining the standards in line with changes in technology, practice and increasing diversity of the disciplines covered is an ongoing responsibility of the Board. Furthermore, developments in education also need to be considered. Given the significant changes in both of these areas that have taken place in the last decade, a decision was made by the Board to revisit the style in which the stan-dards are presented. Over the last five years the Board has fully revised the standards in terms of their structure, coverage, content and description of competencies. Principles underpinning the new standards are presented here.

2. Trends in program recognition

Programs submitted against the standards are considered by the Board each year through a report prepared by the submitting institution demonstrating that their offering is aligned; representatives are also strongly recommended to make a presentation to the Board. Guidelines to assist in the preparation of submissions developed by the Board are published by the IHO (2017a). Successful programs are awarded recognition for a period of six years; prior to 2007 it was ten years: in view of rapidly changing advances in technology ten years proved to be too long a period. ***Figure 1*** shows that the number of programs being submitted for recognition has risen considerably since 2011; this is partly due to the reduction in the recognition period and partly due to new programs that are being put forward. There was a reduction of submissions in 2017 when a number of institutions requested a one year extension to their programs for hydrographic surveyors in order that they could revise programs in alignment with the new standards that came into force from 2017 for submissions.

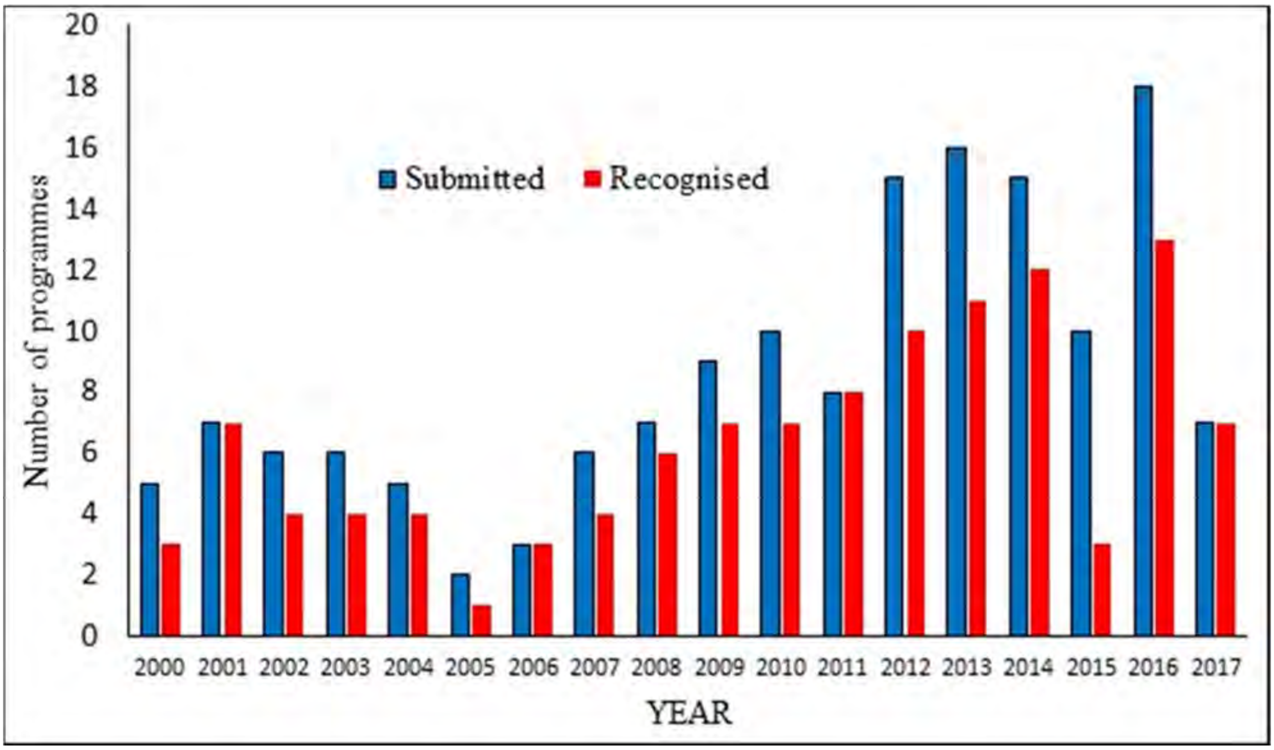

Figure 1: *Number of programs submitted and recognized by year*

Standards for both hydrographic surveyors and nautical cartographers are provided at Category "A" and Category "B" levels. Kapoor (1980) explained why these terms were adopted rather than variants such as professional for Category "A" and technical for Category "B". There are currently 60 recognized programs spread across 30 countries: the division between hydrography and cartography at the different levels and between sectors is provided in ***Figure 2***. At a national level, the hydrographic office responsible for surveys and charting may come under military or civilian authority and this distinction is made. Education covers establishments such as universities and colleges where teaching towards qualification is the primary business. Programs offered by the industrial sector are either delivered commercially to fee paying students or internally for staff development within the organization. Category "A" programs in hydrographic surveying and nautical cartography are separated between national hydrographic agencies and educational institutions. All sectors run Category "B" programs in both disciplines, but more are offered in hydrographic surveying by the hydrographic agencies than in any other sector.

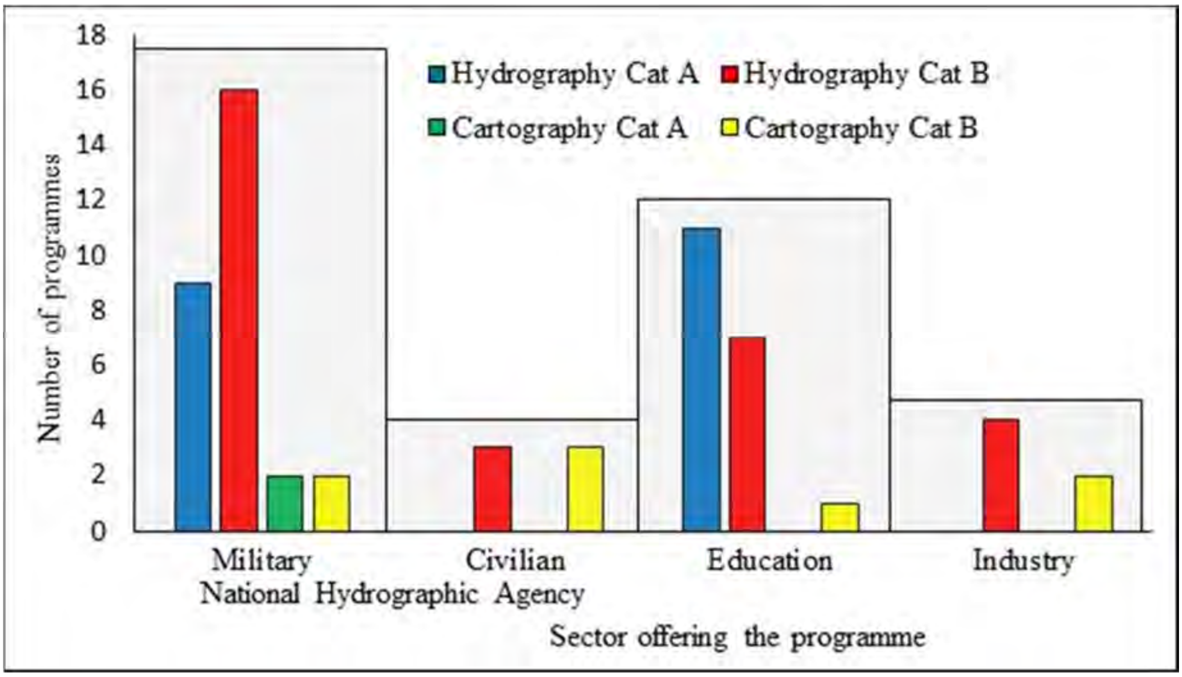

Figure 2: *Distribution of programs by type and sector*

3. Structure of the standards

Until the recent revision of the standards, the Category "A" level was provided as an addition to the Category "B" requirements with Standard S-5 representing hydrographic surveying and S-8 nautical cartography. Under the use of modern technologies and associated quality control processes, the roles and responsibilities of those charged with managing the survey and cartographic operations have now become sufficiently differentiated from those conducting the survey and chart production to warrant separation of the standards. While the Category "A" requirements still include equipment operation, the required skill set expects much more in terms of the assessment and management of data acquired. On this basis, the suite of standards was separated into:

- S-5A Standards of Competence for Category "A" Hydrographic Surveyors (IHO, 2017b)
- S-8A Standards of Competence for Category "A" Nautical Cartographers (IHO, 2017c)
- S-5B Standards of Competence for Category "B" Hydrographic Surveyors (IHO, 2017d)
- S-8B Standards of Competence for Category "B" Nautical Cartographers (IHO, 2017e)

In addition to separation of the standards, options that were previously defined have been removed. An article that appears on the National Oceanographic and Atmospheric Administration (NOAA, 2014) website written to celebrate World Hydrography Day in 2014 with the theme "*Hydrography - Much More Than Just Nautical Charts*", demonstrates how the disciplines of hydrographic surveying and nautical cartography have become more diverse in their applications than can be satisfactorily expressed in a short list of options. It is also considered desirable for students and for industry and government to have a range of programs offered globally, each with a unique flavor, rather than it is to have a set of clone programs offered in different locations. The minimum standards must ensure coverage of core components expected of any hydrographic surveyor or nautical cartographer while allowing flexibility to specialize in alignment with the aim of a particular program. Options that were included to allow specializations to be covered by the standards are no longer specified within the standards with some key components being incorporated into the body of the new standards.

Initially the disciplines of hydrographic surveying and nautical cartography are organized into the subject headings given in ***Tables 1 and 2***, respectively. While some of the titles are the same in the different standards, the expectations are aligned differently and set at different levels. The aim of the standards is to describe the core requirements, but this is dependent on the academic background of the entering matriculants. Exemptions on the basis of prior learning may then be permissible. The standards are structured with subject groups identified as:

* Basic (B) and Essential (E) at Category "B" level; and,
* Basic (B), Foundation (F), and Hydrographic Science (H) or Cartographic Science (C) at Category "A" level;

with exemptions being allowed in the Basic and Foundation subjects. The latter only exist at Category "A" level, which might be offered for example as a Master's degree program. Then, in S-5A or S-8A, a student entering with a first degree in Land Surveying, Ocean Science, Geology, Cartography or Geographic Information Science could be exempt from the relevant Foundation subject provided evidence of prior coverage at the required level can be validated. Essentials and specialist science subjects in hydrographic surveying and nautical cartography are then grouped into relevant theoretical, operational and managerial headings.

4. Expressing competencies

Constructive alignment as presented by Biggs (1996) is a development in the guidelines for education that is now accepted practice in tertiary education: it is a component of the Bologna Process (European Commission/EACEA/ Eurydice, 2015) that standardizes educational practices across Europe. The intention is to deliver material constructively in a way that the learner thinks and to align the assessment accordingly through a set of learning outcomes: implementation is documented by Biggs and Tang (2011). The concept of alignment hinges on assessment against the desired outcomes of a course with appropriate verbs used to indicate the expected level of learning. It is not possible to assess each small component of a course independently and to determine that a student has grasped concepts that are spread across the course; the assessment must be set with a broad scope. Outcomes must therefore be generic. Williamson (2014) suggests that between 4 and 6 is a reasonable number for a program module and a typical university student would take about 6 modules per semester. On this basis, a student might spend 12 weeks of study towards about 30 learning outcomes at first degree or at master's level. Outcomes must be well defined in terms of scope and measurable through assessment, although not all need to be assessed directly; this is considered in relation to the standards within the discussion.

Table 1. *Subjects in Standards of Competence for Hydrographic Surveyors.*

S-5A Subjects	S-5B Subjects
B1 Mathematics, statistics, theory of observations B2 Information and Communication Technology B3 Physics B4 Nautical science B5 Meteorology	B1 Mathematics, Statistics, Theory of Errors B2 Information and Communication Technology B3 Physics B4 Earth Sciences B5 Nautical science B6 Meteorology
F1 Earth Models F2 Oceanography F3 Geology and geophysics	E1 Underwater Acoustics E2 Remote Sensing E3 Water Levels And Flow E4 Positioning E5 Hydrographic Practice E6 Hydrographic Data Management E7 Environment
H1 Positioning H2 Underwater Sensors and Data Processing H3 LiDAR and Remote Sensing H4 Survey Operations and Applications H5 Water Levels and Flow H6 Hydrographic Data Acquisition and Processing H7 Management of Hydrographic Data H8 Legal Aspects	COMPREHENSIVE FINAL FIELD PROJECT
COMPLEX MULTIDISCIPLINARY FIELD PROJECT	

Table 2. *Subjects in Standards of Competence for Nautical Cartographers.*

S-8A Subjects	S-8B Subjects
B1 Mathematics, Statistics, Theory of Errors B2 Information and Communication Technology B3 Earth Sciences	B1: Mathematics, Statistics, Theory of Errors B2: Information and Communication Technology B3: Earth Sciences
F1 General Geodesy F2 Hydrography and Nautical Products F3 Photogrammetry and Remote Sensing	E1: General Geodesy E2: General Cartography E3: Hydrography and Nautical Products E4: Data for Nautical and Special Purpose Charting E5: Photogrammetry and Remote Sensing E6: Geospatial Information and Processing E7: Nautical Cartography E8: Legal aspects (Relating to nautical cartography) E9: Special Purpose Charting E10: Map/Chart Reproduction
C1 General Cartography C2 Data for Nautical and Special Purpose Charting C3 Geospatial Information and Processing C4 Nautical Cartography C5 Legal aspects (Relating to nautical cartography) C6 Special Purpose Charting C7 Map/Chart Reproduction	
COMPREHENSIVE FINAL CARTOGRAPHIC PROJECT	COMPREHENSIVE CARTOGRAPHIC PROJECT

The standards intend to express competencies necessary to function in a particular role. Kennedy, Hyland and Ryan (2006) consider the difference between competencies and learning outcomes, concluding that the term ‘learning outcomes’ is better defined in educational literature. Learning outcomes can be written to cover a range of skills based on knowledge acquired, understanding or ability to perform some task, which is exactly how a set of competencies can be described. However, the term ‘competencies’ is much broader in its scope; for example, at a technical level there could be a binary response to completion of some simple operation. As the standards intend to address programs of education at tertiary level, it is appropriate to write standards of competence in terms of learning outcomes. Drafting of the standards in this format was informed by documentation published by those involved in education for university curriculum design such as Biggs and Tang (2011), Williamson (2014) and Kennedy, Hyland and Ryan (2006). However, due to the generic nature of learning outcomes it was also found necessary to offer a context and to indicate required coverage, which is achieved by providing a list of content. Within the standards, the subjects identified in ***Tables 1 and 2*** are further divided into topics and topics into elements with one or more learning outcomes associated with each element. Content may be shared across elements. The example provided in ***Table 3*** from S-5A also indicates the intended scope of applications for the standards in relation to hydrographic surveying.

Bloom's taxonomy (Bloom, B.S. (Ed.) 1984, Anderson, L.W. et al. 2001) has been applied to describe each element of the standards and the associated verbs used within the learning outcomes are an indication of the depth of learning. Verbs such as "*define, identify, describe, explain, differentiate, predict*" are associated with knowledge and comprehension, while "*apply, use, calculate, solve, classify, analyze*" require a deeper understandding of principles and are associated with application and analysis. Finally, to demonstrate deep knowledge required for synthesis and evaluation, students should be assessed on their ability to "*evaluate, select, design, specify, plan, create*". Learning outcomes prescribed within the standards follow these guidelines; however, it was also considered necessary to introduce further indication of level expected and this is achieved through quantifiers: Basic (*B*); Intermediate (*I*); or, Advanced (*A*) that are given within the element as shown in ***Table 3***. In this example, the verbs used in the learning outcomes (Establish, Specify and Evaluate) require deep knowledge and the level is Advanced. Another example provided in ***Table 4*** uses verbs associated with learning levels of knowledge and comprehension, but the elements are also considered as Advanced to reflect the complexity of the subject. The two learning outcomes in element H1.4a (***Table 4***) draw on content from the Basic subject in Physics (B3) and on Vessel and Sensor Reference Frames (contained in H1) requiring application of principles learned in these elements, which have levels of Basic and Advanced respectively. While the verbs "describe" and "relate" used in H1.4a imply comprehension under Bloom, the student is expected to be able to offer a description and a relationship at a detailed (Advanced) level aligned with knowledge of concepts developed previously.

Table 3. *Extract from S-5A with elements in relation to content and learning outcomes.*

H4: Survey Operations and Applications		
Topic/Element	**Content**	**Learning outcomes**
H4.1 Hydrographic survey projects		
H4.1a Hydrographic survey requirements *(A)*	(i) IHO S-44 and other survey quality standards. (ii) Underkeel clearance (iii) Procedures and installations required to conduct hydrographic surveys of specific types, for example: • Nautical charting survey • Boundary delimitation survey • Ports, harbor and waterways surveys. • Engineering works and dredging surveys • Coastal engineering surveys • Inland surveys • Erosion and land-sea interface monitoring • Oceanographic surveys • Deep sea and ROVs /AUVs surveys • Seismic, gravity and geomagnetic surveys • Pipeline route, pipeline installation, inspection and cable laying surveys • Wreck and debris surveys.	Establish procedures required to achieve quality standards in hydrographic surveys. Specify the type of survey system and equipment needs together with associated parameters and procedures for various components of the overall survey operation. Evaluate the impact of local physical and environmental factors on survey results.

Table 5 gives the number of learning outcomes in each of the standards, broken down into subjects. There are more requirements in the Basic and Foundation subjects in the hydrographic standards; this is because there is a greater likelihood of students entering these programs possessing some relevant background with nautical cartography being less dependent on a material that might have been previously covered. There is little difference in the number of outcomes prescribed in the two nautical cartography programs, but the level of expectation of those outcomes is significantly different.

Minimum durations for programs are set at 24 weeks for Category "B" and 40 weeks for Category "A". It is anticipated that students on an intensive program of such duration will spend in the region of 50 to 60 hours per week on their prescribed studies and personal study. Any Category "B" program in nautical cartography will be particularly intensive in terms of learning expectations over the minimum period. It should be noted that the program durations are set at a minimum, many programs submitted against the standards are longer. Here, the reader is reminded that the standards are *minimum* standards.

Table 4. *Extract from S-5A with theoretical and applied learning outcomes.*

H1.4 Subsea positioning		
H1.4a Acoustic positioning principles *(A)*	(i) Long base line (ii) Short baseline (iii) Ultra-short baseline (iv) Doppler velocity log (v) Transponders (vi) Acoustic modems (vii) Subsea INS (viii) Water column structure (ix) Acoustic ray multipath (x) Time synchronization	Describe the signal structure and observables of mobile and fixed acoustic positioning devices. Relate observables and platform orientation to relative positions through observation equations.
H1.4b Acoustic positioning systems *(A)*		Explain how acoustic positioning observables, orientation and surface positioning data are used to achieve subsea rover spatial referencing. Specify the deployment and calibration methods for fixed and mobile acoustic positioning systems.

Table 5. *Number of learning outcomes in each of the standards.*

Subject type	S-5B	S-5A	S-8B	S-8A
Basic	49	62	34	38
Foundation	-	49	-	35
Essential	118	-	191	-
Cartographic Science	-	-	-	164
Hydrographic Science	-	169	-	-
TOTAL	**167**	**280**	**225**	**237**

6. Final project

Each of the standards specifies the expectations for a comprehensive final project of 4 weeks in duration, which is independent of any practical work undertaken during previous program modules. Dunlap (2005) describes the advantages of problem-based learning in this style as a transition between education and the working environment. Project work in groups allows students to practice the knowledge acquired through program modules, operate in a team environment and reflect on their experiences. Specifications for project work given to students working towards a program that is recognized against the FIG/IHO/ICA standards expects the program participants to be involved in planning, execution and reporting on the project that is suited to the level of the standard. The objectives of the project are aligned with aspects of a "*capstone project*" that is common to engineering disciplines in the USA. As the accreditor for Engineering education in the USA, the Accrediting Board for Engineering and Technology (ABET) introduced a set of five engineering criteria for engineering programs, these are documented by Lattuca, Terenzini and Volkwein (2006). Criterion 3 relates to program outcomes and assessment requiring programs to demonstrate that students can apply knowledge gained in the program, design and conduct tests, function in a team, solve problems and communicate. Criterion 4 is aligned with preparing students for the professional environment through the application of knowledge gained in previous courses together with elements of professional conduct such as ethics and health and safety. A difficulty that is encountered with this type of team project is assessment of the individual against the prescribed learning outcomes. In conducting a review of the use of capstone project schemes offered by universities in the USA against ABET criteria 3 and 4, McKenzie, Trevisian, Davis and Beyerlein (2004) offer a summary of assessment techniques. They found that multiple assessments of different styles were generally applied throughout the project. While those associated with criterion 3 could be measured, it was more difficult to deal with criterion 4 with only about half of the requirements being considered measurable. Most of the learning outcomes in the FIG/IHO/ICA standards are aligned with criterion 3, only the measurable component of application of knowledge from criterion 4 is relevant. Professional elements of the ABET criterion 4 relate to requirements for individual membership of professional bodies, which is beyond the scope of the standards.

The final project specified in each of the standards is a learning exercise, it is aligned with some of the criteria set down by ABET and project work should be led by the students. By the time they reach this stage, the knowledge in each of the component parts should have been acquired, this is the opportunity for them to consolidate the information and skills gained within the prior program modules. However, they are still being assessed and relevant learning outcomes specified in the standards are applicable.

6. Quality assurance of programs

National councils such as the Quality Assurance Agency for Higher Education (QAA, 2017, part B) in the United Kingdom and the Tertiary Education Quality and Standards Agency (TEQSA, 2017) in Australia, lay down standards for academic programs that are designed to assure quality of the student experience. Aspects such as currency of material, standard of the learning environment and student engagement in the learning process are conducive to the acquisition of knowledge and skills that are relevant to potential student destinations. The S-5A, S-8A, S-5B and S-8B standards detail the minimum requirements of curricula and currency of content is maintained through updates to the standards. However, the Board also strives to ensure that further quality assurance measures are in place within organizations offering recognized programs. Guidelines for submissions against the standards (IHO, 2017a) detail expectations of internal quality assurance mechanisms that are expected to be in place.

An appropriate level of attainment prior to entry into any program of education is fundamental to the student experience and requirements for entry must be specific, together with details of any prior qualifications that may lead to exemptions from Basic and Foundation subjects. For host institutions in the commercial and academic sectors it is common to accept candidates who are changing career and may not have studied for some years. Such candidates may be required to undertake pre-entry refresher courses and a number of potentially relevant options exist on-line. It is important that students are prepared to undertake a program in terms of both their level of prior knowledge and state of preparedness to study for assessment. Individual students must then be monitored as they progress through the modules of the program. As indicated when discussing learning outcome H1.4a shown in ***Table 4***, a program must be structured for progression with the later components having a dependency on prior material. In order to progress, each student must have demonstrated an understanding of learning outcomes within the earlier modules and work undertaken in the final project requires an understanding of all previous material. Means of assessment must be in place at each stage to ensure that students have grasped the concepts and practical skills at the level necessary for progression with an allowance for remedial action in case they have not. The required level is indicated by the verb used in the learning outcome and level associated with the element.

Resources must be available for delivery in all respects including specialist staff for delivery of the various components, teaching space including facilities for practical work, study space for students with access to reference material and specialist software. In addition to scheduled delivery times the students are expected to undertake guided study both individually and in group activities, the necessary space and access must be provided.

Institutions are required to have in place an internal review process for each program with the review considering feedback from stakeholders. The review considers aspects of the program such as content, scheduling, delivery and assessment with a view to improvement and update. QAA (2017, part B) recommends that any program should undergo a comprehensive internal review every 3-5 years, more frequently for new programs. An important part of the review is student feedback on their experience, which must be obtained from each cohort on exit for immediate consideration. Urgent issues raised by the student body can be dealt with for the next delivery. The institution must have in place a formal mechanism for obtaining documented feedback from students on program completion together with a structured approach for immediate review and reaction to responses.

To complement documentation submitted towards recognition and annual reports received for recognized programs, the Board also has a mechanism for undertaking on site visits to host organizations. A visit typically involves 2 or 3 Board members reviewing documentation submitted by the organization in advance then visiting the location of program delivery to meet with staff and stakeholders and review resources. Details of the purpose and procedures are provided in IHO (2017a).

7. Discussion

Competencies that are applicable internationally for hydrographic surveyors and nautical cartographers are now provided in a form that is accepted in educational practice. During development of the standards, a review process took advantage of professional events for presentation of progress and feedback. The structure and style of presenting standards through learning outcomes was readily accepted by members of the various sectors offering programs and by those in a position to employ graduates from the programs. Endorsement of the standards is given by the FIG, the IHO and the ICA; in the case of the IHO the approval depends on its 87 Member States. Constructive comments were all considered in detail and many led to the drafts being changed prior to adoption.

The standards express competencies in terms of learning outcomes and guidelines that accompany the standards lay down expectations in terms of quality assurance processes that must be in place together with requirements for submission against the standards. Organizations submitting programs are expected to provide details of teaching schemes, practical work, assessment specifications and assessment criteria for theoretical and practical elements. This information offers evidence that learning outcomes are being met at the level prescribed in the standards, that competencies are being gained through knowledge, that this is underpinned with experience and that practical skills are acquired. The standards are international and Miller (2010) considers the cultural differences in learning that will lead to different styles of delivery. The standards do not specify delivery mechanisms, but there is an expectation for sufficient practical content. Technology is available that will allow some of the competencies to be acquired remotely and some programs that incorporate e-leaning components are currently recognized at Category "B" level in hydrography.

Specifications within the guidelines require that submitting institutions specify the program modules in which each element of the standard is assessed. In a well-constructed program module the learning outcomes will cover the material holistically, they do not provide a teaching scheme and as such it is not always possible to relate each individual learning outcome from the standards to a particular assessed task or practical exercise. Adam (2008) states that over-prescribed learning outcomes can lead to an assessment based curriculum that inhibits the learning process. The learning outcomes should be more general in their coverage of the material. Therefore, in reviewing submissions towards recognition, it would be difficult to determine whether each and every learning outcome is being assessed within the program. In many instances, learning outcomes from different elements will be merged into one practical task or into one exam question, a one-to-one relationship between learning outcomes and assignment components is not expected and, as such, it would be difficult to identify each individually within the assessment. For example, within S-5A an assessment task might require students to compare methods of seabed classification from optical and acoustic data in some carefully construed environmental situation. This is assessing learning outcomes in elements: H4.3a *Explain the techniques available and their limitations for observing, interpreting and classifying differences in seabed characteristics from acoustic sensors* and H4.3b *Explain the techniques available and their limitations for observing and interpreting differences in seabed and inter-tidal zone characteristics from optical sensors*. However, in constructing their arguments in response, students will be addressing other elements from the standards including H3.1b: *Explain how to incorporate information from full waveform analysis in the production of LiDAR mapping products* and the *specify* element of H2.5a *Specify and configure a side scan sonar and a swath echo sounder for backscatter acquisition under varying environmental conditions and for specific application.* The *configure* requirement of this latter learning outcome will require a practical exercise, otherwise these latter two outcomes are being assessed indirectly within the response to the question. There is a requirement within the guidelines for a submission to identify time spent on each element, and it is this information together with the examples of assessment that is used by the Board to review the program against the standards. This informs on the scope of coverage in alignment with that of the learning outcomes and that the level conforms to the specifications in the standards.

The extract from S-5A on acoustic positioning provided in ***Table 4*** demonstrates how learning outcomes are used to cover theoretical components as well as connecting that theory to applications and associated practical skills. Element H1.4a addresses the principles of acoustic positioning and draws on subjects covered at Basic and Foundation level. The first learning outcome in H1.4b then extends these principles to an application in positioning of a subsea rover and the second learning outcome requires the provision of specifications for an associated practical task. In order to respond to this requirement the student must have a full understanding of relevant methods available at a level where comparison can be made for justification of specifications. By comparison, a learning outcome at the Category "B" level in hydrographic surveying requires the student to be able to *Describe the deployment, calibration, signal structure and performance of acoustic positioning devices* and they must also be able to *Deploy and recover oceanographic and hydrographic equipment*, both at Basic level. Under these two learning outcomes the Category "B" student must demonstrate an ability to perform a practical task with an awareness for purpose and procedure. While this is relevant to acoustic positioning there is no specific requirement in the standards for students to deploy and use acoustic positioning equipment. It would be expected that a programme offering particular aspects of industrial hydrography would have access to such equipment, but this is considered beyond the resources that may be available to programs in other areas such as charting. Learning outcomes associated with equipment that is widely used across all applications are more specific in requirements for deployment, operation and detailing system specifications. All programs are expected to provide access to multibeam echo sounding equipment, the associated learning outcomes are written accordingly and the inclusion of multibeam echo sounders in the final projects in hydrographic surveying is a requirement.

In considering the number of learning outcomes in the standards as given in ***Table 5***, it was noted that the expectation may be more than is typical of an academic program of the same duration. In providing learning outcomes to function professionally against international requirements, there are a number of learning outcomes within the Basic and Foundation subjects that are essential elements of a program and must be referred to specifically, but which are integrated within the wider scope. For example, many of the seamanship skills in nautical science would be incorporated within practical exercises afloat and in basic training and mobilization tasks that would be undertaken within practical work. These outcomes are included to ensure that the students themselves are actively involved in equipment mobilization and deployment. Some of the learning outcomes associated with these tasks will be delivered and assessed simultaneously in a short time-frame. Similarly, some outcomes within the standards deserve less attention than others. For example, the outcome of element F1.3e in S-5A reads *Relate historical surveys to legacy positioning systems*. This might be delivered briefly in a class room, afloat on a practical exercise while running survey lines, or in a mathematics class when considering error propagation. Once the students are responsive to the notion that GNSS technologies have not always been available and indicate an awareness of the deficiencies and accuracies associated with techniques of the past then the learning outcome has been covered. There may be no evidence of coverage of this outcome beyond a cross reference to a program module and a very short time allocation is expected.

8. Conclusions

Two new FIG/IHO/ICA standards of competence for hydrographic surveyors are in force, those for nautical cartographers were sent to the IHO Member States for ratification in 2017 for approval[1]. These replace the previous standards and offer a complete update in terms of structure of the documents and style in which competencies are presented. The drafting process took an intensive five years, included interaction with stakeholders and a full review by IHO member states was undertaken. Standards of Competence for Category "B" Hydrographic Surveyors (S-5B) was released in January 2016 and S-5A in August 2016, both were used for recognition of programs submitted in 2017 with the three programs submitted against S-5A and two against S-5B all being awarded recognition. Guidelines for submitting organizations have also been revised in alignment with the new standards, these provide full details of requirements for submission against the standards.

Institutions submitting against the standards are expected to provide evidence that their program is compliant. There is a requirement to identify time spent on each element of the standards and the module in which this is delivered. The standards are not prescriptive in this regard and this is to allow flexibility within the aim of individual programs so that they

[1] *Since submission of the original manuscripit these standards were adopted.*

carry an identity. However, time allocated to competencies that are common across the respective disciplines are expected to be set at an appropriate level with a suitable distribution between practical and theoretical components. The level of learning is evidenced by expectations within the program assessment, which must also demonstrate coverage across the scope of learning outcomes specified within the standards. The guidelines that accompany the standards specify further requirements for program management to ensure that quality assurance mechanisms are in place; these processes are designed to support the learning experience of the student. In addition, minimum time periods without exemptions are set for programs at 24 weeks for Category "B" and 40 weeks for Category "A", these are considered as absolute with the amount of learning expected within this duration leading to highly intensive programs.

While professional bodies offer membership to individuals who meet academic and professional requirements, the FIG/IHO/ICA standards prescribe a detailed suit of theoretical knowledge and practical skills that reflect the international needs of the workforce in all aspects of hydrographic surveying and nautical cartography. Two professional bodies working at regional and national levels have adopted the standards as meeting competency requirements to practice in a professional capacity. The needs of industry and relevance of recognition against the standards is also apparent in the number of programs seeking recognition, which has increased from an average of 6 per year prior to 2012 to 13 since then.

Looking to the future, the standards have now been updated to reflect and incorporate the new trends, technologies and expectations of the profession. The hydrographic and cartographic professions are likely to have a greater emphasis on regulation, standards and the competencies of the work force placed upon them by a more diverse, demanding and knowledgeable stakeholder community. These four new standards and their associated guidelines aim to provide that foundation.

9. Acknowledgements

The Authors acknowledge, on behalf of the Board, the International Federation of Surveyors (FIG), the International Hydrographic Organization (IHO) and the International Cartographic Organization (ICA) for their ongoing support in all aspects of the Board's work. The Board also acknowledges representatives from numerous institutions internationally who have contributed to the development of new standards by attending stakeholder meetings, providing feedback on drafts and hosting working group meetings of the Board. To the organizations who submit their programs to the rigors of the standards, the Board acknowledges the wider and mutual interest of all who seek to assure the adoption of best practice internationally for education in the disciplines of hydrographic surveying and nautical cartography.

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Biography

The International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers consists of ten members nominated by the parent organizations of the FIG, the IHO and the ICA. The diverse interests of these bodies brings a wide range of experience and expertise to the table. Board members are regularly employed in various roles within national hydrographic agencies, educational institutions and industry, with many having career paths that extend across these sectors. All are further involved in professional activities within their region and internationally. Their common interest is the support of training and education in hydrographic surveying and nautical cartography for the development of professionals to operate at different levels required within all sectors. The worldwide composition of the Board together with their combined experience of working globally provides the insight to the needs of the disciplines necessary to cover the breadth and depth required of standards of competence that are applicable internationally.

The 2016 annual meeting of the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers hosted by SHOM in Brest, France. From left to right with Board members identified by their representative organization and territory: Ronan Leroy (SHOM), Lysandros Tsoulos (ICA, Greece), Alberto Costa Neves (IHO, Secretary to the Board), Sobri Syawie (FIG, Indonesia), Gordon Johnston (FIG, UK), Nickolas Roscher (IHO, Brazil), Andy Armstrong (IHO, USA), Nicolas Seube (IHO, Canada), Bruno Frachon (SHOM), Ron Furness (ICA, Australia), Adam Greenland (FIG, New Zealand), Rod Nairn (IHO, Australia), Keith Miller (FIG, Trinidad and Tobago).

Article

THE ANALYSIS OF ERROR SOURCES AND QUALITY ASSESSMENT OF MULTIBEAM SOUNDING PRODUCTS

By C. HUANG [1], G. BIAN [2] , X. LU [1], M. WANG [2], X. HUANG [1], K. WANG [1]

Abstract

The use of multibeam sounding systems for bathymetric surveys requires an understanding of the gross errors and deviations caused by the dynamic marine environment and the instrumentation in use. This paper discusses these errors and the quality inspection specifications and processes applied to multibeam system measurements. The quality control plans covering the multibeam sounding data collection and stages of processing including pre-production, data evaluation, checking and final acceptance are then identified.

Résumé

Le recours à des systèmes de sondage multifaisceaux pour l'exécution de levés bathymétriques requiert une compréhension des erreurs grossières et des écarts causés par le milieu marin dynamique et par les instruments utilisés. Cet article traite de ces erreurs ainsi que des spécifications et procédures d'inspection de la qualité appliquées aux mesures du système multifaisceaux. Les plans de contrôle de la qualité couvrant la collecte de données provenant de sondages multifaisceaux ainsi que les étapes de traitement incluant la pré-production, l'évaluation des données, la vérification et l'approbation finale, sont ensuite identifiés.

Resumen

El uso de sistemas de sondaje multihaz para levantamientos batimétricos requiere una comprensión de los errores gruesos y las desviaciones causados por el medio ambiente marino dinámico y por los instrumentos que se estén utilizando. Este artículo aborda estos errores y las especificaciones de la inspección de la calidad y los procesos aplicados a las mediciones de los sistemas multihaz. Se identifican entonces los planes de control de calidad que cubren la recogida de datos de sondajes multihaz y las etapas del procesado, incluyendo la producción previa, la evaluación, la verificación y la aceptación final de los datos.

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1. Introduction

Marine topographic data is an important component in any model (or similar abstraction) being developed for the marine environment. The majority of this information is obtained by ship-borne measurements using single beam echo sounding (SBES) and multibeam echo sounding (MBES) technologies. Due to the improved seafloor coverage, efficiency and precision of MBES, this technology is now widely employed in the surveying of important port and channel routes and for detecting underwater obstructions (LI JB et al., 1999; ZHAO JH et al., 2008). The nominal precision and resolution can be in the order of centimetres for new generation MBES technologies and errors caused by the sounding system, in comparison to other factors, can have little influence on the quality of the sounding data. Therefore, these other factors need to be considered to evaluate the impact on products generated from MBES data collection. These factors include field organization and the standardization of data processing activities including comprehensive product inspection.

An analysis of multibeam sounding data collected in recent years by different survey units indicates that the quality of products are mainly affected by the following factors:

- dynamic environment factors (wind, air pressure, temperature, salinity, density, wave, tide and current);
- diligence of field work practices; and
- data processing.

A number of gross and systematic errors were found to exist in the products and these affect the value of the MBES data collection and the application of the products. In addition, quality problems can be due to system hardware configuration and the improper maintenance of the equipment. These can be difficult to understand but must be given the appropriate attention by the hydrographic system engineers responsible for maintaining the equipment.

Therefore, rigorous quality control and assurance processes must be applied during the data acquisition, data processing and product generation steps to eliminate each type of gross and/or systematic error. Furthermore, the quality control schemes must be described with enough detail and rigor to assure a third party of the data quality. These schemes must address the operation of the equipment to ensure system characteristics and capabilities are comprehensive, have wide applicability and meet the expected level of operation.

2. Analysis of MBES Error Sources

2.1 Gross Errors

A MBES survey operation typically combines a number of systems including a transducer, positioning system, surface sound velocity probe, Position and Orientation System (POS), sound velocity profiler, tide gauge and other auxiliary systems. Abnormal data will inevitably exist in the collected sounding data e.g. position, attitude, sound velocity, tide, depth. These data abnormalities are caused by equipment noise, the complex and dynamic environment and the sonar parameter complexities. During processing operations, if these abnormal data are not correctly identified and dealt with to correct the issue, isolated depth and position abnormalities will exist in the sounding data. This kind of gross error is also named a pseudo signal. Hence, a false picture of the marine topography will be presented by the gross errors and these must be determined and eliminated.

When analyzing MBES data, the common processing methods include artificial translation, trend surface filters, robust estimation and the Combined Uncertainty Bathymetry Estimator (CUBE) algorithm (YANG FL et al., 2004; LI MS et al., 2007; HUANG CH et al., 2010; HUANG XY et al., 2010; HUANG MT et al., 2011). An example of bathymetric data being analyzed and cleaned using the CUBE algorithm method is shown in Figure.1. The gross errors that exist in Figure 1(a) have been eliminated by the application of the CUBE algorithm in Figure 1(b). A more faithful and accurate representation of the marine topography can be depicted after eliminating the errors.

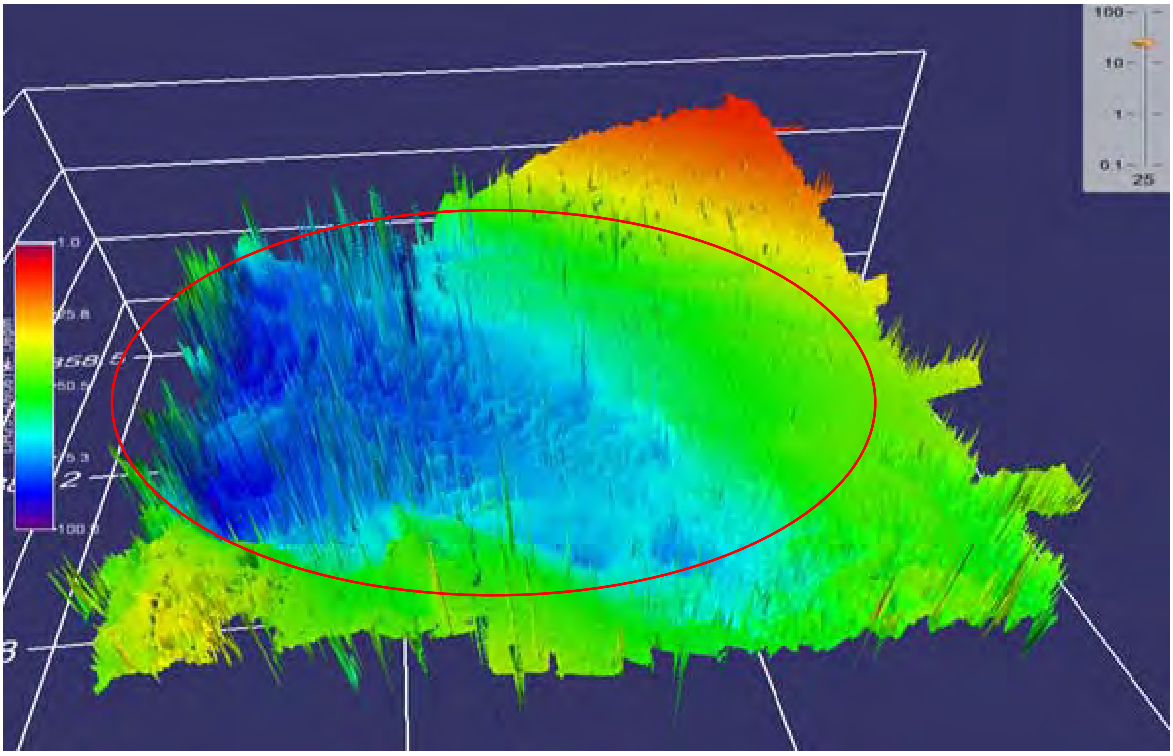


Figure 1(a): *Before filtering*

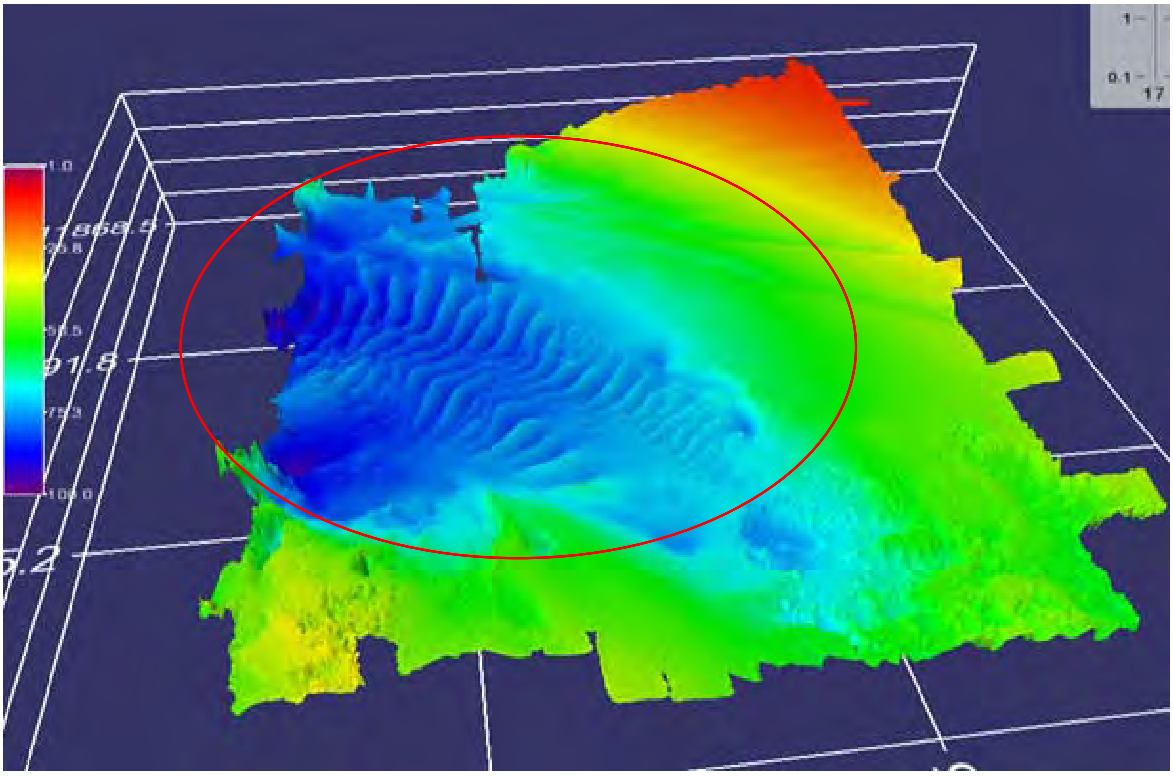


Figure 1(b): *After Filtering*

Figure 1*: A typical gross error and filtering effect – (a) Before Filter (b) After Filter*

2.2 Systematic Errors

Based on the MBES equipment configuration, systematic errors can occur in position, attitude, sound velocity, tide and sounding system measurements. Furthermore, these errors affect position and depth data. Systematic errors need to be qualitatively and quantitatively analyzed.

The systematic errors in position data can be detected and calibrated by the fixed deviation in the plane position. This is obtained by the stability test of the positioning system. Furthermore, where the positioning signal is lost by an equipment malfunction and poor environment, the sampling interval of the position information can be considered to be reasonable and accurate by using interpolation and extrapolation measures.

The systematic errors caused by poor calibration of the transducer installation results in the undulation of "V" phenomena of the marine topography. This will be visible along the track showing pitch, roll and heave errors as shown in ***Figure 2***. Although the transducer installation errors can be corrected, systematic errors can also be caused by environment conditions such as wind, wave and current. Meanwhile the systematic errors will result in a slow linear change during the capture process. Hence, these errors must be corrected in post processing.

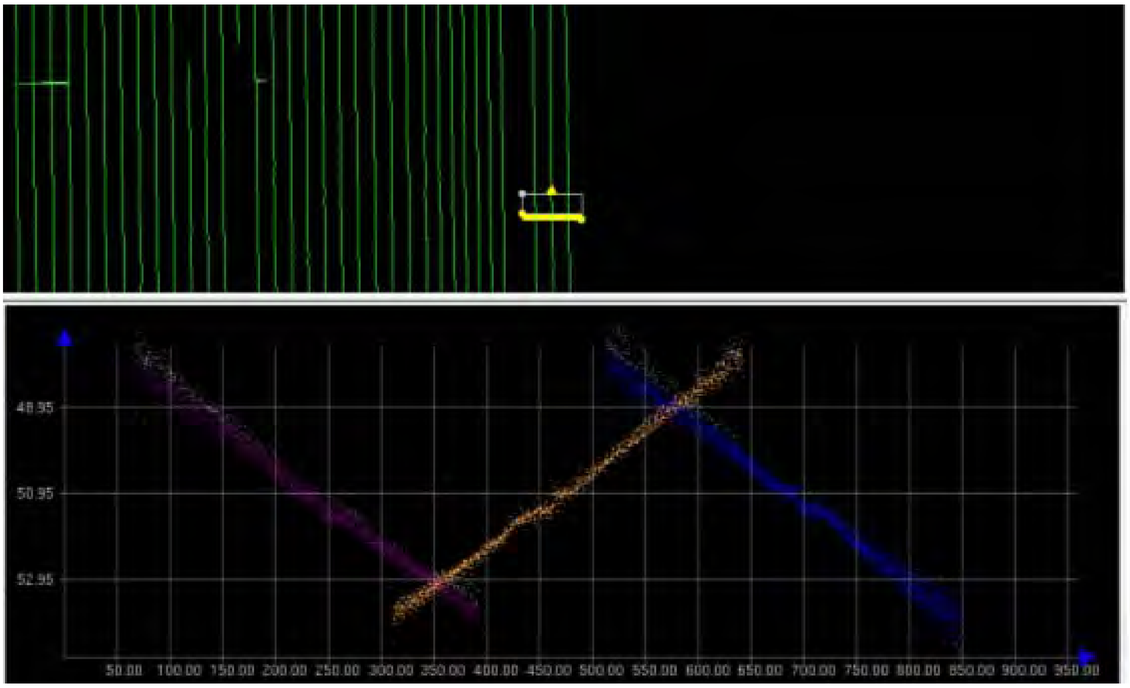


Figure 2: *The systematic error of "V" phenomena in sounding swath*

Systematic errors from an incorrect attitude correction occur for two primary reasons:

- The instability of the transducer installation - the real attitude will not be in accordance with the observed attitude of the POS. There will be a high frequency resonance of the transducer and survey platform, which is also influenced by the environment factors such as wind, wave and current (YANG FL et al., 2009). If this influence can not be reduced, regular undulations will be found in the sounding data.
- Due to possible un-synchronized GPS 1PPS signals, inconsistent time lags can exist between the POS and transducer, so the attitude data and sounding data will not be synchronized and a "butterfly" phenomena will be observed in the swath as shown in ***Figure 3***.

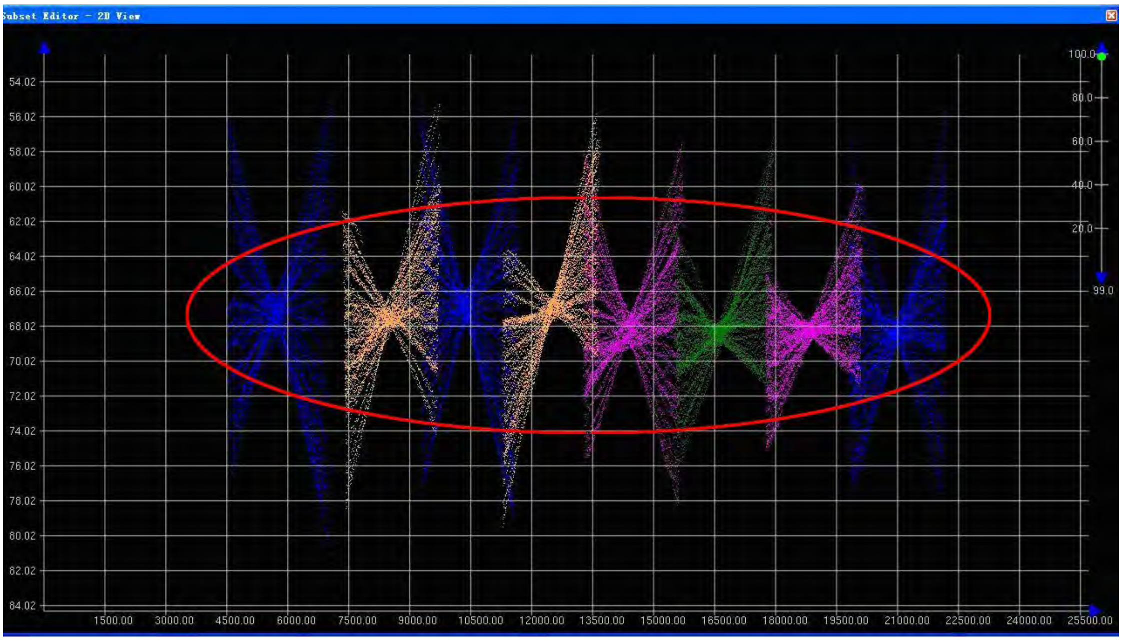


Figure 3: *The systematic error of "butterfly" phenomena in sounding swath*

The accuracy of the marine topography will also be affected by any inaccuracy in the sound velocity profiler. The "smiling face" or "weeping face" phenomena will be visible, especially for the fringe beams, shown in ***Figure 4.*** Research on the influence of the sound velocity error and the sound ray tracing theory indicates these systematic errors can be removed by adjusting the sound ray value step by step. In addition, the surface sound velocity probe must be deployed during the actual time of sounding capture to ensure the accuracy and reliability of the sounding data (LIU SX et al., 2009, 2011; DONG QL et al., 2011).

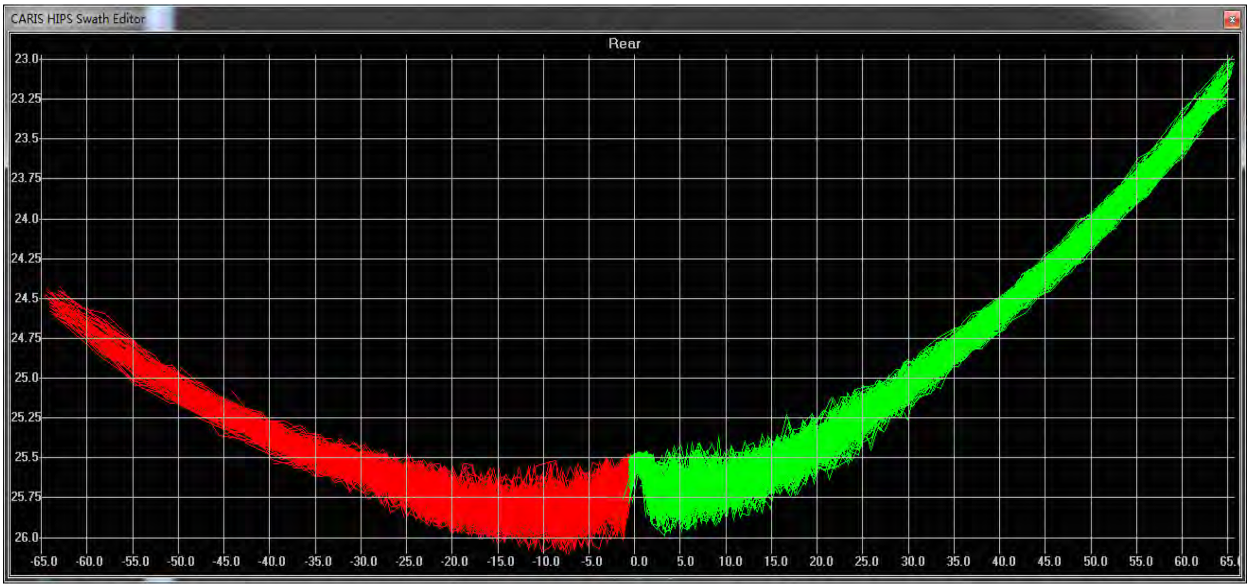


Figure 4（a）: "smiling face"

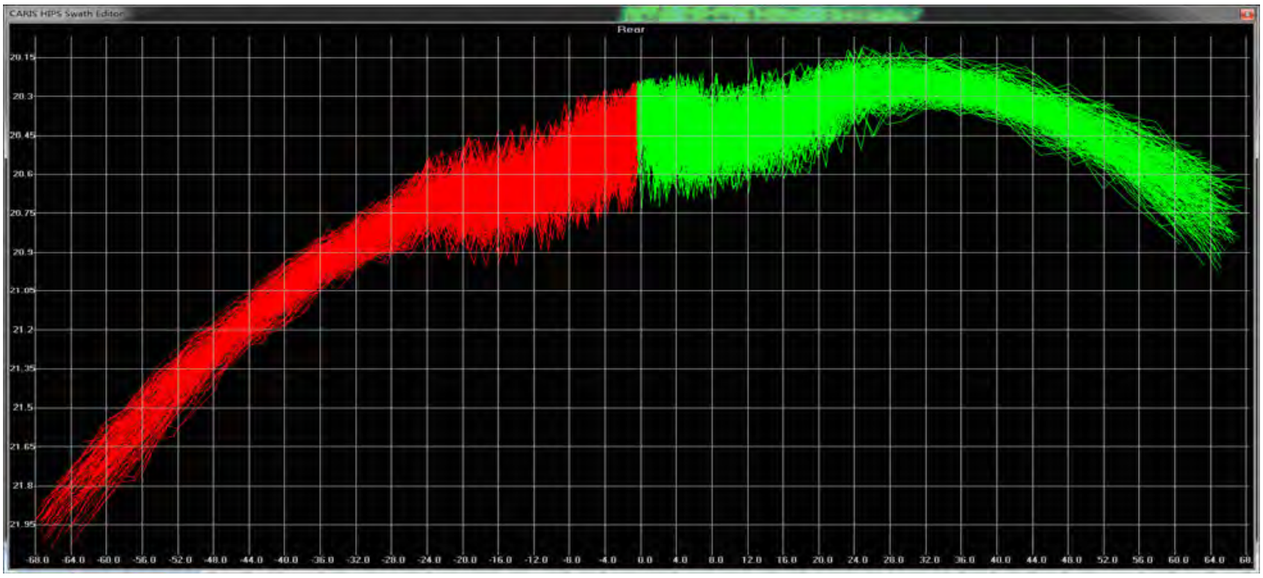


Figure 4（b）："weeping face"

Figure 4: *The systematic error of (a) "smiling face" or (b) "weeping face" phenomena in a sounding swath due to the inaccuracy in the sound speed profiler.*

The effect of systematic errors due to incomplete tide adjustments are shown in ***Figure 5***. These errors can be removed by improving the tide gauge station distribution, use of tidal predictions, non-tide GPS mode and tide calculation based on the residual water level collocation (OUYANG YYZ et al., 2005; BAO JY et al., 2006; LU XP et al., 2008; HUANG CH et al., 2011, 2013).

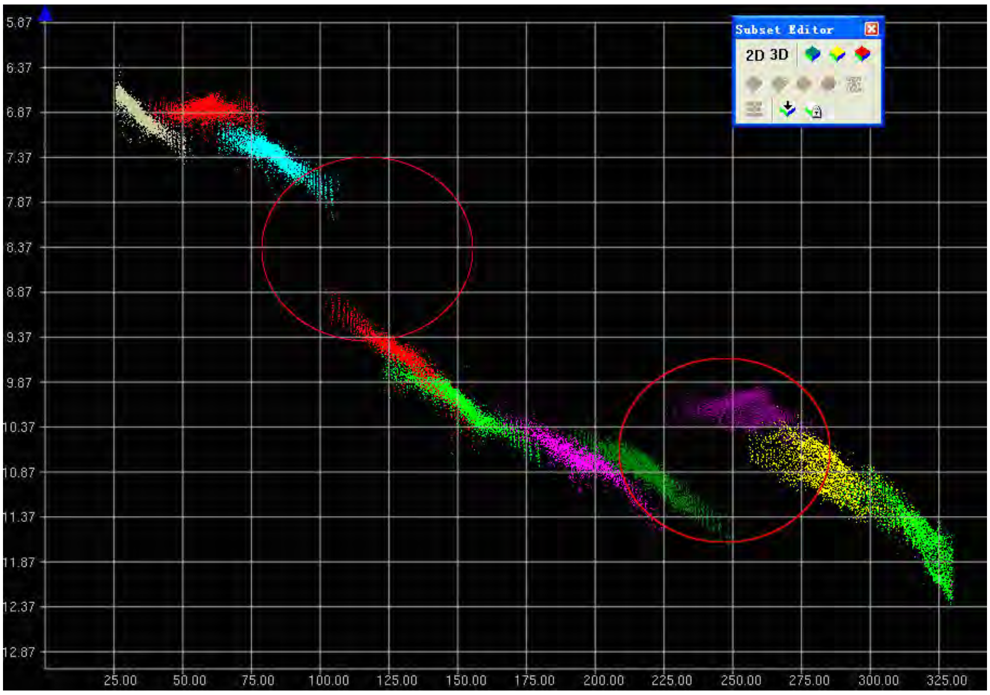


Figure 5: *The stitching faults between the swaths*

During multibeam sounding processing, tide corrections, sound velocity corrections and attitude corrections are applied to the sounding swathes. During this process, a "concave-convex" phenomenon can appear. These are more than "smiling" and "weeping" phenomenon and these errors are considered residual systematic errors relating to the instruments. (ZHAO JH et al., 2013).

Any malfunction or improper maintenance of the transducer will manifest themselves as other data quality problems. In ***Figures 6*** and ***7***, a systematic error is observed that illustrates the “W” phenomena and can be found in the center beam of certain swaths. Once identified, such a transducer hardware malfunction must be rectified as soon as possible.

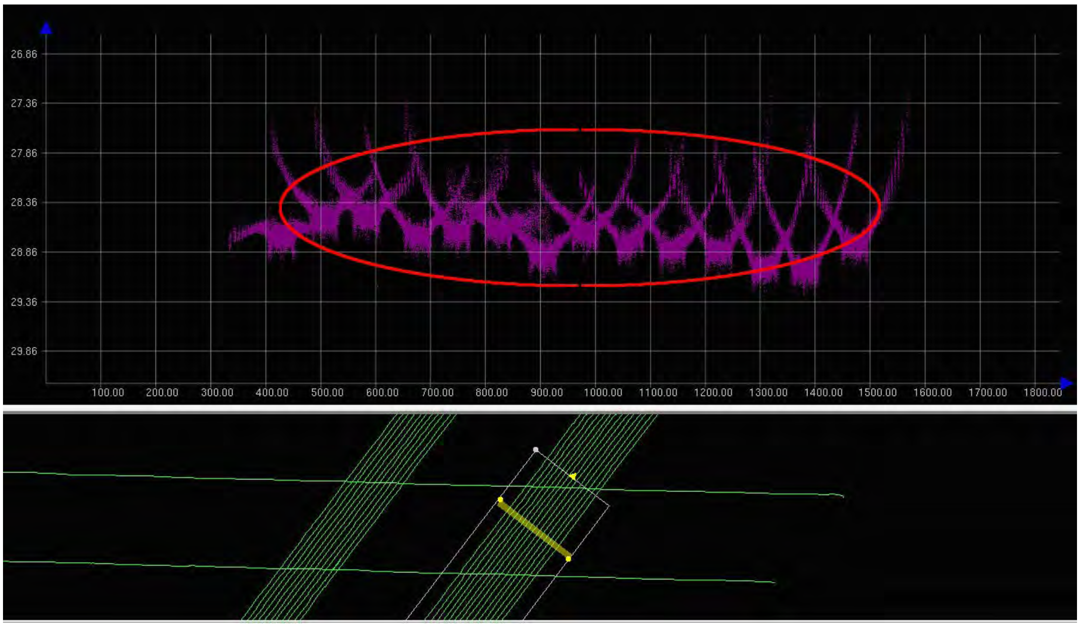
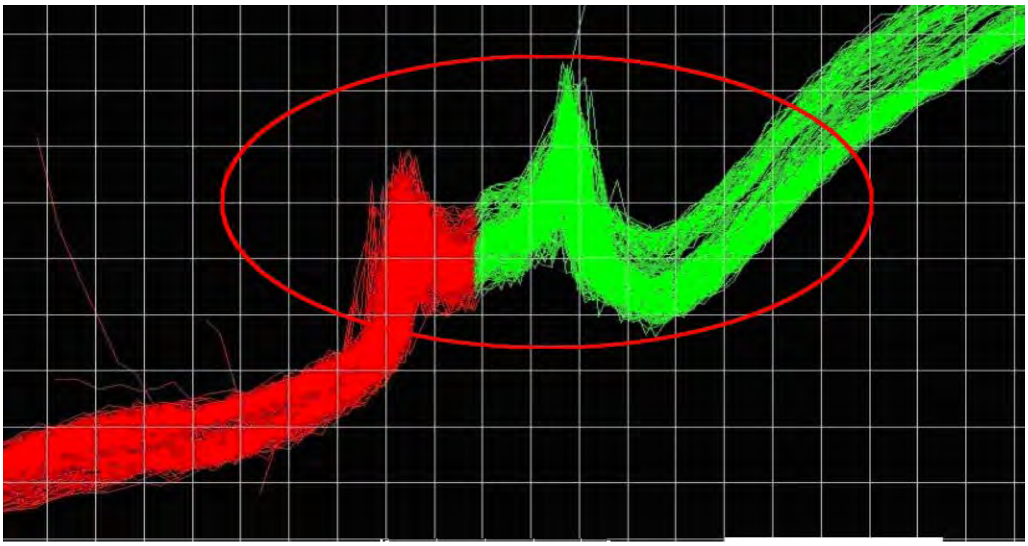


Figure 6: *The residual systematic errors in sounding swath*



7（a）Swath edition mode

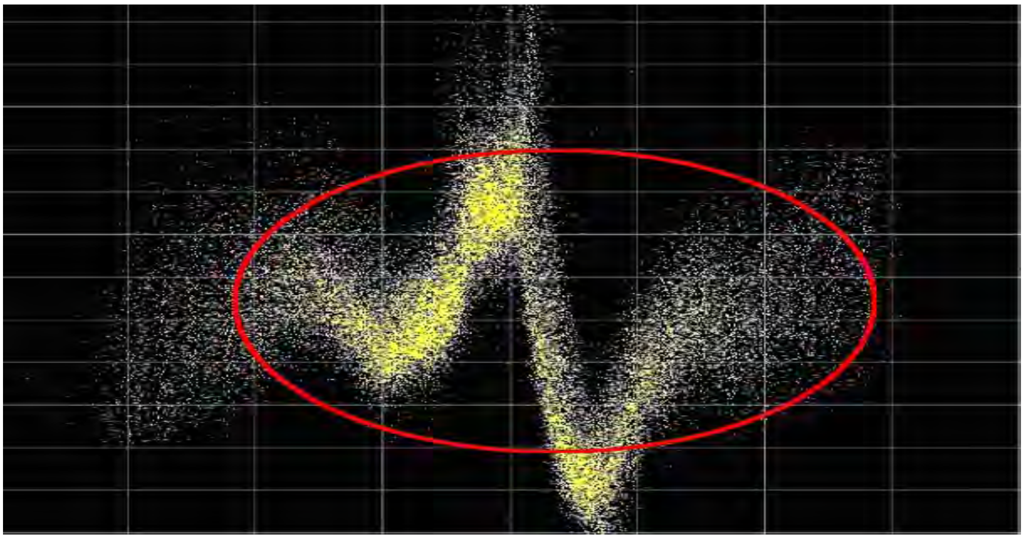


Figure 7（b）： Subset edition mode

Figure 7: *The "W" phenomena caused by the hardware problem in sounding swath (a) Swath edition mode and (b) Subset edition mode*

Internal ocean waves can affect sounding quality as shown in ***Figure 8***. The sound velocity is expected to be steady through stratified distributions in the water column. The presence of internal ocean waves results in the supposed horizontal layer containing peaks and troughs. The sea bottom will be distorted and the accuracy of the multibeam sounding will be affected (LIU SX et al., 2012). Furthermore, this kind of systematic error cannot be effectively reduced.

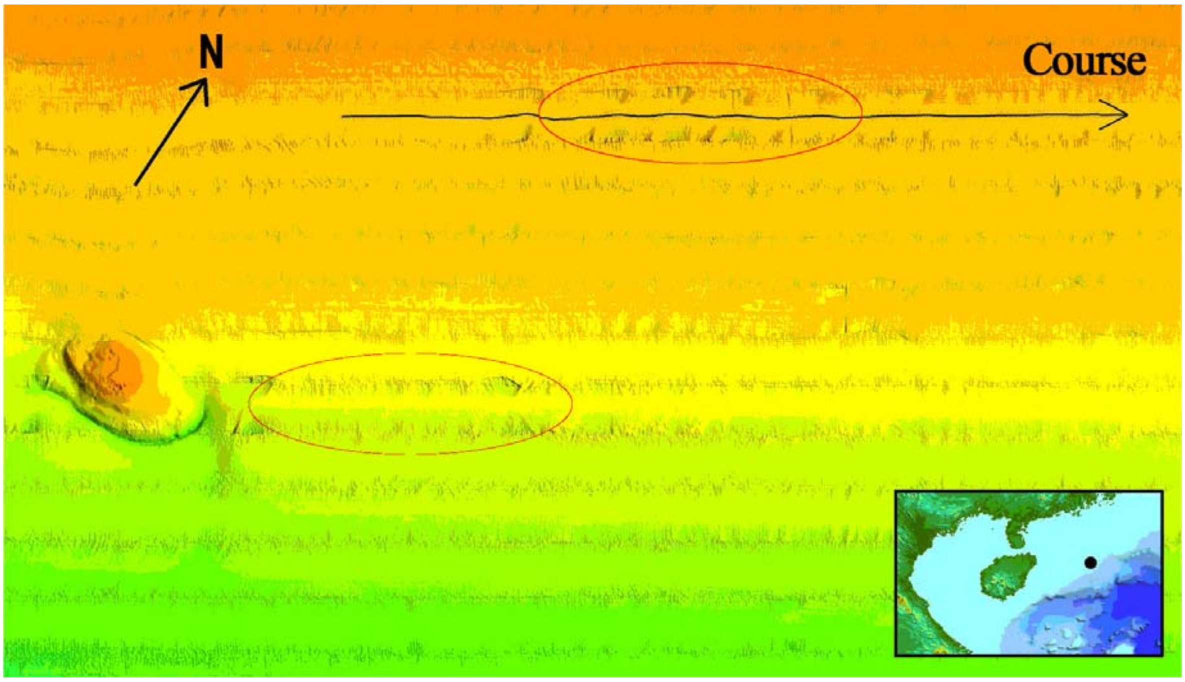


Figure 8: *The distortion of smooth sea bottom caused by ocean internal waves*

3. Quality Assessment of MBES Products

3.1 Quality Assessment Indexes

Similar to single beam sounding products, there are two quality assessment indexes for multibeam sounding products (GB, 1998 and CHB, 2011):

(i) the sounding limit error in different depths; and

(ii) the differences in depths between the main lines and cross-over check lines.

The precision of the sounding system is reflected by the sounding limit error shown in ***Table 1***. The accuracy of the survey data are reflected by the allowable depth differences of the cross points as shown in ***Table 2***. The survey specifications require the comparison between cross point depths to be less than the 15% of total calculation point depths.

Table 1: *The sounding limit error in different depths*

Depths（ z ）(m)	The sounding limit error（2σ）(m)
0< z ≤20	±0.3
20< z ≤30	±0.4
30< z ≤50	±0.5
50< z ≤100	±1.0
z >100	± z ×2%

Table 2: *The allowable difference in the comparison between cross points*

Depths（ z ）(m)	Allowable difference in the cross point comparison (m)
0< z ≤20	0.5
20< z ≤30	0.6
30< z ≤50	0.7
50< z ≤100	1.5
z >100	± z ×3%

For single beam soundings and according to the distribution characteristics of the sounding lines and sounding points, the surveying precision can be mainly evaluated by the correlative indices in Table 2. Therefore, the integrated dynamic effects of the marine environment are concealed in the indexes, as well as the effects of draft, ground swell, sounding velocity and the tide. In other words, the accuracy of each correction can not be reflected by the differences of the cross points.

For multibeam sounding collection, the sounding data provides full coverage of the seafloor. Apart from using the above two indexes, the surveying precision can also be evaluated through each step of the surveying operation including data acquisition, processing and product making. The refraction of the sound ray can be checked during the swath editing of the single survey lines. Likewise, other data can be independently evaluated using the neighboring swaths, observing stitching faults and the “concave-convex” phenomenon caused by the integrated dynamic effects of the marine environment (such as the draft, sound velocity, ground swell and the tide) as well as the calibration and the installation errors in the system as shown in Figures 1 to 8. These gross and systematic errors can be detected during the acceptance inspections of the multibeam sounding data. Therefore the single ping, single swath and neighboring swaths and sounding surface have been included in the acceptance inspection and quality assessment of multibeam sounding.

3.2 Acceptance Inspection and Assessment

Based on the analysis of the sources and impacts of gross and systematic errors in multibeam sounding products, a quality inspection scheme has been developed for data acquisition, processing, product making, inspection and assessment processes. During the inspection of the multibeam sounding products, gross and systematic errors (seen in ***Figures 1 to 8***) are identified. A full seafloor coverage inspection of the multibeam sounding capture and the variation in the marine topography is also undertaken.

When the "map sheet" area is selected as the basic unit for inspection, eleven primary Quality Elements are tested. Each Element has several Inspection Items leading to 120 items being checked in total. The Quality Elements and the more important Inspection Items are listed in ***Table 3***.

Table 3: *The Quality Elements and Inspection Items of multibeam sounding products*

Quality Element	Inspection Item
Positioning system	1. The accuracy of the stability test of the system and the results
Sounding system	1. The accuracy of the stability test of the system and the results
Auxiliary systems	1. Test of surface sound velocity probe 2. Test of POS 3. Test of sound velocity profiler 4. Test of current meter
System Calibration	1. The spatial position accuracy of the installation of the positioning system and sounding system 2. The calibrations and results of the positioning system and sounding system 3. The quality, precision and rigor of the calibrations of the transducer installation
Tide control	1. The rationale of the control range of the tide gauge 2. The accuracy of the datum 3. The accuracy of observed data 4. The rationale of the observed time period 5. The rationale of the tidal data editing 6. The rationale of the tide correction
Data acquisition	1. The overall quality of the transducer 2. The validity of the sound velocity at the surface 3. The rationale of the acquisition time and space density of the sound velocity profile 4. The validity of the attitude survey, such as Pitch, Roll and Yaw 5. The valid coverage of the swaths (meet the requirements of the full coverage) 6. The detection of the special depths (without missing measure)
Data processing	1. The gross error of the attitude have been completely deleted or not 2. The gross error of the sound velocity have been completely deleted or not 3. The gross error of the position have been completely deleted or not 4. The integration of the position, attitude, sound velocity and tide data being successful or not 5. The gross error of the depth has been deleted or not 6. The accuracy and rationality of the manual and auto editing of the depths 7. The selection of the cross points and the calculation of the differences are reasonable

Quality Element	Inspection Item
Map drawing	1. The method, interval and output of the data thinning are reasonable 2. The plane, height, depth and tide datum are correct 3. The depth interval on the chart are reasonable 4. The selection of the special depth are reasonable 5. The gross errors in 3D bathymetric map 6. The systematic errors in 3D bathymetric map 7. The consistency with the known depth map sheet

After completion of checks on all of the Quality Elements and Inspection Items, faults are sorted by quality element and graded by inspection element into:

- Serious Fault (Sort A): represents a fault which can result in the disqualification and rejection of the product for further use;
- Heavier Fault (Sort B): represents a fault which can influence the normal use of the products in a certain situation; or
- General Fault (Sort C): represents a fault which only has a slight influence on the normal use of the products.

The outcome of the assessment of the Quality Elements and Inspection Items are categorized into corresponding Fault Sorts (***Table 4***). According to the standards listed in ***Table 4***, the quality value *S* of the multibeam sounding system can be calculated by the following formula (1).

$$S = 100 - 41a_1 - k(6a_2+a_3) \quad (1)$$

Where:

a_1, a_2, a_3 is the number of the Sort A, Sort B, and Sort C faults

k is the adjust parameter: $k=2$ for class I, $k=1$ for class II, $k=0.5$ for class III.

Table 4: *The Fault Sort (A, B, and C) of multibeam sounding products*

Quality Elements to be tested	Sort A	Sort B	Sort C
Positioning system	1. The positioning system has not been tested, the products are invalid, which can not be remedied. 2. The test results are unqualified, the products are invalid, which can not be remedied.	1. The test items are incomplete 2. The time of the test does not conform to the ordinary demands	1. The test precision is near to the tolerance
Sounding system	1. The sounding system has not been tested, the products are invalid, which can not be remedied. 2. The test results are unqualified, the products are invalid, which can not be remedied.	1. The test items are incomplete 2. The time of the test does not conform to the ordinary demands	1. The test precision is near to the tolerance
Auxiliary systems	1. Test of surface sounding velocity meter, POS system, sounding velocity profiler and automatic tide gauge have not been tested, the products are invalid, which can not be remedied.	1. More than 2 types of auxiliary system have not been tested, but has little influence to the products	1. Only one type of auxiliary system has not been tested, and has little influence to the products
System Calibration	1. Calibration of transducer installation errors have not been tested, the products are invalid, and can not be remedied. 2. Calibration of position installation errors of the systems have not been tested, the products are invalid, which can not be remedied.	1. Errors are found due to the irregular vibration in the instability of the transducer installation. 2. The transducer installation errors have not been calibrated 3. Calibration of transducer installation errors is incomplete, the systematic errors are introduced and observed between the swaths	1. Calibration of transducer installation errors is incorrect, the systematic errors are introduced and observed between the swaths, but the sounding precision has not exceeded the tolerance 2. Errors due to the irregular vibration has been observed due to the instability in the transducer installation, but the sounding precision has not exceeded the tolerance
Tide control	1. The vertical datum relation is faulty and the products are invalid, which can not be remedied.	1. The tidal correction is incomplete, and stitching faults exist between the swaths, and the sounding precision have exceed to the tolerance	1. The tidal correction is incomplete, and stitching faults exist between the swaths

Quality Elements to be tested	Sort A	Sort B	Sort C
Data acquisition	1. The datum is faulty and the products are invalid, which can not be remedied. 2. The surface sound velocity meter has been damaged	1. The stitching faults exceed the tolerance in more than 10% of the swaths, and the products are invalid, which can not be remedied 2. The sea bottom has not been fully covered by the effective beam points, which can result in missing an important navigation obstruction.	1. The other faults are within tolerance.
Data processing	1. The profile of the sound velocity does not meet requirements, which can reduce the inconsistent with the real marine topography in more than 20% of the swaths, which can not be remedied 2. The stitching faults have exceed the tolerance, which can not be remedied 3. The systematic errors exist in more than 20% of the swaths, which can not be remedied 4. The artificial sound ray correction must be applied, but has not been performed. 5. The internal accuracy of the cross points exceed the tolerance	1. The attitude correction is incomplete, which can reduce the consistency with the real marine topography in more than 10% of the swaths, which can not be remedied 2. The profile of the sound velocity does not accord with the requirements, which can reduce the consistency with the real marine topography in more than 10% of the swaths, which can not be remedied 3. The artificial sound ray correction must be effectively applied, which can reduce the consistency with the real marine topography in more than 20% of the swaths, which can not be remedied 4. The stitching faults or systematic errors exist in more than 10% of the swaths, which can not be remedied	1. The edit of the positioning data is incomplete 2. The sound velocity correction is incomplete, which impacts the systematic errors in specific swaths 3. The attitude correction is incomplete, which impacts the systematic errors in specific swaths 4. The edit of the sounding depth is incomplete, which reduce the spurious signal
Map drawing	1. The systematic errors exist in neighboring map sheets, which can not be remedied 2. The systematic errors exist in 3D marine topography in large area, which have exceed the tolerance 3. The spurious signal exist in 3D marine topography in large areas, which exceed the tolerance	1. The error impact on the special depth have exceed more than 10% 2. The systematic errors exist in 3D marine topography in some areas, which exceed the tolerance 3. The spurious signal exist in 3D marine topography in some areas, which exceed the tolerance	1. The error impact on the special depth are under 10% 2. The systematic errors exist in 3D marine topography which exceed the tolerance 3. The spurious signal exist in 3D marine topography in some areas, which exceed the tolerance

4. Conclusion and Recommendations

Differences exist between multibeam and single beam sounding systems during the data acquisition, processing and product generation processes. The nature and extent of gross and systematic errors also differ between these systems. For single beam sounding, resolving gross and systematic errors are more difficult. However, if each kind of quality issue can be resolved for multibeam sounding systems and processes, the quality problems in single beam sounding will be resolved accordingly. Meanwhile, where gross and systematic errors can been adequately recognized in the multibeam systems and processing, systematic problems can be resolved in multibeam sounding output data. The results of this paper provide reference to the system and environmental phenomena and the required inspection of the multibeam sounding products.

Multibeam sounding technology and methodologies will continue to be the mainstay of bathymetric surveying capability in the future, so the software and hardware technologies and processing capabilities for these sounding systems must continually improve. Meanwhile the correlative work processes and data inspections must be rigorously performed during surveying to identify and resolve data quality problems. By following a rigorous approach towards system installation, calibration, processing and inspection, it has been found to achieve twice the product output with half the effort.

5. Acknowledgements

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Notes

AIRBORNE LIDAR BATHYMETRY
By the Japan Hydrographic and Oceanographic Department

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Abstract

The Hydrographic and Oceanographic Department of the Japan Coast Guard (JHOD) has been conducting airborne lidar bathymetry (ALB) for 14 years. Owing to ALB's survey efficiency and high resolution, JHOD has applied the technique to various purposes such as, to say nothing of charting, recovery of tsunami-stricken harbors, surveillance for security, and research into volcanic activity. This note briefly describes the operation of the JHOD lidar system and outlines our typical outcomes.

1. Introduction

The Japan Coast Guard (JCG), an external agency of the Ministry of Land, Infrastructure, Transport and Tourism, is responsible for maritime safety and security in Japanese waters. The Hydrographic and Oceanographic Department of the JCG (JHOD) is mandated to publish nautical charts around Japan to ensure navigational safety for mariners. In relation to the hydrographic survey for charting, JHOD provides a variety of information for minimizing damage caused by natural disasters, such as earthquakes and tsunamis, and by maritime disasters, such as oil spills, caused by accidents at sea.

To support detailed bathymetry, an efficient survey technique with sufficient sounding density is required for shallow waters. Airborne lidar bathymetry (ALB) can rapidly survey a broad area of shallow waters even where there are rocks or coral reefs. JHOD introduced ALB in 2003 as a technique to complement multibeam echo-sounding, and overcame various problems with ALB in its initial stages over five years before it was put into practical operation.

2. Operation of JHOD Lidar System

We have been operating two lidar systems manufactured by Teledyne Optech Inc.: Scanning Hydrographic Operational Airborne Laser Survey (SHOALS) 1000 (***Figure 1***) since 2003, and Coastal Zone Mapping and Imaging Lidar (CZMIL) (***Figure 2***) since 2013. ***Table 1*** lists the main specifications of SHOALS and CZMIL. SHOALS scans the seafloor in a circular arc pattern, whereas CZMIL uses a full circular pattern at a measurement frequency 10 times higher (Kawai, 2015). CZMIL's field of view for each laser shot is narrower, especially for land topography and shallow water (shallower than 15–20 m) (***Figure 3***). Thus, CZMIL has improved the point density of deep-water bathymetry 6-fold and that of shallow-water bathymetry and land topography 51-fold (***Figure 3***). ***Figure 4*** depicts the common principles of lidar operation for the both systems.

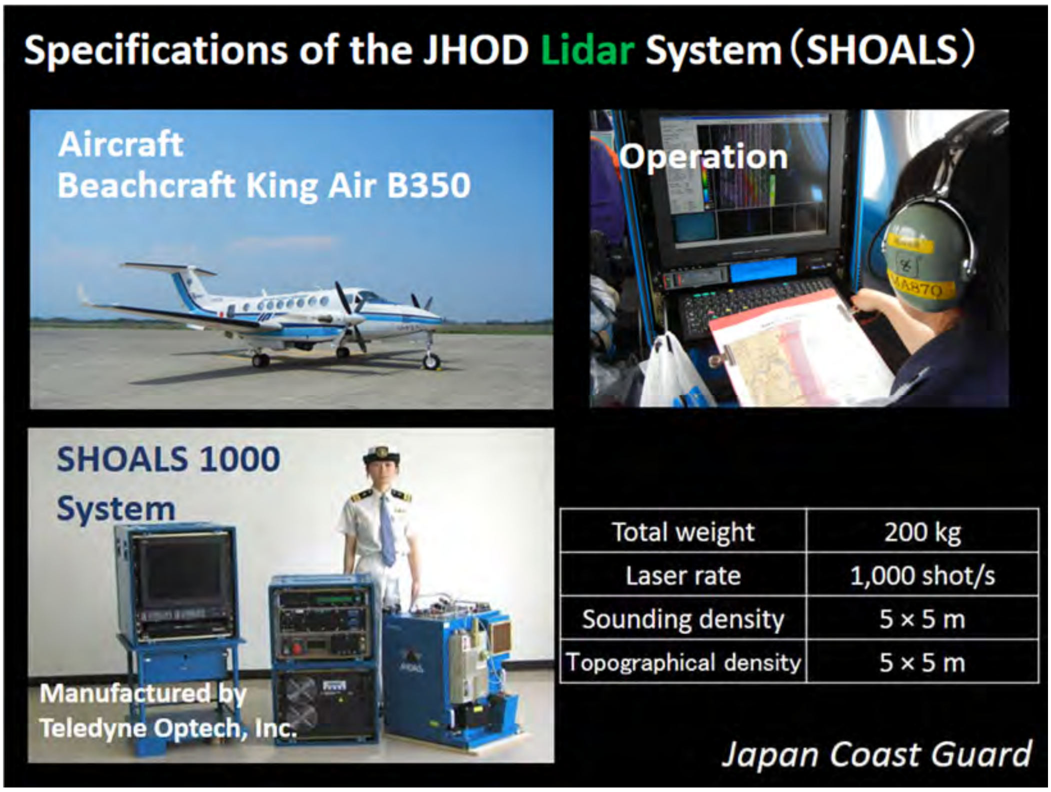

Figure. 1: *Main specifications of the JHOD lidar system.*

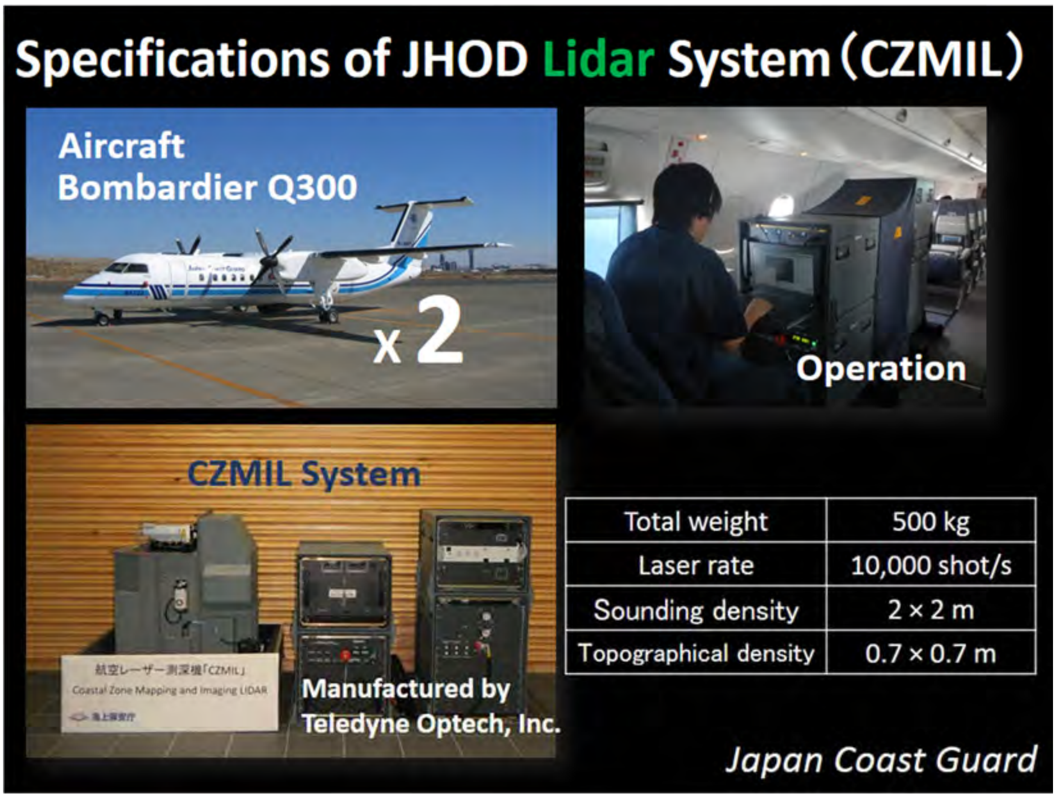

Figure 2: *Main specifications of the JHOD lidar system.*

Table 1: *Comparison of the specifications of SHOALS and CZMIL (based on Kawai, 2015).*

	SHOALS	CZMIL
Total weight	200kg	500kg
Aircraft	Beechcraft King Air 350	Bombardier DHC-8-Q300
Laser rate	1,000 shot/s	10,000 shot/s
Receiver	Refracting telescope (10 cm diameter)	Reflecting telescope (20 cm diameter)
Scan pattern	Circular arc	Circle
Sounding Density	5 x 5 m	2 x 2 m
Topographical density	5 x 5 m	0.7 x 0.7 m
Depth range	2 x Secchi depth	2 x Secchi depth
Swath width	230 m	298 m
Data volume	1.5 GB/h	350 GB/h

(based on Kawai, 2015)

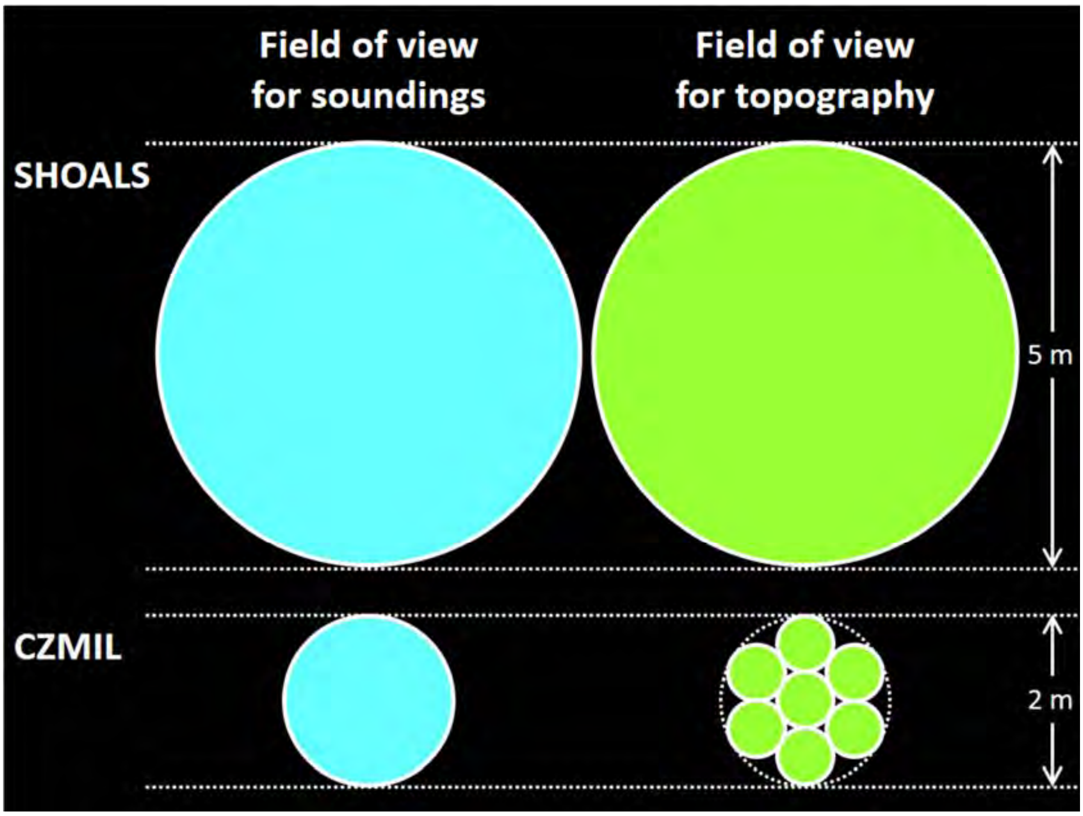

Figure 3: *Comparison of the fields of view of SHOALS and CZMIL.*

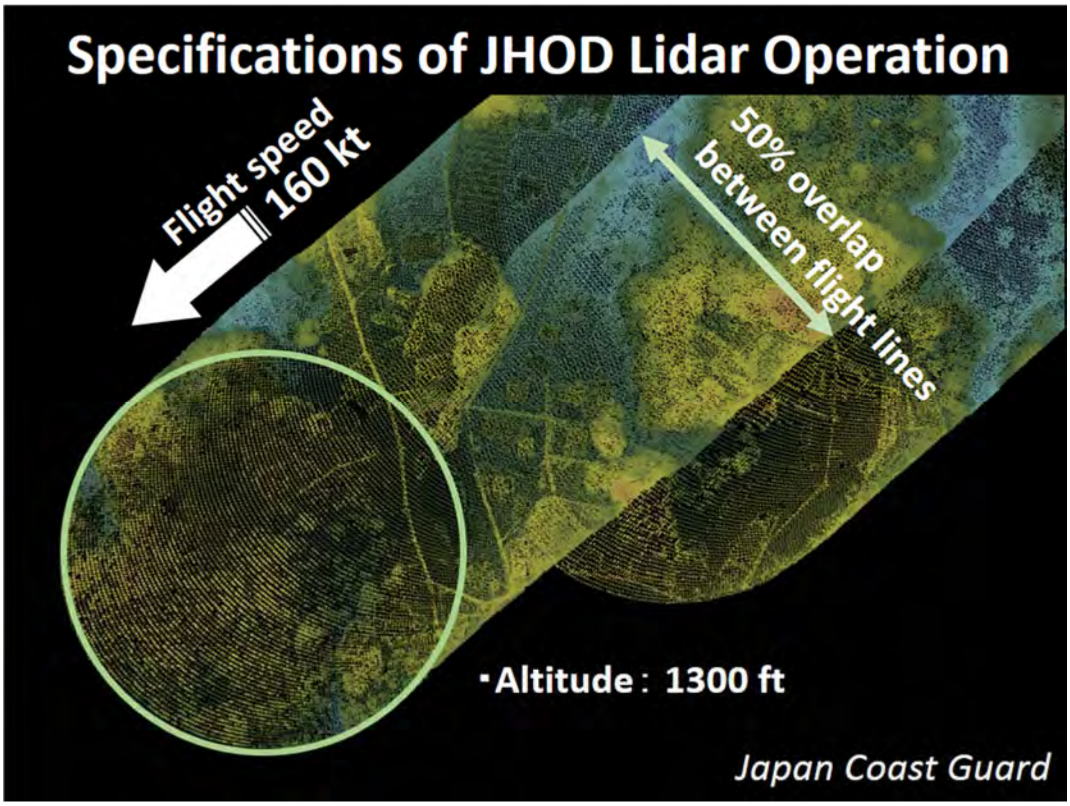

Figure 4: *Typical specifications of JHOD lidar operation.*

The following sections give an overview some examples of the JHOD's ALB survey. All of the figures shown in the following sections are preliminary results after simple noise reduction processing.

3. Supporting the Reconstruction of Disaster Areas Affected by the "2011 off the Pacific coast of Tohoku Earthquake"

On 11 March, 2011, the northeastern part of the main island of Japan (Tohoku region), was struck by a megathrust earthquake called "the 2011 off the Pacific coast of Tohoku Earthquake". This was the largest in Japan's observation history, as well as the fourth-largest in the world since 1900, according to the records of the United States Geological Survey. In response, JHOD conducted ALB immediately and extensively to help remove obstacles in affected harbors to facilitate the transport of relief supplies to the disaster areas. ***Figure 5*** shows part of the survey data from Miyako Bay obtained by SHOALS. Because this area is surrounded by mountains around 600 m high, aircraft cannot maintain an adequate survey line under normal operation conditions with an imposed bank restriction. For reliable reception of GNSS signals in a survey flight, the aircraft is allowed to turn with a bank angle within 20°, which is shallower than the constraint of the aircraft's turning performance. Although it increases risk of failure for the lidar system, we eased the bank restriction in this survey flight. Positioning accuracy was later verified to be 0.1 m or less, which is sufficient for a hydrographic survey. In the Tohoku region, laser penetration is usually shallow due to the abundance of plankton in the water. In addition, the inflow of turbid river water could decrease the transparency of the water in the bay. After the disaster, it was a concern that suspended material and spilled oil carried from the devastated coast into the bay could prevent laser penetration. Fortunately, the water depth was measured down to as deep as 15 m in most of the survey area, so that we obtained seamless topography on land and the seabed, including the destroyed breakwaters.

One possible factor for this result could be the small inflow of river water into the bay; this area had had no rain for two weeks before the survey flight (Ono and Shibata, 2012). The bathymetric and topographic data were used for revising the nautical charts, reconstruction planning of the destroyed harbors, tsunami simulations, and coastal erosion control.

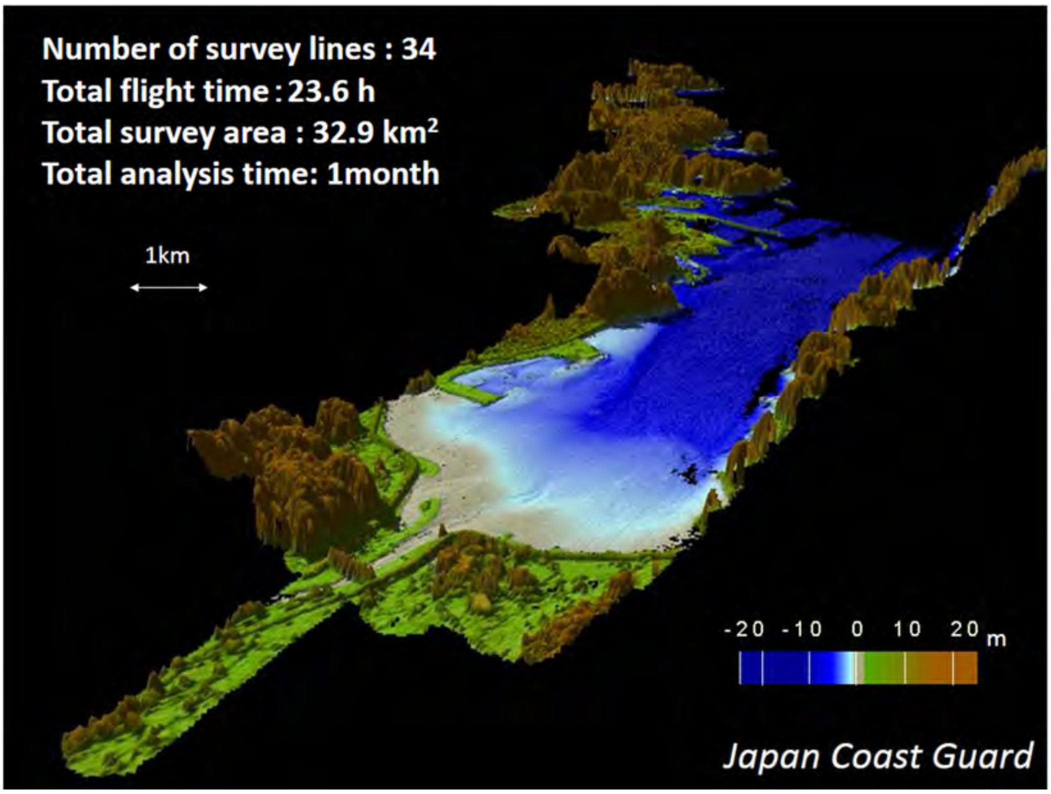

Figure 5: *Survey data at Miyako Bay obtained by SHOALS. The technique reproduces seamless topography on land and the seabed, including destroyed breakwaters.*

4. Security for the Venue of the G7 Ise-Shima Summit 2016

Japan hosted the G7 Ise-Shima Summit in Mie Prefecture, central Japan, on 26 and 27 May, 2016. The Ise-Shima area is a national park that boasts the beautiful terrain of the Ria Coast on the Pacific Ocean. As part of the safety measures for the summit, a JCG fleet secured the waters around the venue. We provided the Coast Guard offices and patrol vessels with information, such as special nautical charts tailored to fit the needs of the patrols on the waters. We conducted ALB and multibeam echosounding using several survey vessels belonging to the main JHOD office and the regional headquarters. ***Figure 6*** shows part of the survey results, at Ago Bay. Because the water transparency is excellent in this area, ALB complements the lack of multibeam survey data where a number of small islands, inlets, reefs, and other topographic features prevent survey boats from safe, efficient survey work.

The survey results were processed into an electronic navigational chart, which was viewable on tablets. The chart enhanced the patrol capability of the JCG fleet, including a small boat that cannot carry an Electronic Chart Display and Information System. JHOD provided the coastal municipalities with the survey results to help with their coastal zone management.

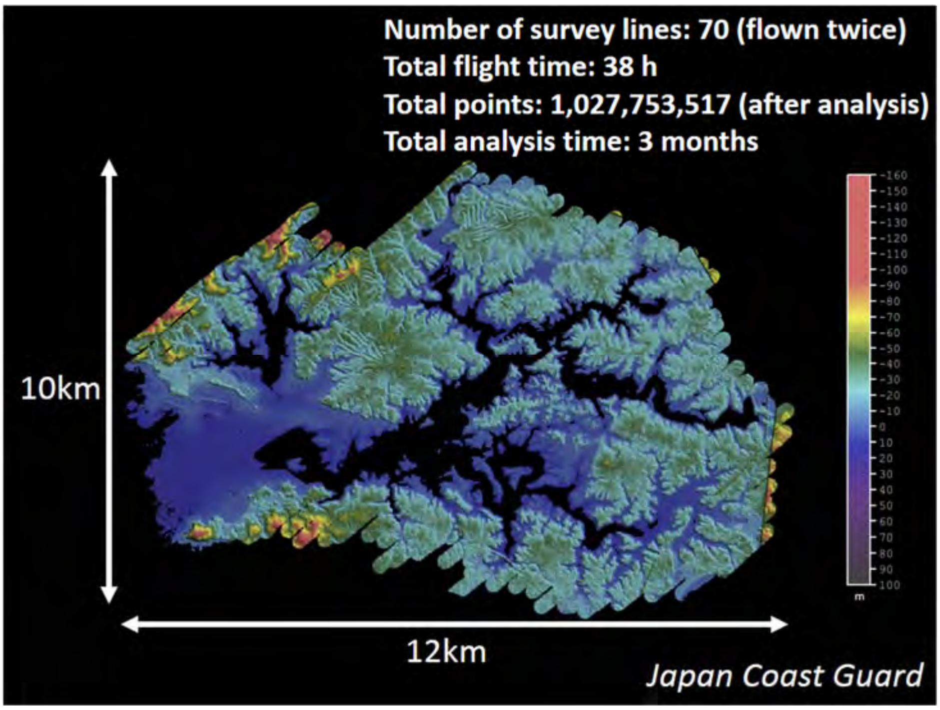

Figure 6: *Survey data from Ago Bay in Ise-Shima obtained by CZMIL.*
The complex terrain of Ria Coast is clearly reproduced.

5. Nishinoshima Volcano

Nishinoshima is a volcanic island located about 1,000 km south of Tokyo. Between 2013 and 2015, intense volcanic activity occurred and a lava flow extended over the island. JHOD conducted a coordinated survey of ALB and multibeam echosounding in October to November 2016. The survey conditions were difficult for the aircraft, because the survey area was about 1,000 km from the air base in Tokyo, and there were no alternative airfields to divert to.

This survey provided the first quantitative topographic information about the shallow-water area around the volcano (***Figure 7***). ALB clearly captured the topography of the consolidated lava flow that had been already sighted in aerial photographs before the eruption from 1973 to 1974 (***Figure 7***, **white rectangles**) (Ono et al., 2017). CZMIL managed to acquire seamless bathymetric and topographic data. Despite the persistent presence of discolored water accompanying the volcanic activity near the coastline around Nishinoshima, CZMIL penetrated the water deeper than expected. The CZMIL data, combined with the multibeam data from a survey vessel and an unmanned survey boat, were used for charting. These fine seamless bathymetric and topographic data provide important clues to the evolution of Nishinoshima Volcano.

After one and a half years of dormancy, Nishinoshima Volcano has been erupting again since April 2017. Further resurveys after the eruption has ceased will quantify the topographic deformation, which may reveal the full picture of the ongoing volcanic activities.

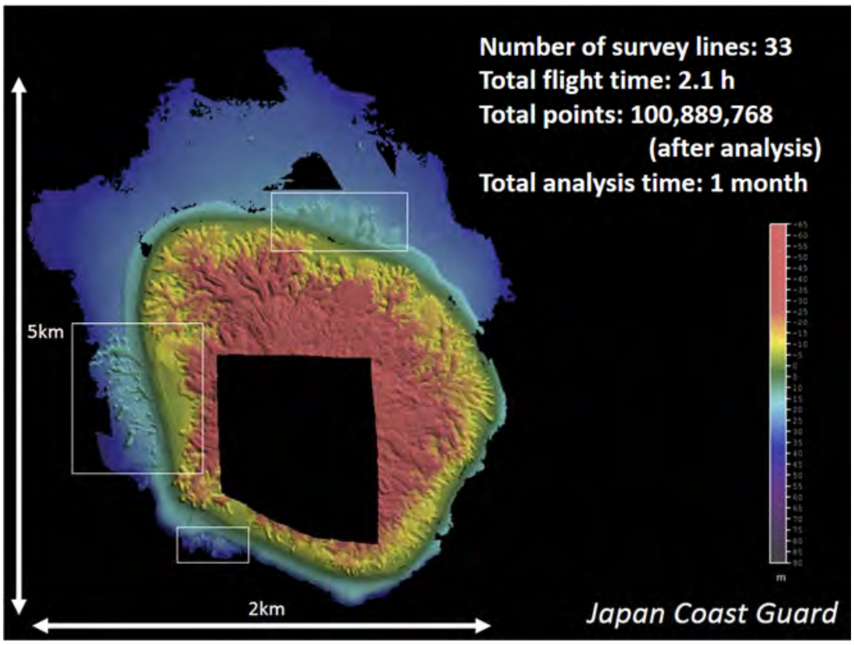

Figure 7: *Survey data around Nishinoshima obtained by CZMIL.*
The topography of the lava flow is identified in some areas (white rectangles).

6. Hateruma Island

This section presents one of the best examples of our 14-year ALB operation. ***Figure 8*** shows a bathymetric map of Hateruma Island in Okinawa, the southwestern-most prefecture in Japan. This survey area is characterized by high water transparency and clustered coral reefs, as commonly found in the subtropics. It is dotted with sunken rocks and wash rocks due to the development of coral reefs. In such an area, shipboard echosounding carries a high risk of grounding. We chose ALB to survey the broad area around the island efficiently.

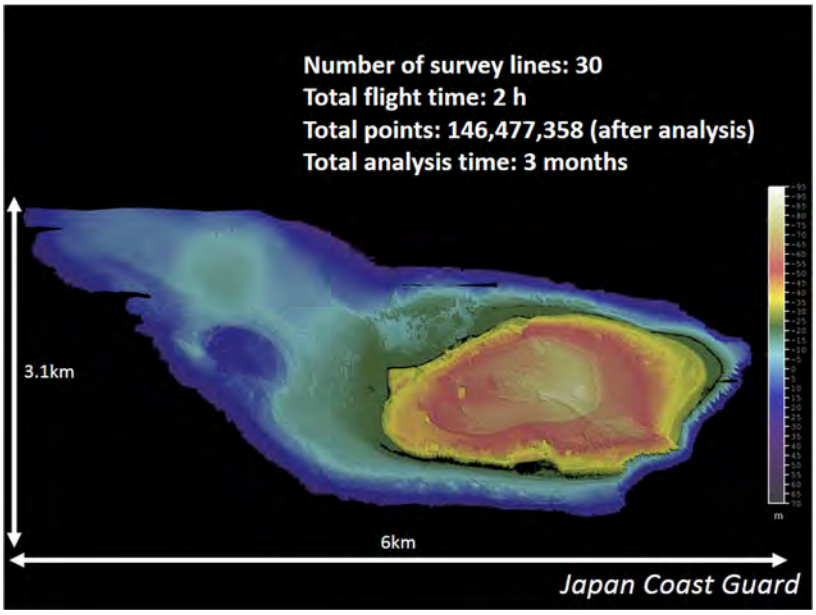

Figure 8: *Survey data around Hateruma Island obtained by CZMIL. High water transparency in this area helped the broad coverage of ALB.*

CZMIL's high resolution captured the complex terrain of coral features clearly over a wide area. ***Figure 9*** shows the lagoon-like topography of the northwest offing of Hateruma Island. The detailed distribution of coral reefs is shown in ***Figure 10***.

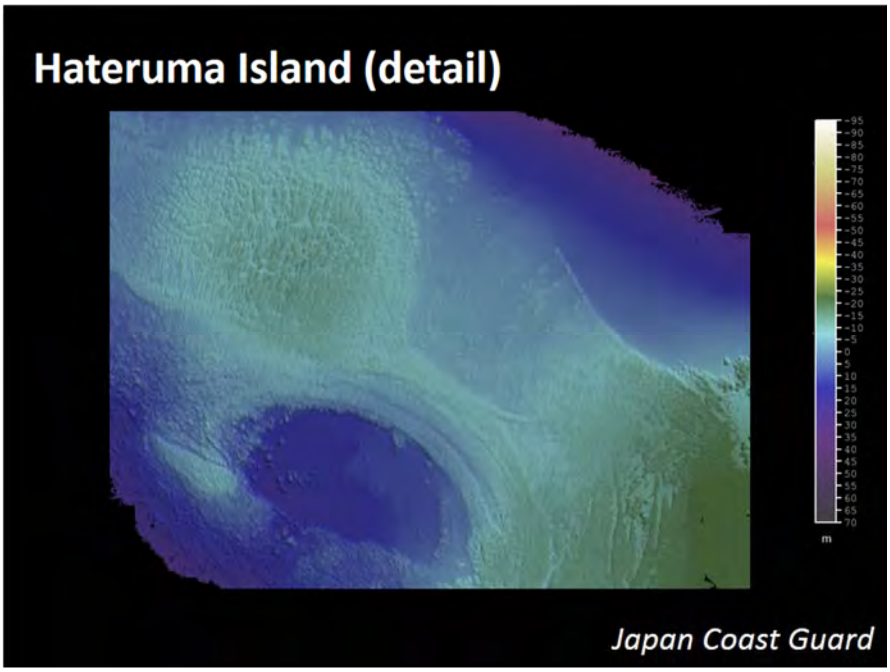

Figure 9: *Enlargement of the chart in Fig. 8, showing the northwest offing of Hateruma Island. Lagoon-like topography is clearly reproduced.*

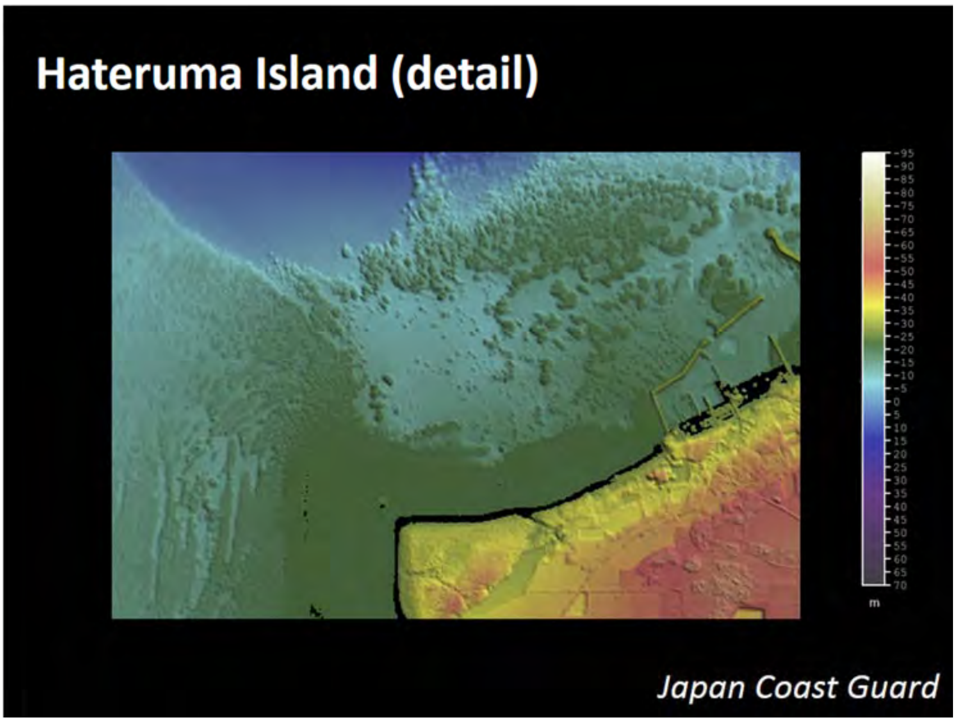

Figure 10: *Enlargement of the chart in Figure 8, showing the area off the Hateruma fishing port. The detailed distribution of coral reefs is visible.*

CZMIL measured water depth down to around 50 m, which is the performance limit of the device. Seamless topography from land to seafloor was reproduced, except in some parts of the surf zone, where whitecaps prevented laser penetration. The broad coverage of the ALB data in this survey area was attributed to the high water transparency of around 30 m and the high reflection intensity of the seabed mainly formed from coral features.

7. Conclusion

ALB is much more than just for nautical charts. In connection with, or sometimes apart from charting, the JHOD has conducted ALB surveys to accomplish a variety of missions, such as disaster response, surveillance for security, and volcanological research.

The applications described here used the advantages of ALB of broad coverage, high resolution, and rapidity in shallow-water surveys. ALB's seamless acquisition of bathymetric and topographic data is extremely effective; no other technique can achieve greater efficiency in surveying reefs, very shallow areas, or intertidal zones. However, the availability of ALB is susceptible to oceanic and weather conditions such as strong winds, waves, and water transparency. Combining ALB and shipboard surveys, primarily multibeam echosounding, produces a good balance of performance, efficiency, and cost. Keeping pace with advances in survey technology, we will strive for further efficient charting and mapping of shallow waters.

8. References

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Notes

SUCCESSFUL DELIVERY OF THE CAT.B MARINE GEOSPATIAL INFORMATION PROGRAMME

By the Korea Hydrographic and Oceanographic Agency (KHOA)

The Phase 3 of the Category "B" Marine Geospatial Information Programme was successfully delivered from 3 to 28 July 2017 at the Korea Hydrographic and Oceanographic Agency (KHOA), Busan, Republic of Korea. The programme was run by the Capacity Building Fund of the International Hydrographic Organization (IHO) sponsored by the RoK from 2015 to 2017. It was recognized as Category "B" by the FIG/IHO/ICA International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC) in April 2014.

Phase 1 involved learning the foundations of marine geospatial information, marine data assessment and basic compilation for paper charts; Phase 2 addressed advanced compilation for paper and electronic navigational charts; and Phase 3 focused on marine spatial data infrastructures and remote sensing for hydrographers.

Eight trainees from Bahrain, Cuba, Ecuador, Philippines (2), Republic of Korea (2) and Viet Nam learnt comprehensively on nautical cartography and the programme will enable them to pass on the knowledge and skills obtained to other colleagues in home countries. Once the final project is completed, they will be qualified Category "B" cartographers.

KHOA will continue to contribute to capacity building in collaboration with the IHO. Information on future programmes can be found at IHO Circular Letters: http://www.iho.int

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SURINAME AIDS TO NAVIGATION ACADEMY HOSTS THE FIRST IALA AIDS TO NAVIGATION LEVEL 1 MANAGER COURSE, PARAMARIBO, SURINAME

By the Suriname Aids to Navigation Academy

The first IALA Aids to Navigation level 1 Manager Course started on the 22 May 2017, the same day that the Suriname Aids to Navigation Academy (SAA) was officially launched.

The Maritime Authority Suriname (MAS) is the national authority that is legally responsible for the provision, maintenance and operation of marine Aids to Navigation in Suriname. As the National member of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), the Maritime Authority Suriname established the Suriname Aids to Navigation Academy. MAS is also the Hydrographic Authority of Suriname.

In that regard a Memorandum of Understanding was signed between the MAS and the IALA World Wide Academy to provide the Suriname Aids to Navigation Academy with the necessary technical assistance for delivering the Aids to Navigation Course.

The instructors for this training course were:

1. Miss Gerardine Delanoye (Programme Manager from IALA World-Wide Academy);
2. Miss Bernice Mahabier (Manager Nautical Management at the MAS);
3. Mr. Brain Ristie (Level 1 AtoN Manager at the MAS and staff member Nautical Planning and Development);
4. Mr. John Naingie (Level 1 AtoN Manager at the MAS and captain of the Buoy-laying vessel “Marwina”;

5. Miss Nancy Yang (Cartographer Category "B" at the MAS).

Guest lectures were also delivered by representatives from the Meteorological Center of Suriname, the Suriname Maritime Institute, SeaLite and the International Hydrographic Organization (IHO).

Noteworthy is that the Suriname Aids to Navigation Academy is the only training organization for the North & South America, Latin & Caribbean Region that is accredited to deliver aids to navigation training based on the IALA recommendation E-141.

The course consists out of the following modules:

Module 1: International Organizations;
Module 2: Nautical Knowledge and Navigation;
Module 3: AtoN Design and Management;
Module 4: Technical Functions of AtoN;
Module 5: Power Supply.

The course is targeted at those who will fulfill the role of aids to navigation managers in either the competent authorities or their aids to navigation service providers.

The principle theoretical course covered the complete syllabus for Level 1 AtoN Managers set out in IALA Model Course Recommendation E-141/1. The practical segments of the course comprised site visits to the Port and to the Hydrographic Office at MAS. Furthermore, the participants witnessed a live buoy maintenance and deployment operation.

The primary goal of the Suriname Aids to Navigation Academy is to facilitate education and training for personnel with responsibility for aids to navigation in key target regions and to provide assistance to enhance the knowledge and expertise of AtoN personnel in order to achieve a resilient competence in the defined target regions.

The first Aids to Navigation level 1 manager course was attended by participants from Argentina, Barbados, Belize, Guatemala, Guyana, Saint Kitts & Nevis and Suriname. Participants who completed all 5 Modules, three tests of Competency and a final Planning Task successfully were awarded with a Level 1 AtoN Manager International Certificate of Competency.

The course finished on Friday 16 June 2017.

The next Level 1 AtoN Manager course will take place from 29 October to 23 November 2018.

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