HYDROGRAPHY AT MASTER AND IHO CAT-A LEVEL AT ENSTA-BRETAGNE[1]

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Abstract

This paper aims at analyzing the requirements for the education of surveyors acting at the IHO Cat A level, namely those who will manage independently hydrographic fieldworks. We also propose an analysis of the educational capacity in hydrography, with regards to both the professional demand of hydrographers and the required level in the industry. This paper is the fruit of a work conducted for four years at the ENSTA-Bretagne, the French IHO Cat A course. We use the results of a complete redesign of our course that occurred in 2006 and from our three years of feedback from the industry.

Résumé

Cet article vise à analyser les besoins en matière d'enseignement d'hydrographes qui interviennent au niveau de cat A de l'OHI, à savoir ceux qui gèreront de façon indépendante les travaux hydrographiques sur le terrain. Nous proposons également une analyse des capacités d'enseignement en hydrographie, à la fois eu égard à la demande professionnelle en hydrographes, et au niveau requis dans l'industrie. Cet article est le fruit de travaux menés pendant quatre années à l'ENSTA-Bretagne, dans le cadre du cours français de cat A de l'OHI. Sont utilisés les résultats d'un réaménagement complet de notre cours effectué en 2006 et de trois ans d'informations en retour de l'industrie.

Resumen

El objetivo de este artículo es analizar los requerimientos para la enseñanza de los hidrógrafos que actúan a nivel de la Categoría A de la OHI, a saber aquellos que manejan de forma independiente estudios hidrográficos sobre el terreno. Proponemos también un análisis de la capacidad educativa en hidrografía, con respecto a ambas cosas, la solicitud profesional de los hidrógrafos y el nivel requerido en la industria. Este artículo es el fruto de una labor llevada a cabo durante cuatro años en el ENSTA de Bretaña, el Curso Francés de la OHI en Categoría A. Utilizamos los resultados de un nuevo diseño completo de nuestro curso, que tuvo lugar en el 2006 y de nuestros tres años de retroinformación de la industria.

1 ENSTA-BRETAGNE was formerly ENSIETA

1 Introduction

The International Hydrographic Organization (IHO), together with the Federation Internationale des Géomètres (FIG) and the International Cartographic Association (ICA) have defined since the early 1970's a standard of competence for hydrographic surveyors, known as the M5 norm. The main aim of this norm is to "provide guidance whereby individual surveyors may be trained and qualified in accordance with internationally accepted levels of competence". The IHO M5 norm defines the minimum knowledge and experience that are considered necessary for hydrographic surveyors, for essential subjects (bathymetry, water levels and flows, positioning, hydrographic practice, hydrographic data management, environmental science, legal aspects), as well as for optional units (nautical charting, hydrography to support port management and coastal hydrography, offshore seismic surveying, offshore construction hydrography, remote sensing, military hydrography, and inland waters hydrography). The essential fact of the S5 norm is that each item *is defined in details in terms of competence, but not in terms of ability to set-up a methodology in response to a global surveying problem*. The aim of this paper is to present how, starting from the S5 norm[2] as a basis, we provide to students an educational program that enables them to define robust methodologies to face complex hydrographic surveying problems.
It is now widely known that only 60 to 70% of the industry demand for hydrographers is satisfied, which means that institutes could increase their capacity without having any student[3] placement problem. In quantitative terms, in the European Union, the training capacity is about 75 Cat A students per year (the ENSTA -Bretagne course representing 40% of this capacity). The industry (mainly survey companies, dredging companies and offshore companies), the hydrographic offices and governmental institutes would need between 110 and 125 trained hydrographers.

A direct consequence of this fact is that the industry has to recruit as hydrographers, students that have limited background in hydrography; namely land surveyors, engineers, etc. Therefore, due to a mechanical effect between the lack of well trained personnel and the growing demand, the level of practice will certainly decrease in the near future, if not already done. But what do we mean by a decrease of the level of practice? We believe (or observe) that surveyors that did not undertake any training course in hydrography will be more and more dependent on the technology, sometimes without mastering the basics of this technology, so being unable to identify the source of errors that are always present during a survey. This fact, combined with a more complex and integrated technology (multibeam systems, inertial sensors, for instance) may create an increasing dependency on the technology (which includes equipments and software).
From the training institutes' point of view, this situation may seem to be comfortable, the demand for students being much more than the training capacity. But in a long term view, we believe that the lack of well trained hydrographers may lead to some kind of ``blind" or "automated" practice of hydrography, which might affect the future need for well trained Cat A level hydrographers. This means that increasing the training courses capacity is one of the key responses, but this aim seems difficult to achieve in the global context of reduction of public sector expenses. Indeed, hydrography training courses requires important infrastructures and investment (survey vessels, costly equipments, and staff).
Another key point, which is the major focus of this paper, is to promote high standards of education for hydrography; namely training the student to a detailed knowledge of equipments, to provide proper education for identifying the sources of errors with an adequate level of scientific education in physical and mathematical modelling. We shall focus on three main topics that greatly impact the quality of a course:

The scientific methodology:

Rather than using built-in tools or software to solve complex problems, we first provide students with a knowledge of the mathematical and physical background of the method that will used by making them implement basic algorithms. They are then invited to use their detailed knowledge of these tools to solve hydrography related complex problems. As an outcome, students are not reliant on black-box solutions. This approach of hydrography education seems very important to us, since hydrographers have permanently to assess the quality of survey data and to identify sources of errors.

Putting practicals and theoretical course modules alternately:

Every essential subject includes practicals (either by simulation or by dealing with real data) that progressively drive the students towards at sea training. The first practical training sessions at sea are organized quite early in the course, and aim at putting students in situations which are sometimes not manageable with their actual knowledge. Other practical sessions are organized through the course, the final one being a survey project where students are fully autonomous. During all the phases of survey projects, students are naturally driven to mobilize their scientific knowledge in order to process, analyze and interpret data.

2 Which is now referenced as th FIG/IHO/ICA/S5 norm
3 In these figure, the educational capacity includes students that we train for non-EU hydrographic offices.

Figure 1 *A view of Brest, the city is located on the right side (south side, which is the area used for ENSIETA hydrographer practices at sea. On the right, a view of the ENSTA-Bretagne campus.*

The paper is organized as follows: first we describe the outline of the ENSTA-Bretagne course content. Then we describe the several practical situations that face students during their education and how a continuous closed-loop between training and data analysis helps to develop highly skilled hydrographers.

2 ENSTA-Bretagne Course Outline

2.1 Context

The hydrography course has existed at the ENSTA-Bretagne since 1971, and is now the reference French IHO Cat A course. Being a French ``Grande Ecole" under the authority of the French Ministry of Defence, the ENSTA-Bretagne trains 2 military engineers per year who join the SHOM after graduation, and 28 civilian students who will work with the industry. The "Grandes Ecoles" ensure the quality of their education by their recruitment through a national competitive examination, common to a large set of institutes. The scientific level at the entrance of the ENSTA-Bretagne is adequate for dealing with topics ranging from sensor physics understanding to abstract mathematical modelling. The main goal is to give students the ability to measure the physical properties of the environment, thanks to their physics background, to process large data sets and finally, to provide abstract representations of those data, thanks to mathematical and computational methods.

Located in Brest, the ENSTA-Bretagne course benefits from the presence of most of the French marine science institutes: SHOM, IFREMER, and Brest University. Moreover, the ENSTA-Bretagne as a ``Grande Ecole" has the possibility of recruiting external lecturers from other universities or from the industry. The lecturing team of the course is therefore a mix of professionals and university professors.

The number of graduated hydrographers from the ENSTA -Bretagne increased around 2008-2009, due to a complete course redesignin 2006 which aimed at better fitting with the maritime industry needs. From an average of 5 students around 2000, last year's graduation class comprised 30 students, which makes the ENSTA-Bretagne the largest Cat A course in the European Union.

2.2 Course short description

The ENSTA-Bretagne course duration is two years, and leads to a Master level degree (diplôme d'ingénieur). As the French educational system is quite specific, *Figure 2* shows a synoptic view of the programme structure, including relations with the classical university programmes. *Table 1* shows the list of the course modules and the evaluation type: E means exam, and P means project. One can see that most of the evaluation is based on projects. We will describe projects in more detail in the next section.

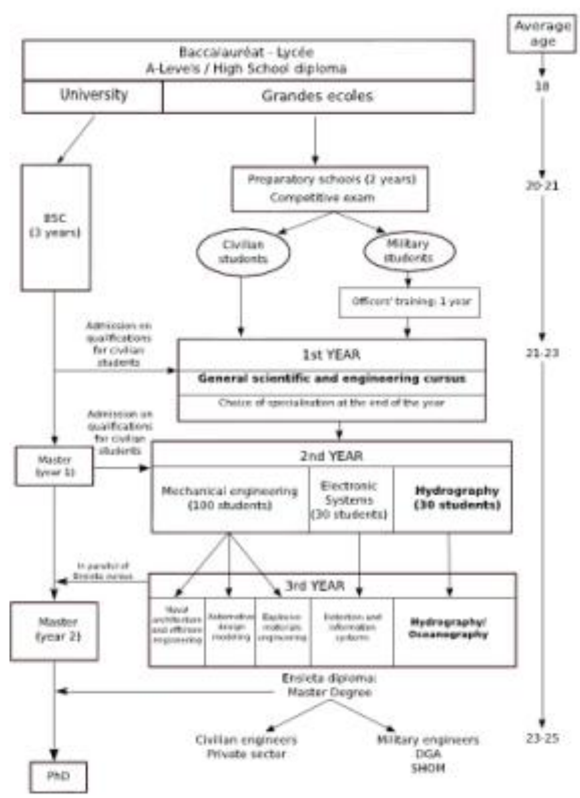


Figure 2. *Overview of Programme structure*

YEAR 2					
Semester 1			Semester 2		
Module name	Hours	Evaluation	Module name	Hours	Evaluation
Geodesy	25	E	Maritime Training	25	
Bathymetry	60	EP	Hydrography	40	EP
Oceanography	30	E	Remote sensing, GIS	50	P
Positioning	60	EP	Bathy data proc.	45	EP
Geo. databases	20	P	Water levels	35	E
Digital signal proc.	35	P	Geophysics	35	EP
Meteorology	15	E	Image processing	25	P
Numerical methods	25	P	Inertial Navigation	25	P
Acoustics	25	P	Survey Project	100	P
SUMMER TRAINING: 2 months in industry					
YEAR 3					
Semester 1					
Module name	Hours	Evaluation	Module name	Hours	Evaluation
Pre-dredging survey project	80	P	Sediment dynamics	30	E
Hydrography for off-shore construction	20	P	Inertial navigation and optimal filtering	30	EP
Hydrography for coastal engineering	20	P	Coastal modeling	40	P
Cartography	35	E	Data assimilation	20	P
Law of the sea	15	EP			
OPTION Advanced bathymetry (120h)			OPTION Oceanography (120h)		
Semester 2					
MASTER THESIS, 5 months					

Table 1*. Outline of the course modules, teaching hours, and evaluation type for the second and third school year.*

As shown in *Table 1*, the ENSTA-Bretagne course includes a set of oceanographic course modules that are largely beyond the scope of the S5 norm. ENSTA-Bretagne students are capable, due to their good mathematical and information technologies background of performing studies in the field of oceanographic modelling.

One can observe from this Table that the course incorporates a detailed module on inertial navigation, which may seem strange. Having observed the lack of knowledge of students in this field, and taking into account the fact that INS system may be a serious source of hydrographic uncertainty (maybe much more that MBES systems in some cases), we decided to setup this new course, focusing on the understanding of navigation equations, ground alignment methods (static of in motion), and optimal estimation of position with navigation aids (GPS in air, and Doppler or LBL under-water).

2.3 Practicals

Practicals are organized in such a way that students can work more independently. We describe only the hydrographic surveying part, but keep in mind that oceanographic practicals are also organized with the aim of gathering, analyzing and modelling CTD data coupled to tide and ADCP data.

From the hydrographic survey point of view, practicals consist of:

The Hydrographic Survey project: In this project, teams of three students are tasked to survey some small areas of the Brest commercial harbour. The project is graded with respect to quality and confidence of results, methodology, project management, and communication. One of the aims of the project is to survey the area specified by the client, by using at least three different systems: a SBES (or mechanical profiler), a MBES, and a Side-scan sonar. The data returned by these three different sensors have to be correlated, in terms of hydrographic accuracy and ability to detect obstructions. Both data sets have to be reduced from water level by at least two methods: a classical tide reduction, using tide gauge data and heave data, and a RTK levelling method, using the ellipsoidal height of the chart datum.

The summer internship: Students have to perform survey work in a foreign organization (dredging company, survey company, hydrographic office). This period must include at least 3 weeks of at sea work and 5 weeks of office work. The minimum internship duration is two months, and students must deliver a written report and perform a project presentation.

For the 2008/2009 series, the distribution of students was the following:

Dredging companies: 9 students,
Survey companies: 10 students,
Hydrographic offices (Brazil, NL, FIN, CAN, UKHO, SHOM): 6 students,
University of Oceanographic Labs : 5 students.

The pre-dredging survey project: This project is the last survey project. Students have to work without any supervision in real conditions Instructors play the roles of clients giving assignments and requiring quality control procedures. Students have to make a tender, as they would have to rent the survey equipment from the ENSTA-Bretagne. They have to perform a survey, a volume computation and to prove the quality of results.

Each student can practice with the ENSTA-Bretagne survey equipment, namely:

The survey vessel "Panopée ": A 7.6 catamaran, with 100 HP engines, speed range 2-17 knots, draught: 40cm. This survey vessel allows working sessions including three students, and two members of the teaching staff (technician/pilot, professor).

A RTK GPS system: Reference station and mobile station from Magellan, used at sea. The reference station is installed on the roof of the Brest Pilots Station, the mobile station is onboard the Panopée Vessel.

A 2D/3D laser scanner: Leica HDS6200.

A land based RTK system: Aquarius 5002 from Thalès Navigation, which is used for land survey purposes and topometric works.

Two SBES: Simrad-Mesotech 210Khz, 120kHz.

A sub-bottom profiler: Tritech 210kHz-20Khz.

A side-scan sonar: Tritech.

A single beam mechanical profiler: Tritech.

Two MBES sensors: A R2SONIC with Quinsy acquisition system, a Tritech Horizon, with PDS2000 acquisition system.

Sound velocities probes: Valeport (surface and profiling VOS probes)

Two tide gauges: Aanderaa.

A MRU6: Seatex.

An OCTANS 4: Ixsea.

A 3D motion simulator platform: TRI30 from IXmotion.

A GPS compass: Hemisphere.

A CTD gauge: SBE37 from Seabird.

Figure 3. *The Panopée survey craft*

3 Hydrographic survey training analysis

In this section, we focus on the new training system that the ENSTA-Bretagne recently implemented. Survey industry feedback has provided some interesting results. This new training course is based on several facts:

1. Hydrographic data gathering, processing, and analysis require a wide variety of skills, ranging from physics (sensor technology) to information technologies, applied mathematics (data processing). Assessment of data quality can only be done by people with a detailed knowledge of all processes involved in a hydrographic data production scheme.
2. Surveys are now performed with survey *systems* which include many different technologies (acoustics, positioning, inertial measurements, mechanical integration, acquisition devices and software, data processing tools, visualization tools). In order to be able to plan a survey with minimum quality requirement and to assess data quality, the total propagated error assessment requires a deep understanding of each sensor, and not only to consider them as black boxes whose accuracy is given by the manufacturer.
3. Hydrographic surveyors at Cat A level have the role of chief surveyors, and therefore will have (after some years spent gaining expereince in industry) the responsibility of a complete survey work, which mobilizes significant financial resources. Therefore, they have to be extremely reactive when the survey system behaviour is not satisfactory. This requires a deep understanding of all the components of a survey system.
4. An interaction between institutes, hydrographic tool developers, and the industry is necessary to deliver a complete education in a complex field such as hydrography.

4 Panopée is the name of a Nereide from the Greek mythology. She had prediction skills and the ability to see everything
5 Thanks to a sponsoring of R2SONIC that provides a 2024 unit twice a year for a one month period.

The progressive practical training that we implemented is based on three principles: first to alternate practical exercises with theoretical course modules, in order to develop their ability to think independently. Secondly, to alternate training periods within the industry with academic education, in order to give them the opportunity to discover other point of views or methodologies than the one we deliver at the ENSTA-Bretagne. Finally, to perform their master thesis in focusing on a scientific subject related to hydrography, in order to initiate them to applied research which can be very helpful for their future adaptation to new technologies.

In order to achieve these goals, we scheduled our course in the following way:

Academic scheduling				
Semester 1	Semester 2	Semester break	Semester 3	Semester 4
Main topics				
Hydrography			Oceanography	Both
Practicals				
P1	P2		P3	
Internships				
		Summer training		Master thesis

Table 2: Scheduling of practicals at ENSTA-Bretagne. "P" letters means practicals which includes at sea works and data processing

From Table 2, practicals alternate with theoretical course modules, and that internships alternate with practicals.

As a result, we give students assignments including at sea work before a complete education about the tools they manipulate. The effect is to force them to accept the idea that a theoretical background is absolutely necessary in order to perform proper work in hydrography. For example, the first practical P_1 is a patch test that they carry out for a multibeam system. The data selection is done by using dedicated software (CARIS HIPS), but the data processing is done by students themselves, by using a free scientific computation environment (Scilab), therefore without dedicated patch test software. They have to manipulate the data, and to choose a statistical method in order to estimate latency, pitch, roll and yaw misalignment angles from several profiles.

Students face quite a difficult situation as data may be affected by ray-bending, the time resolution for latency estimation over a footstep is affected by the footprint of the sounder and therefore the operating frequency of the sounder. Their knowledge of acoustics does not enable them to solve this kind of problem. The bathymetry course module, which comes just after, details the answers to all these questions. In this way, the bathymetry course module is motivated by a first at sea practice experience, and gives answers to problems that the students faced in reality.

At the end of their hydrography education in Semester 1 and 2 of the course, students perform a survey project P_2. At this stage other problems are to be solved including vertical references determination methods, data cleaning, choice of a sounding reduction method, motion sensor misalignment, etc. After the first survey, they have to perform both a sounding reduction by using tide and heave information. The students were at this stage not aware that heave compensators may be unreliable in some situations. Therefore, tide reduction might be affected by bad heave compensation. They discover this fact through practice, and we intentionally do not make any prior induction of inertial navigation before the third survey project. Having identified some errors from a comparison with LRK reduction which does not involve heave measurement, they can take benefits and be very motivated by the inertial navigation course module that explains sources of errors in heave compensators. Moreover, in comparing the two sounding reduction techniques they quite often realize that none of them is the best, but that in some situations, LRK is better, and in some other tide information coupled to heave is better: this is the first contact with hydrographic surveying complexity in terms on data quality assessment.

In facing such difficult situations without a deep knowledge of the tools they use, and when everything ' goes wrong'' students quickly understand that without detailed knowledge of each part of a survey system, they cannot detect errors, make a diagnostic and correct them properly.

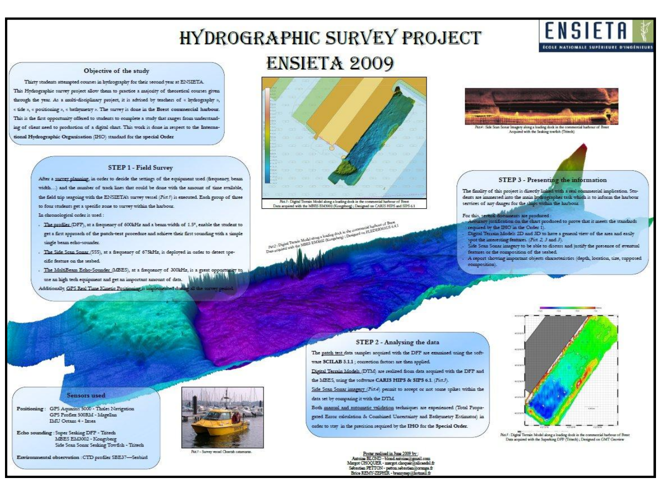
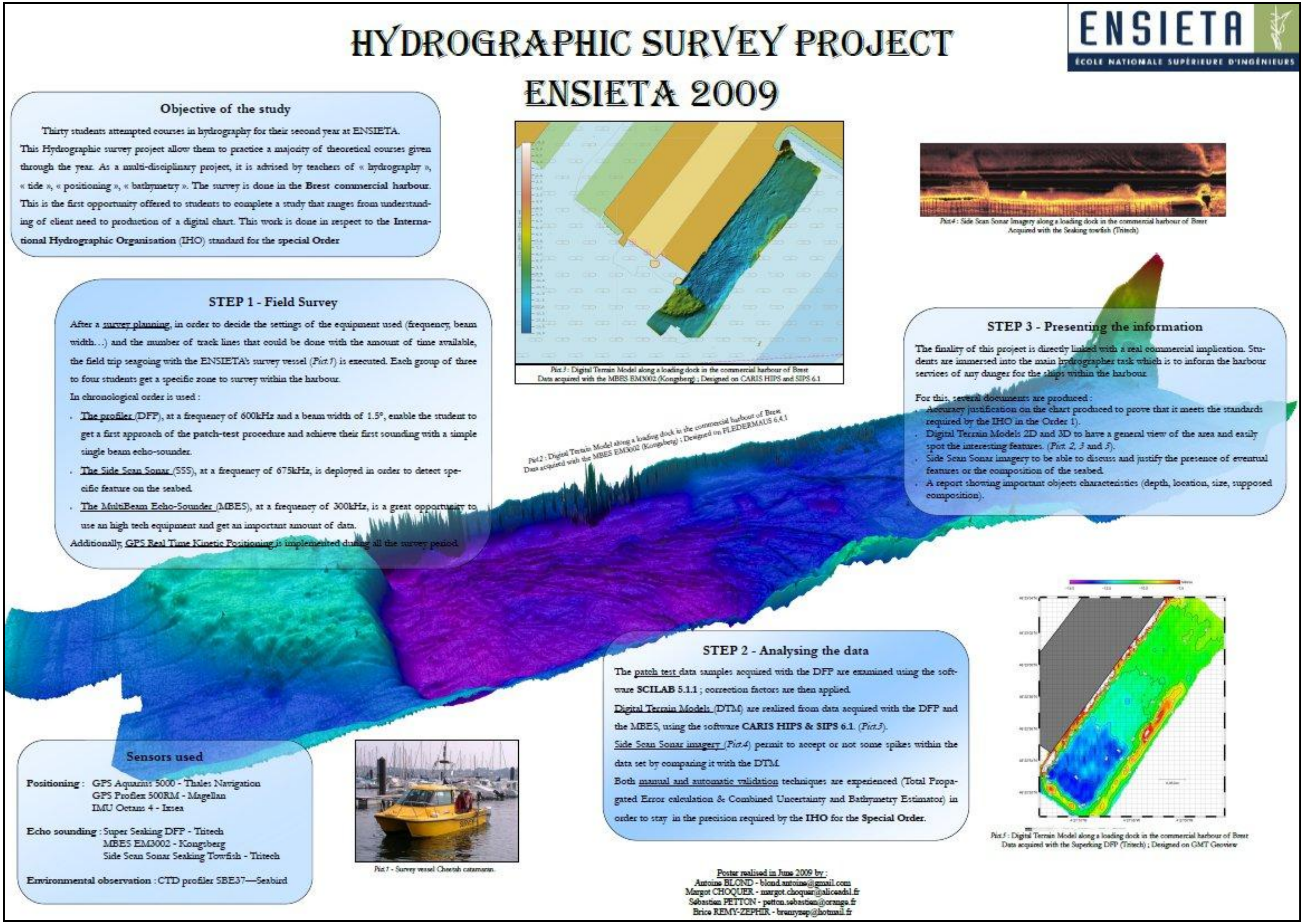


Figure 4. See details on next page



Figurre 4. *An example of student work for the 2009 survey project session. They surveyed an area with a side-scan sonar, a multibeam sonar, a single beam mechanical profiling sonar, and made comparisons results in terms of DTM, target detection and height estimation.*

The last stage of the hydrographic survey practical education is a pre-dredging survey which is carried out by one team (the whole group of student). The student group receives several assignments from a (virtual) client, in terms of products, confidence indexes, volumes computation, etc. Then, the group is divided in subgroups of 3 students. A project manager is elected, and he (or she) organizes the project work, assigning the tasks (determination of vertical references, tide gauge installation and check, calibration of equipment, survey of the different areas). The survey area is generally chosen in a difficult estuary which produces VOS variations, levelling problems due to bad tide modelling, and the chart datum is not available. The project has to report to the client specification, with an indication of the survey quality. This last survey project is the opportunity for student to face a real complex survey situation and to try to get the best quality of data. This project enables us to check the ability of each subgroup to address difficult surveying problems, and to quantify properly hydrographic errors. This concludes the hydrographic survey education of our student. They are evaluated by an expert from industry, in order to guarantee the independence of the grading.

It is also worth mentioning the problem of survey software training. It is right that the practice of complex softwares, for data acquisition, for data processing and visualization is a key point, as students will have to use some of those tools in the industry. But, we insist on the fact that a hydrographer's education only based on the *utilization* of software tools is *not sufficient* for at least two reasons:

* Hydrographers need to know the basic principles of the numerical algorithms they use. To do so, it is highly desirable that students program basic prototype algorithms of these methods by themselves. For instance, sounding data cleaning, detection algorithms in acoustics or spherical positioning for LBL. It is essential for getting a detailed knowledge.
* When they have to focus on a specific problem (for instance heave estimation from inertial sensors and LRK by using a Kalman estimator) they will have no other solution than to program the computer code by themselves. Dedicated software will not be sufficient.

We believe that hydrographers have to receive a proper education in information technologies, and that more and more, data processing will be a central activity in hydrography. Indeed, the use of multibeam echosounders, the future use of laser scanners coupled to multibeams will create massive datasets, which require advanced data processing tools to make full usage for charting. Without this education, hydrographers would be limited to the surveying activity, which is not sufficient for Cat A level hydrographic surveyors.

We also believe that the black-box "culture", when applied to hydrographic surveying may lead to unexpected errors. For instance, using modern softwares which offer functionalities in automatic data processing, data cleaning, digital terrain model production, without detailed knowledge of their basis prevent any objective accuracy assessment. For instance, producing a DTM with a variable sounding density by using an averaging method may lead to unexpected errors. Specific methods must be applied, which are sometimes not available in classical software suites.

3.1 Internships

In Table 2 we have shown that two internships are mandatory in the ENSTA-Bretagne course. The first one is a summer training period, which must be performed abroad, and must include at sea survey and data processing for a minimum period of 6 weeks. Thanks to a close cooperation with the survey industry, all of our 30 students perform this internship in very good conditions, and they have the opportunity of experiencing their knowledge in real-world situations. This fact should not be neglected, as we observed that after this summer training period, *all students* return to the ENSTA-Bretagne with a very high degree of motivation and a new vision of their education (they seem to be more mature as they have seen that theoretical background is useful for fieldworks). We thank all our industrial partners for this essential contribution to our course. Allowing students to discover hydrographic surveying in industry at some point of the two years of the syllabus provides real added value to our academic education.

3.2 Focusing on a master thesis subject

The hydrographer education is completed after a master thesis. ENSTA-Bretagne students have to perform their internship outside of the institute: private companies or university labs. But the master thesis is realized under our advice, and for some students, this includes periods at the ENSTA-Bretagne in the framework of a cooperation with industrial partners.

The main aim of the master thesis is to focus student work on a research subject related to hydrography or to oceanography. In the field of hydrography, we investigate with industrial partners new subjects (like laser scanning, sonar data fusion, characterization of multibeam errors on specific bottom types, data cleaning algorithms), or subjects related to hydrographic error characterization (multibeam errors on specific bottom types, inertial sensors error understanding, underwater positioning aids). This last stage of ENSTA-Bretagne education is essential as the student will learn how to face a difficult generic problem, to mobilize parts of their hydrographic education to analyze situations, to offer new solutions, to implement and to test them and finally to analyze the results they obtained.

We list here some examples of master thesis topics which have been performed in cooperation with survey companies or survey departments of dredging companies: The use of range-aided navigation systems for spoolpiece metrology; vertical reduction for a seamless digital database; silt layer variability in the port of Rotterdam; motion sensor error characterization; hybridization of motion sensors and RTK signals for heave estimation; analysis of multibeam behaviour on dumped rocks on the seabed; testbed comparison of multibeams systems; structure positioning with laser scanner data; and tests and improvement of data cleaning algorithms.

4 Conclusion

The experience of the mixing of practical and theoretical course modules throughout the ENSTA-Bretagne course have been positive. Thanks to a close cooperation with the industry, training periods efficiently complement our academic courses, and they represent real added value: for companies who can select experienced and motivated people, after final graduation, and for the hydrography course which efficiently increases with the induced student motivation. We have also seen that basic science background is absolutely necessary to hydrographers to enable them to have a detailed knowledge of every part of a complex survey system, and to assess the hydrographic data quality. Developing the educational capacity and the level of education seems necessary, since hydrography at Cat A level requires a high level of expertise and the capacity to define a survey plan, to make diagnostics on erroneous or incoherent data, and to assess data quality.

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Biographies of the Authors

Nicolas SEUBE obtained a PhD in applied mathematics from Paris Dauphine University in 1992. He was awarded the winner of the SIAM prize for the best student paper competition at ICIAM'91. Then, during ten years, his research interests were in dynamic systems theory, and he authored more than 20 papers on viability analysis of non linear systems, observers design, and applications to underwater system design (Autonomous Underwater Vehicles, Gliders, Floats). In 2002, he obtained an HDR and became a full Professor. Since then, his research interests are motivated by underwater technologies and hydrographic surveying. In 2005, he became coordinator of the hydrographic course of the ENSTA Bretagne, and developed a research group in bathymetry, hydrographic instrumentation and cartography. His present research interest includes cartography-aware ship dynamics, inertial sensors errors identification and modeling, bathymetric data processing and uncertainty management in hydrographic surveying.

Nathalie Debese received an engineering degree in Computer Science from The University of Technology of Compiègne (UTC) in 1989, and a MSc degree in Statistics. She obtained a PhD in System Control Theory in December 1992 for her research works at IFREMER - the French research institute for exploration of the sea- on the *Learning registration of the navigation through bathymetric data*. She worked from 1995 to 2009 in the SHOM – the French hydrographic and Oceanographic service - as the MBES co-project manager. As an expert in bathymetry, she contributed to the definition of the MBES data quality workflow. She was also involved in several research projects focusing on bathymetric data processing. Since 2009, she works with the ENSTA Bretagne as an Associate Professor in the "Ocean Sensing and Mapping" group. Her research interests include automatic cleaning of bathymetric data, surface's modeling, geometrical and morphological properties of digital terrain, features extraction and representation, data compression and registration algorithms.

Rodéric Moitié received his Msc degree in Computer Science from ENSIMAG (Ecole Nationale Superieure d'Informatique et de Mathematiques Appliquees de Grenoble) in 1996. For five years, his research interests were in dynamic systems and underwater robotics. Since 2002, his research interests are related to underwater technologies and hydrographic surveying. In 2004 he became involved in the training of students undertaking the hydrographic course of the ENSTA Bretagne, and joined a research group in bathymetry, hydrographic instrumentation and cartography. His present research interest includes cartography-aware ship dynamics and bathymetric data processing.