ARG-23085 Knipovich Project

AUV data acquisition and processing; extended field report

- The Norwegian Offshore Directorate

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1 Introduction

This report presents the results of a successful collaboration between the Norwegian Offshore Directorate (NOD) and Argeo AS.

NOD engaged Argeo to undertake a near-seabed data acquisition in selected areas on the Knipovich Ridge in the Norwegian Barents Sea (Fig. 1.1). The main objective of the project was geophysical and environmental surveying of the selected areas of interest using Autonomous Underwater Vehicles (AUVs).

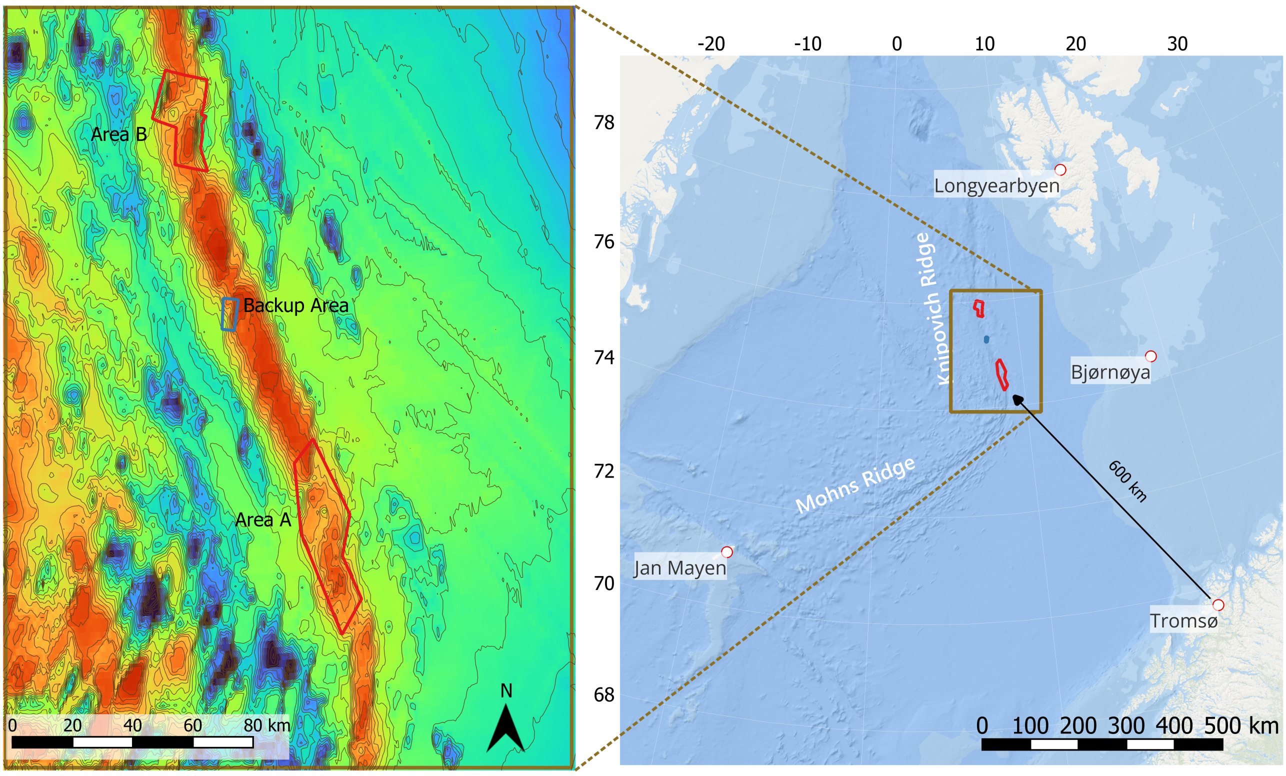

Fig. 1.1 Survey area overview map

Project background, objectives, and scope of work are described in Section 1 Introduction along with an explanation of how to use the report.

2 Data delivery Section explains the data delivery contents and structure.

Data acquisition, including field operations, equipment and methods overview are presented in Section 3 Data acquisition.

Section 4 Data quality and processing presents a summary and a brief description of the measurements and methods used for processing and quality assurance. Section 5 Summary summarizes the complete project.

In order to keep the main part of the report succinct and easy to follow, long-form attachments such as documents can be found in Section 6 Appendix.

Table 1.1 Document versions

Rev	Date	Description	Prepared by	Controlled by
02	07.12.2023	Final Report. Part I	TS, GR, LK, VT	TR

Project number: ARG-23085

Client:	NOD
Client Contact person:	Nils Rune Sandstå
Project leader in Argeo:	Frans Vellema

1.1 Project overview

The Norwegian Offshore Directorate (NOD) have appointed Argeo AS to undertake a geophysical survey for the deep-sea mineral area at the Knipovich Ridge in the Barents Sea. The area is situated southeast of Svalbard as shown in Fig. 1.1. Distances to the Norwegian mainland is as indicated, more than 600 km.

The marine acquisition campaign described here is part of the NOD’s program for mapping the deep-sea mineral resources of the Norwegian Continental Shelf. The data acquisition program will be administered by the NOD, funded through the Ministry of Petroleum and Energy. The Norwegian Offshore Directorate is a national directorate and shall contribute to the greatest possible values for Norwegian society from the oil and gas activities through efficient and responsible resource management, where health, safety, the environment, and other users of the sea are taken into consideration. In addition to being involved in oil and gas projects, NOD is also involved in offshore wind, CO2 storage and seabed minerals projects.
The current project on the Knipovich Ridge is part of a larger campaign for resource mapping on the Norwegian Continental Shelf. The overall goal of the entire exploration program for minerals is collecting data on the location and characterization of Seafloor Massive Sulphide (SMS) deposits along the Norwegian Exclusive Economic zone. The survey was focused on three areas of interest (Lokeslottet, Area A and Area B. In addition an optional Backup Area was included - Fig. 1.1). The work was performed using SeaRaptor 6000 AUV's from the board of M/V Argeo Searcher.

1.2 Project objectives

The main objective of the Survey is detailed near-seafloor data acquisition using an Autonomous Underwater Vehicle (AUV). Argeo has been provided with previously acquired bathymetric data that forms the basis for mission planning. NOD has also provided information of preferred areas for data acquisition. To achieve this objective, Argeo deployed two autonomous underwater vehicles (AUV's), SeaRaptor 6000, equipped with a suite of state-of-the-art sensors. The survey is designed to provide information needed primarily for the following:

- Detailed seafloor mapping
- Near-seafloor geophysical data acquisition
- Water column data acquisition in the vicinity of the seafloor
- Environmental mapping
- Deep-sea mineral resource identification and delineation

The payload sensors deployed on SeaRaptor-6000 AUV during the survey are listed below along with the description of various data types collected by the sensors listed in Fig. 1.2.

Sensor	Data type
Multibeam Echosounder (MBES)	Bathymetric data
	Backscattering strength
	Water Column Image data
Sub-Bottom Profiler (SBP)	Acoustic sub-bottom data (SBP images)
Synthetic Aperture Sonar (SAS)	Ultrahigh-resolution seafloor image data
	Simultaneous bathymetry data
Magnetometer	Magnetic field (3 components)
Argeo Listen	**Passive Mode:** Spontaneous Potential (SP) measurements of Electric field (3 components)
Environmental sensors	CTD, Dissolved Oxygen, CH4, pH, Turbidity, ORP

Fig. 1.2 SeaRaptor 6000 sensor list

1.3 Scope of work

The scope of work included acquisition of various geophysical and environmental data in the pre-selected areas along the Knipovich and Mohns Ridges. Note that only standard data processing of the collected data was included in the scope of work.
The client requirements included the following datasets to be acquired with an AUV:
- spontaneous potential data (SP)
- high resolution multi-beam bathymetry (preferably of Synthetic Aperture Sonar)
- back scatter data
- self compensating magnetometer
- high resolution gravimeter
- geochemical sensors, including pH, methane, turbidity, ORP
- sub-bottom profiler (SBP)
- temperature

The survey focused on three areas of interest:

1. NOD Lokeslottet (Fig. 1.3). The area is approximately 2 km2 and water depth ranging from 2200 – 2500 m. This area was selected by NPD as a sensor verification program and due to its geological interest.
2. NOD Knipovich Area A (South) (Fig. 1.4). The area is approximately 692.3 km2 and water depth ranging from 2800 – 3500 m.
3. NOD Knipovich Area B (North) (Fig. 1.5). The area is approximately 385.5 km2 and water depth ranging from 2300 – 3300 m

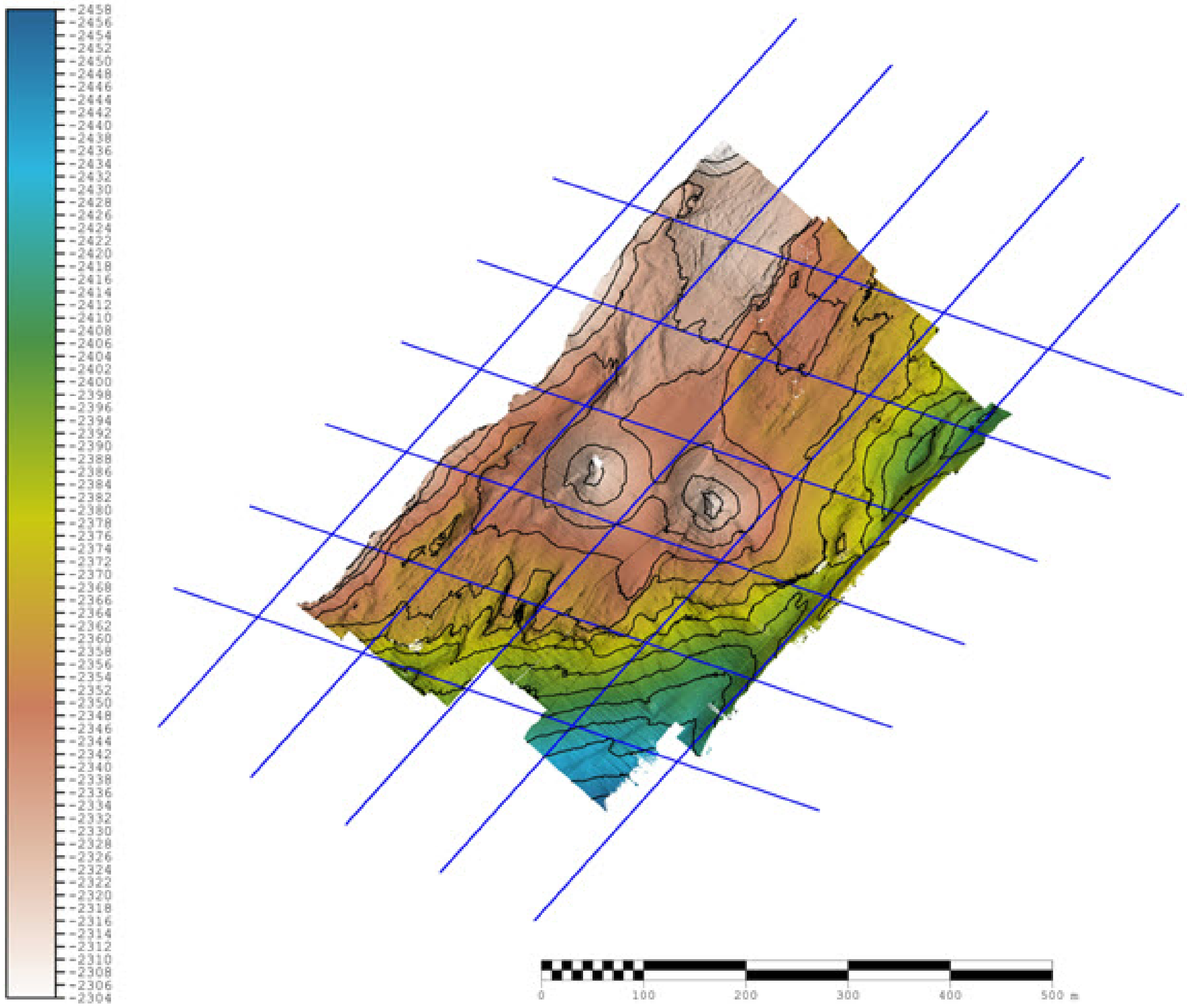

Fig. 1.3 NOD Lokeslottet – Planned Survey lines draped over client supplied MBES data.

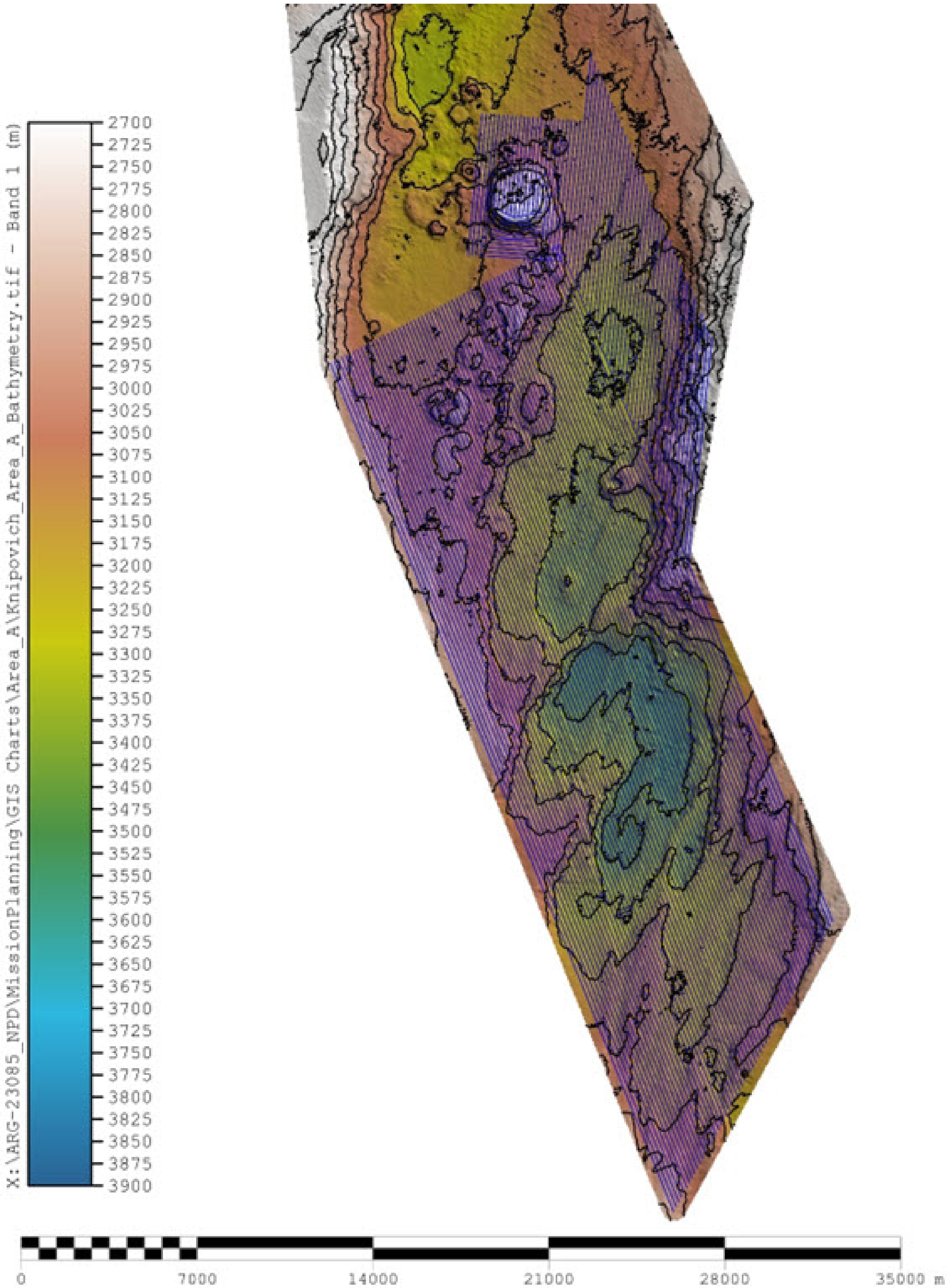

Fig. 1.4 NOD Knipovich Area A (South). Planned Survey lines draped over client supplied MBES data.

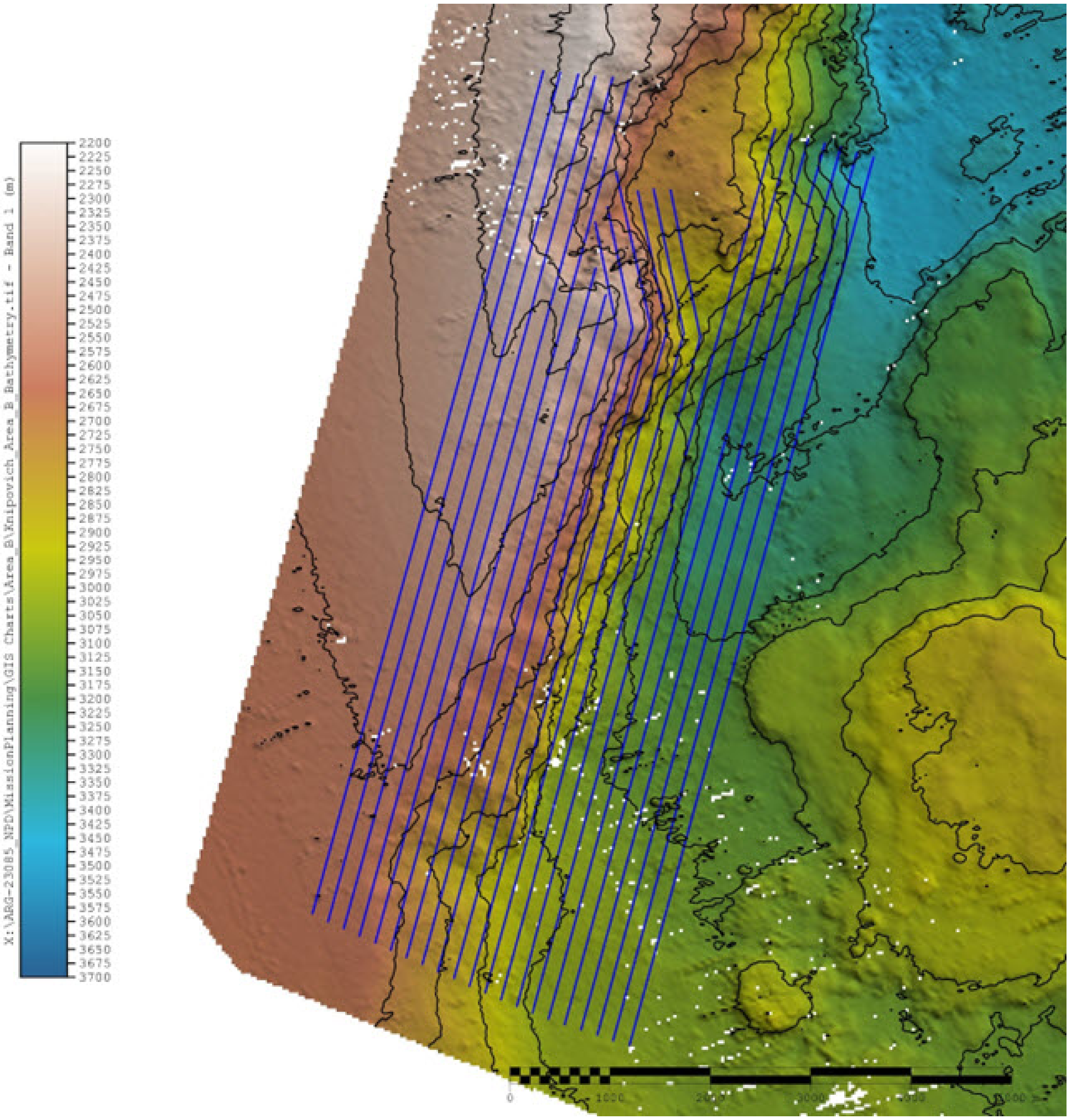

Fig. 1.5 NOD Knipovich Area B (North). Planned Survey lines draped over client supplied MBES data.

Note: The original acquisition plan was to gather 3500 line kilometres in the three NPD areas of interest. This was reduced due to weather constraints and a total of 2960.57 acquisition kilometers were collected across the three survey areas.

More details about the conducted data acquisition can be found in 3 Data acquisition.

1.4 Acronyms and definitions

Table 1.2 Acronyms

Acronyms	Definition
AOI	Area of Interest
AUV	Autonomous Underwater Vehicle
Chirp	A sweep signal where signal frequency increases or decreases with time
CTD	Conductivity Temperature Depth
CUBE	Combined Uncertainty and Bathymetric Estimator, gridding algorithm for MBES data
DSM	Deep-Sea Minerals
DTM	Digital Terrain Model
DVL	Doppler Velocity Log
EM	Electromagnetics
ENV	Environmental sensors
EOL	End of Line
GNSS	Global navigation satellite system
HSEQ	Health Safety Environment and Quality
IMU	Inertial measurement unit (used to measure motion and normally combined with GNSS systems)
ISA	International Seabed Authority
LARS	Launch And Recovery System
M/V	Multipurpose Vessel
MAR	Mid-Atlantic Ridge
MBES	Multibeam echosounder
MOPO	Matrix of Permitted Operations
MSL	Mean sea level
ORP	Oxydation Reduction Potential
RTK	Real-time correction of GNSS data
SAS	Synthetic Aperture Sonar
SBP	Sub-bottom profiler
SEGY	Data format developed to store geophysical data, like seismic data
SMS	Seafloor massive sulphides (same as polymetallic sulphides)
SOL	Start of Line
SVP	Sound Velocity Profiler
TPU	Total propagated uncertainty
TWT	Two-way-travel time

1.5 Contents and use of this report

This AUV data acquisition and processing report presents results from a comprehensive survey conducted with the use of advanced technology suitable for ultradeep-water operations. Special maritime, hydrographical, geophysical, and geological nomenclature and descriptions are used throughout the report. This implies that specialised knowledge and competence in these fields may be prerequisites for further use of this report. The report does not include any assessment of buildable areas, methods or measures needed for building, and it is strongly recommended having geophysical and geological competence included in further work on the project.

Disclaimer

Argeo AS do not make any guarantees regarding the completeness of information, accuracy or content in the interpreted results of the data in this report. Including, reliability, accuracy, interpretation, information, drawings, models, advice, or statements etc. Any action you take upon the information in this report is strictly at your own risk, and Argeo AS will not be held liable for any losses and/or damages in connection with the use of any information in this report.

1.6 HSEQ

Argeo is fully committed to ensuring the safety and well-being of employees, partners and contractors. Health risks shall be minimised. Argeo actively encourages awareness and responsibility in relation to the environment, public and legislation through an open dialogue. Following contract award, Argeo developed project-specific HSE and Quality plans. An HSEQ summary specific to the project can be found in 3.1.1 Survey HSEQ. Argeo`s set of key policies on Health and Safety plus Environment, Social and Governance are enclosed in the Appendix section as Fig. 6.1 and Fig. 6.2.

Argeo conducts quarterly HSEQ Management review meetings to assess the status of our HSEQ performance as well as reviewing targets and assessing new initiatives to ensure continuos improvements. Currently, Argeo is working according to a set of processes and procedures as defined in its Management System (SIMPLI) which ensures quality of work and deliverables.

SIMPLI

Argeo’s management system is a process-driven system implemented upon the SIMPLI Integrated Management System platform and comprised of several inter-linked systems. MANAGE is the process-flow-based management system describing Argeo’s processes and procedures and linking these to the organisational structure, defining ownership and responsibilities. BETTER is the related reporting system with a fully integrated case management system. The SIMPLI system also contains a fully integrated RISK management module as well as a GDPR and a document-development and management modules for controlled documents related to the management system. SIMPLI is built on top of Microsoft’s SharePoint platform and is fully integrated with Argeo’s Microsoft 365 solution. This allows for flawless links into e.g. Outlook for notifications; as well as full integration into the user management handled within Microsoft 365. Argeo SIMPLI core processes formed the basis of project execution in line with agreed Contract requirements. Key HSEQ processes and policies are outlined with our organisation process management system, please see .

Fig. 1.6 Argeo HSE Processes

2 Data delivery

The final data delivery package includes this report, a digital copy of the processed data, results of processing for all three areas, Lokeslottet, Knipovich Area A (South), and Knipovich Area B (North). Due to the large amount of data, the raw data are only made available on physical drives delivered to the client. All raw data was delivered to the client at the end of acquisition and received on two portable hard drives on 12th October 2023.

Table 2.1 Processed data delivery contents

Folder name	Description	File type
02_MBEs	Composite Bathymetry, DTM (depth, standard deviation, soundings density, roughness, and 10 m contours) Composite Backscatter mosaics (intensity)	geotiff, xyz, gpkg
03_SBP	Processed SBP data: SEGY (envelope and full-waveform) and profile plots	segy, png, pdf
04_ENV	Environmental data	csv, geojson
05_EM	Electric field (Spontaneous Potential) data and Magnetic field data Output file (Argeo EM Listen)	csv, geojson, png
06_Charts	Report in PDF format, including high resolution figures of relevant maps and figures Daily progress reports archive	pdf
07_MAG	APS Fluxgate Magnetometer measurements	csv, geojson

3 Data acquisition

3.1 Field operations

M/V Argeo Searcher, complete with two SeaRaptor 6000 AUVs, was mobilised in the port of Tromsø, Norway and departed at 05:30 UTC on July 6, 2023, and arrived in field at the first survey location, Lokeslottet, at 13:00 UTC on July 7, 2023.

A summary of key project activities with a timeline is presented in Table 3.1

Table 3.1 Project Timeline Overview

Start Date	End Date	Activity	Description
SURVEY LEG I			
230719_D066_Fenris	19/07/2023	20/07/2023	Lokeslottet
230720_D067_Neri	20/07/2023	20/07/2023	Lokeslottet
230721_D068_Fenris	21/07/2023	21/07/2023	A_Block1AOI
230721_D069_Neri	21/07/2023	23/07/2023	A_Block1-l1-17
230722_D070_Fenris	22/07/2023	23/07/2023	A_Block1_L29-42
230723_D071_Neri	23/07/2023	24/07/2023	A_Block1_L43-55
230724_D072_Fenris	24/07/2023	25/07/2023	A_Block1_L56-64_Block2_L1-10
230725_D073_Neri	25/07/2023	26/07/2023	A_Block1_L_Block_2_L2-14
230725_D074_Fenris	25/07/2023	25/07/2023	A_Block2_L16-35
230726_D075_Fenris	26/07/2023	26/07/2023	A_Block2_24-40
230726_D076_Neri	26/07/2023	27/07/2023	A_Block2_L15-23
230802_D082_Neri	02/08/2023	03/08/2023	A_Block2-L20-23_L36-51
230803_D083_Neri	03/08/2023	04/08/2023	A_Block2-L20-23_L36-51
230822_D091_Neri	22/08/2023	23/08/2023	A_North-POI_L16-L37
230828_D095_Neri	28/08/2023	29/08/2023	A_Block2-L51-61_Block3_L1-6
230829_D096_Neri	29/08/2023	30/08/2023	A_Block3_L07-25
230830_D097_Neri	30/08/2023	31/08/2023	A_Block3_L10-28
230907_D100_Fenris	07/09/2023	08/09/2023	A_Block3_L29-48
230908_D101_Fenris	08/09/2023	09/09/2023	A_Block3_L39-57
230909_D102_Fenris	09/09/2023	10/09/2023	A_Block3_L58-61_Block4_L1-15
230910_D103_Neri	10/09/2023	12/09/2023	A_Block4_L11-31
230915_D106_Neri	15/09/2023	17/09/2023	A_Block4_45-61_Block3_L11-14
230917_D107_Neri	17/09/2023	18/09/2023	A_Block4_27-46
230918_D108_Neri	18/09/2023	19/09/2023	A Middle-AOI
230920_D109_Neri	20/09/2023	20/09/2023	A_Block5_L36-20
230923_D110_Neri	23/09/2023	25/09/2023	A_Block5_Patch_L1-13
230925_D111_Neri	25/09/2023	26/09/2023	A_Block5_L14-25
230926_D112_Neri	26/09/2023	27/09/2023	B_POI1_L1-16

3.1.1 Survey HSEQ

Operations in the Area Beyond National Jurisdiction

HSEQ is of paramount importance in conducting AUV surveys at the mid-ocean ridge. This challenging and remote environment demands a rigorous approach to ensure the safety and well-being of personnel, the protection of the fragile marine ecosystem, and the high quality and accuracy of data collected. Prior to the survey, a comprehensive risk assessment is conducted, followed by meticulous planning and preparation to address potential hazards and environmental impacts. Continuous monitoring and adherence to strict safety protocols are maintained throughout the survey to mitigate any unforeseen risks. Moreover, the team is committed to minimizing its ecological footprint by upholding the principles of HSEQ, and *following a precautionary approach as prescribed by the ISA regulations (Principle 15 [1][2]):*

• Prospecting shall not be undertaken if substantial evidence indicates the risk of serious harm to the marine environment.

• Each prospector shall take necessary measures to prevent, reduce and control pollution and other hazards to the marine environment arising from prospecting, as far as reasonably possible, applying a precautionary approach and best environmental practices.

• A prospector shall immediately notify the Secretary-General in writing, using the most effective means, of any incident arising from prospecting which has caused, is causing or poses a threat of serious harm to the marine environment [3].

Argeo's HSEQ polices and principles, as described in section 1.6 HSEQ are stringently upheld in all offshore field operations. All field crew are certified medically fit and competent to undertake their daily tasks at sea. A safety critical matrix of permitted operations (MOPO, Attachment 3.1) is under regular review and sets the limits adhered to in the field, for which the risks inherent in AUV operations can be deemed acceptable. Toolbox talks are completed with all parties involved before every key AUV activity, the most regular of which being launch and recovery. Argeo encourage an open forum of discussion and every crew member has the right and responsibility to stop the job at any time. A licensed doctor was present and available on board at all times.

The table below lists the number of HSE events throughout the offshore phase of the project.

Table 3.2 HSEQ Events

HSE Event	Number
Emergency drill	5
Toolbox talk	131
Permit to work	48
First aid case	1

SAFETY CRITICAL MATRIX OF PERMITTED OPERATIONS (MOPO) 5-2842

Condition	Small Boat operations	MOB	AUV Maintenance	AUV Deployment / Recovery	Close Approaches	Bunkering in port	Helicopter Operations	Lifting operation	Engine Repair	Hot Work	Electrical work	Confined space entry	Work in height / over the side
Twilight													
Wind Speed < 20 knots													
Wind Speed > 20 - 30 knots													
Wind Speed > 30 - 40 knots													
Wind Speed > 40 knots													
Sea State 4 and below < 2.5m													
Sea State 5 and above > 2.5m						n/a							
Visibility < 500m													
Visibility < 2000m													
Small Boat Operations	n/a												
MOB ops		n/a											
AUV Maintenance			n/a			n/a							
AUV Deploy / Recover				n/a		n/a							
Close Approaches					n/a	n/a							
Bunkering in Port			n/a	n/a	n/a	n/a	n/a						
Helicopter Operations						n/a	n/a						
Lifting operation								n/a					
Engine Repair									n/a				
Hot Work										n/a			
Electrical work											n/a		
Confined space entry												n/a	
Work in height/over the side													n/a
Controls in Place	Toolbox	Toolbox	Toolbox	Toolbox	Toolbox / checklist	Toolbox / checklist	Toolbox / Pitch Roll	Toolbox / checklist	Toolbox / Tag out	Toolbox / PTW	Toolbox / PTW	Toolbox / PTW	Toolbox / PTW
Procedure Control	5-0919	5-0919	Argeo	Argeo	5-2326	5-0007	5-1170	5-0011	5-1585	5-0079	5-0079	5-0079	5-0079

Acceptable using standard Procedures
May be acceptable subject to Risk Assessment / Toolbox Meeting and Master / Field Supervisor approval
Not Acceptable (However the Master has ultimate authority to override during an emergency)

3.1.2 Mission planning

A successful subsea survey mission relies on satisfying three key criteria:

1.Mission is operationally safe

2.Mission is designed to provide the highest quality data and insights

3.Mission is efficient; as well as optimised across all three criteria

The first criterion guides the survey line pattern and available altitude ranges for a given area and relies on a thorough analysis of background data and excellent knowledge of the equipment. Initial survey planning was conducted based on low resolution bathymetry provided by NPD. Seafloor topography, and particularly the slope and its gradient, is an important consideration for mission planning. Spatial distribution of high-slope features (topography roughness) is another important factor affecting the AUV's ability to maintain constant altitude while maneuvering and avoiding seafloor collision. Both parameters were carefully considered for each mission, along with technical capabilities and limitations of the equipment.

The second criterion depends on survey objectives, local conditions, and data requirements. In this project, background data was limited to low-resolution bathymetry, CTD cast, and regional geophysical maps. Therefore, some survey parameters were tested in the field during the first production dive. MBES settings were tested in order to define suitable sensor settings such as Coverage Angle, Transmit Power, Spreading Loss, Absorption Loss, Receiver Gain. The test implied allowing dynamic tracking of the listed settings and subsequent analysis of the data, where most suitable set of parameters was defined and later fixed for subsequent missions in the same area. Other payload settings are similarly controlled and verified based on the acquired data analysis immediately after recovery.
Line spacing, survey altitude, and speed are reviewed at this step to ensure proper coverage with necessary overlap, good signal penetration, and data density.
All parameters are subject to continuous review and quality assurance, and are optimised with respect to survey efficiency. As a result, payload settings, GIS files prescribing the planned survey lines and describing the survey area created by the technical lead of the project are provided to the AUV team for assistance in further AUV mission planning and programming. Based on close analysis of the terrain and thorough review of the navigational limitations of the AUVs, the final mission plans are developed offshore to provide full data coverage in each AOI whilst ensuring the safety of the AUV. Important factors considered during final mission planning include the direction of line, direction of travel on a slope, direction of turn relative to the underlying topography, following the natural profile of prominent features, such as steep ridges or crevices.
AUV missions consist of all the information and commands the AUV requires flying along a predefined route and acquire the desired payload data. Multiple separate missions can be loaded on to the AUV and are contained within a unique campaign. Missions within a campaign can be executed over a subsea acoustic telemetry link between the AUV and the topside operator control software. Multiple optional missions are incorporated into campaigns to allow the AUV operator to, for example, redirect the AUV to a different line if the AUV cannot overcome a certain obstacle, e.g. a very steep slope directly ahead.
Naming conventions for dive and missions for the project were as follows:
Dive: Date_Dive Number_AUV name_Area
Example:
230923_D110_Neri_A_Block5_L1-13
Date: 23/09/2023
Dive Number: D069
AUV name: Neri
Area: A_Block5_L1-13
Payload setting: Fig. 3.1

SeaRaptor Payload Setting pr Mission		
Campaign	ARG-23085_NPD	
Mission	All missions	
Created by	TA	
Approved by:		
LineType	NPD mission lines	
Altitude	75	m
Speed	1.6	m/s

MBES T50	Setting to use	Comment
Frequency	400 kHz	Generally : 400 kHz < 100 m altitude, 200 kHz above
Pulse Type	CW	NB: X-range cause payload re-boot, use CW for now. Exception if SAS turned off for whole dive
Track Range	ON	before selecting, untick to set range set to max range 200 m
Track Power/Gain	OFF	
Track Pulse Length	OFF	
Track Coverage	OFF	
Water Column data	Compressed	
Remove beyond detection point	Check	if compressed wc on,, default = ON
Compress to 8 bits	Check	if compressed wc on, default = ON
Remove phase data	Check	if compressed wc on, , default = ON
Downsampling Type	Peak	if compressed wc on, , default = ON
Downsampling Factor	2	if compressed wc on (typically 2-5)
Coverage Angle	110	only set if Track Coverage off
Transmit Power	218 dB	only set if Track Power/Gain off
Spreading Loss	58 dB	only set if Track Power/Gain off
Receiver Gain	20 dB	only set if Track Power/Gain off
Absorption Loss	58 dB/km	only set if Track Power/Gain off
Pulse Length	120 us	only set if Track Pulse Length off
Trigger Mode	Master	Only set as master if SAS is off
Maximum Ping Rate	20 Hz	T50 max is 20 Hz?
Adaptive Percentage	25%	Default = 25 %
Adaptive Gate Depth Min.	25	Default = 2 m, for higher altitudes: consider altitude/2
Adaptive Gate Depth Max.	275	Default = altitude + 200 m?

Sub-Bottom Profiler	Setting to use	Comment
Trasmit Power Index	0 (highest)	Default = 0 (have never changed this actually)
Pulse Lenght	30 ms	Adjust relative to altitude, use GetRecommendedSBP spreadsheet
Hardware Gain	18 dB	Can be increased at higher altitude
Pulse Type	CHIRP (Default)	Always use CHIRP
Date Mode	BIPOLAR (Default)	Alway use BIPOLAR
Data Acquisition Time	266 ms (Default @ 20 m altitude)	Adjust relative to altitude + penetration, use GetRecommendedSBP spreadsheet
Raw Data mode	Processed Data Only	Default (Processed Data Only)

EM Listen	Setting to use	Comment
	ON	NB: Need to be enabled during pre-dive

ADCP ON		
ENV sensors + + all ON		

Fig. 3.1 AUV Payload Settings

3.1.3 Data acquisition summary

Brief fieldwork summary

The main objective of the project was high-resolution near-seafloor data acquisition for the identification and delineation of SMS and/or hydrothermal venting occurrences, and baseline mapping and characterization of the environment. To achieve this objective, Argeo has deployed two autonomous underwater vehicles (AUV's) equipped with a suite of advanced sensors that were activated depending on the survey phase.

The project acquisition timeline starting early July and ending late September.

Payload Settings

The payload settings are listed in Fig. 3.2

Table 3.3 Active Payload Sensors

Sensor Type	Phase I Active

Multibeam Echosounder	Yes
Synthetic Aperture Sonar	No
Sub-Bottom Profiler	Yes
Magnetometer	Yes
'Argeo Listen' (SP)	Yes
Environmental Sensors (pH, ORP, turbidity, methane, dissolved oxygen, CTD)	Yes
Camera and Laser	No

Note: Due to technical failure, SP data is missing in D100 to D103.

SeaRaptor Payload Setting pr Mission		
Campaign	ARG-23085_NPD	
Mission	All missions	
Created by	TA	
Approved by:		
LineType	NPD mission lines	
Altitude	75	m
Speed	1.6	m/s

MBES T50	Setting to use	Comment
Frequency	400 kHz	Generally : 400 kHz < 100 m altitude, 200 kHz above
Pulse Type	CW	NB: X-range cause payload re-boot, use CW for now. Exception if SAS turned off for whole dive
Track Range	ON	before selecting, untick to set range set to max range 200 m
Track Power/Gain	OFF	
Track Pulse Length	OFF	
Track Coverage	OFF	
Water Column data	Compressed	
Remove beyond detection point	Check	if compressed wc on,, default = ON
Compress to 8 bits	Check	if compressed wc on, default = ON
Remove phase data	Check	if compressed wc on, , default = ON
Downsampling Type	Peak	if compressed wc on, , default = ON
Downsampling Factor	2	if compressed wc on (typically 2-5)
Coverage Angle	110	only set if Track Coverage off
Transmit Power	218 dB	only set if Track Power/Gain off
Spreading Loss	58 dB	only set if Track Power/Gain off
Receiver Gain	20 dB	only set if Track Power/Gain off
Absorption Loss	58 dB/km	only set if Track Power/Gain off
Pulse Length	120 us	only set if Track Pulse Length off
Trigger Mode	Master	Only set as master if SAS is off
Maximum Ping Rate	20 Hz	T50 max is 20 Hz?
Adaptive Percentage	25%	Default = 25 %
Adaptive Gate Depth Min.	25	Default = 2 m, for higher altitudes: consider altitude/2
Adaptive Gate Depth Max.	275	Default = altitude + 200 m?

Sub-Bottom Profiler	Setting to use	Comment
Trasmit Power Index	0 (highest)	Default = 0 (have never changed this actually)
Pulse Lenght	30 ms	Adjust relative to altitude, use GetRecommendedSBP spreadsheet
Hardware Gain	18 dB	Can be increased at higher altitude
Pulse Type	CHIRP (Default)	Always use CHIRP
Date Mode	BIPOLAR (Default)	Alway use BIPOLAR
Data Acquisition Time	266 ms (Default @ 20 m altitude)	Adjust relative to altitude + penetration, use GetRecommendedSBP spreadsheet
Raw Data mode	Processed Data Only	Default (Processed Data Only)

EM Listen	Setting to use	Comment
	ON	NB: Need to be enabled during pre-dive

ADCP ON		
ENV sensors + + all ON		

Fig. 3.2 The applied payload Settings

3.2 Vessel equipment and operations

The vessel, named Argeo Searcher, is a multi-purpose DP II vessel, formerly known as the Ocean Pearl. Equipped with modern diesel-electric propulsion, it offers a fuel-economic platform for Argeo operations. The vessel boasts significant capacities, including an impressive 200 days of endurance, accommodation for up to 65 personnel, and a fully certified helicopter deck with an ICE 1A1 classification. Key Specifications are provided in Attachment 3.2 and Attachment 6.1.

1. Vessel particulars

	Requested Information
Name of vessel	M/v Argeo Searcher
Type of vessel	Survey Research Vessel
(include detail of any special features)	+AUT-UMS, HEL, +DYNAPOS- AM/AT- R
Previous name(s)	M/v Ocean Pearl
Vessel owner - Name	Ocean Pearl AS
Vessel owner - Address	N-5384 Torangsvag, Norway
Vessel owner - Tel	+47 99152657
Vessel owner - Email	christian@osterbris.no
Vessel operator (if not owner) - Name	OSM Bergen Offshore AS
Vessel operator - Address	Sandsliasen 46, 5254 Sandasli, Norway
Vessel operator - Tel	+47 48060361
Vessel operator - Email	Fredrik.Winberg@osm.no
Ship or vessel superintendent/manager - name	Fredrik Winberg
Ship or vessel superintendent/manager - address	Same as operator
Ship or vessel superintendent/manager - tel	+47 48060361
Ship or vessel superintendent/manager - email	Fredrik.Winberg@osm.no
Date current vessel operator assumed responsibility for vessel	2022
Manning agent (if different from vessel operator) - Name	OSM
Manning agent - Address	Same as operator
Manning agent - Tel	Same as operator
Manning agent - Email	
Flag	Bahamas
If the vessel has changed flag within the past six months, report date of change	
If the vessel has changed flag within the past six months, report previous flag, otherwise select 'Not applicable'	Please select ...
Port of registry	Nassau
Classification society	Bureau Veritas
If the vessel has changed Class in the past six months, report date of change	2023-01-07
If vessel has changed Class within the past six months, report previous classification society, otherwise select 'Not applicable'	DNV (Det Norske Veritas)
Class ID number	39C470
Additional comments (include any additional specialised equipment vessel has onboard)	
Hull type (e.g. double hull, semi-submersible, catamaran)	Monohull
Length overall (LOA) – in metres	108.6
Beam - in metres	18.0
Maximum draught - in metres	6.3
Deadweight tonnage – in tonnes	2214
Gross tonnage	7828
Main engine manufacturer	2x Stork –Wartsila 6GL28 , 1800 KW, 900 rpm 2x Wartsila Vasa 6R32, 2430 KW, 720rpm (year 2000)
Main engine horsepower - in kW	8460
Number of engines	4

	Requested Information
Number of main propellers	2
Type of main propellers	2 x Aquamaster US 2001, 1600 KW, 0-1200 rpm, FPP
Number of rudders	N/A
Number of generators	4
Kort nozzles fitted?	on
Number of bow thrusters fitted	3
Type of bow thrusters fitted	Tunnel 3 x Ulstein (Rolls Royce) 375 TV, 1275 KW, CPP
Capacity of bow thrusters - in kW	1275
Number of stern thrusters fitted	0
Type of stern thrusters fitted	N/A
Capacity of stern thrusters - in kW	0
Number of other propulsors fitted	0
Type of other propulsors fitted	N/A
Rated bollard pull (as applicable) - in tonnes	
Type of bunkers	MGO
Bunker capacity - in metres³	1671
Daily fuel consumption - in metres³ per day	15
Can vessel make potable water?	on
Potable water capacity - in metres³	611
Inmarsat number	+870325775210
V-Sat number	+4751406211
Vessel mobile phone number	+4797718465
Vessel email address	bridge@argeo-searcher.osm.no
Call sign	C6ZW4
Date of last owner's/operator's superintendent's visit to vessel	2023-03-15
Name of the vessel's P&I club	Gard P&I (Bermuda) Ltd
Date of last port state inspection (see question 2.2)	2023-02-08
Name and contact details for designated person ashore (DPA)	Geir-S. Rasmussen: mail : geir.sasmussen@osm.no, phone : (DPA) +47 92891785
Date of last dry docking or in water survey	2023-03-28
Location of last dry docking or in water survey	Las Palmas, Spain

Argeo Searcher is permanently outfitted with purpose-built installations onboard the vessel to operate two Teledyne SeaRaptor AUVs named 'Fenris' and 'Neri', which are rated for operations at a depth of up to 6000 meters (see more in 3.3 AUV spread).

Dimensional Control Survey and Heading Pitch Roll Calibration

To ensure accurate data acquisition during the survey, necessary preparations were made to the Argeo Searcher. The vessel underwent dry docking to facilitate the installation of new gate valves and transducer dock sea chests. These enhancements allowed for the subsequent installation of Sonardyne Lodestar gyroUSBL LMF and MF transceivers.

During the dry dock period, Anko Marine, a contracted surveying company, conducted the first phase of the dimensional control offset survey. The primary objective of this phase was to establish a common coordinate reference system for the vessel, anchored to a newly defined reference point, see Attachment 6.7.

However, at the time of the initial survey, the USBL transceivers had not been fitted on the vessel. As a result, a second phase survey was carried out after the Argeo Searcher left drydock. This second phase of the survey included obtaining offsets for the USBL transceivers and performing heading, pitch, and roll calibration, see Attachment 6.8.

The two-phase dimensional control survey ensures that accurate positioning data is available for the vessel during the production survey on site, guaranteeing reliable and precise data acquisition throughout the operation.

Key Specifications are provided in Fig. 3.3 and Fig. 3.4 Searcher Vessel Particulars and Attachment 6.1.

1. Vessel particulars

	Requested Information
Name of vessel	M/v Argeo Searcher
Type of vessel	Survey Research Vessel
(include detail of any special features)	+AUT-UMS, HEL, +DYNAPOS- AM/AT- R
Previous name(s)	M/v Ocean Pearl
Vessel owner - Name	Ocean Pearl AS
Vessel owner - Address	N-5384 Torangsvag, Norway
Vessel owner - Tel	+47 99152657
Vessel owner - Email	christian@osterbris,no
Vessel operator (if not owner) – Name	OSM Bergen Offshore AS
Vessel operator - Address	Sandsliasen 46, 5254 Sandasli, Norway
Vessel operator - Tel	+47 48060361
Vessel operator - Email	Fredrik.Winberg@osm.no
Ship or vessel superintendent/manager – name	Fredrik Winberg
Ship or vessel superintendent/manager – address	Same as operator
Ship or vessel superintendent/manager – tel	+47 48060361
Ship or vessel superintendent/manager – email	Fredrik.Winberg@osm.no
Date current vessel operator assumed responsibility for vessel	2022
Manning agent (if different from vessel operator) – Name	OSM
Manning agent – Address	Same as operator
Manning agent – Tel	Same as operator
Manning agent – Email	
Flag	Bahamas
If the vessel has changed flag within the past six months, report date of change	
If the vessel has changed flag within the past six months, report previous flag, otherwise select 'Not applicable'	Please select ...
Port of registry	Nassau
Classification society	Bureau Veritas
If the vessel has changed Class in the past six months, report date of change	2023-01-07
If vessel has changed Class within the past six months, report previous classification society, otherwise select 'Not applicable'	DNV (Det Norske Veritas)
Class ID number	39C470
Additional comments (include any additional specialised equipment vessel has onboard)	
Hull type (e.g, double hull, semi-submersible, catamaran)	Monohull
Length overall (LOA) – in metres	108,6
Beam - in metres	18,0
Maximum draught – in metres	6,3
Deadweight tonnage – in tonnes	2214
Gross tonnage	7828
Main engine manufacturer	2x Stork –Wartsila 6GL28 , 1800 KW, 900 rpm 2x Wartsila Vasa 6R32, 2430 KW, 720rpm (year 2000)
Main engine horsepower – in kW	8460
Number of engines	4

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Fig. 3.3 Argeo Searcher – IMCA Vessel Particulars 1

	Requested Information
Number of main propellers	2
Type of main propellers	2 x Aquamaster US 2001, 1600 KW, 0-1200 rpm, FPP
Number of rudders	N/A
Number of generators	4
Kort nozzles fitted?	on
Number of bow thrusters fitted	3
Type of bow thrusters fitted	Tunnel 3 x Ulstein (Rolls Royce) 375 TV, 1275 KW, CPP
Capacity of bow thrusters - in kW	1275
Number of stern thrusters fitted	0
Type of stern thrusters fitted	N/A
Capacity of stern thrusters - in kW	0
Number of other propulsors fitted	0
Type of other propulsors fitted	N/A
Rated bollard pull (as applicable) - in tonnes	
Type of bunkers	MGO
Bunker capacity - in metres³	1671
Daily fuel consumption - in metres³ per day	15
Can vessel make potable water?	on
Potable water capacity - in metres³	611
Inmarsat number	+870325775210
V-Sat number	+4751406211
Vessel mobile phone number	+4797718465
Vessel email address	bridge@argeo-searcher.osm.no
Call sign	C6ZW4
Date of last owner's/operator's superintendent's visit to vessel	2023-03-15
Name of the vessel's P&I club	Gard P&I (Bermuda) Ltd
Date of last port state inspection (see question 2.2)	2023-02-08
Name and contact details for designated person ashore (DPA)	Geir-S. Rasmussen: mail : geir.sasmussen@osm.no, phone : (DPA) +47 92891785
Date of last dry docking or in water survey	2023-03-28
Location of last dry docking or in water survey	Las Palmas, Spain

Fig. 3.4 Argeo Searcher – IMCA Vessel Particulars 2

3.2.1 GNSS and USBL positioning

Argeo Searcher is equipped with a sophisticated USBL (Ultra-Short BaseLine) acoustic positioning system, which is an integral part of the vessel's survey suite. The system is fully independent from the ship's navigation systems but provides a USBL feed to the Dynamic Positioning (DP) system on the ship for enhanced positioning capabilities. These cross-feeds between the survey suite and the ship's systems provide additional redundancy of heading, pitch & roll.

The survey suite, depicted in Fig. 3.5, comprises the following components:

Searcher Survey System

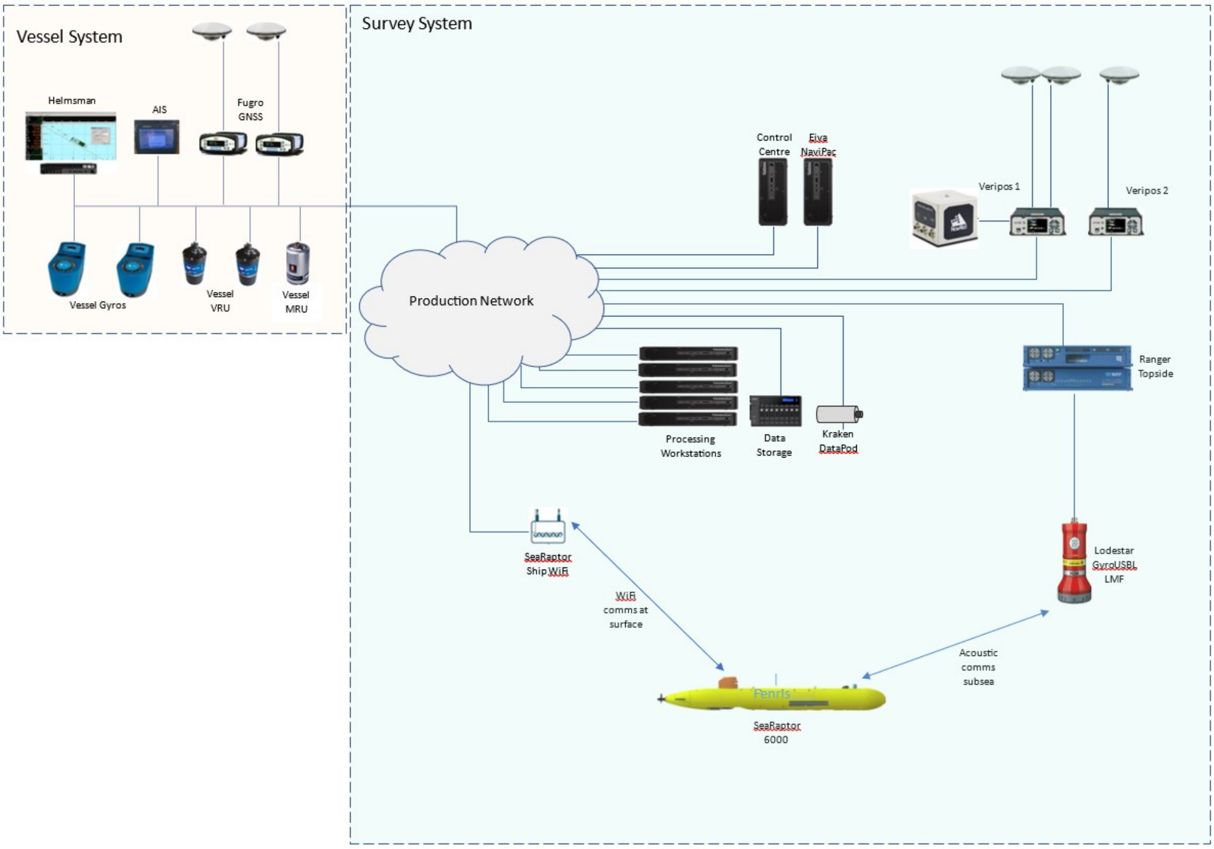

Fig. 3.5 Searcher Survey System Overview

1. GNSS - Veripos LD900+IMU: This system combines GNSS positioning with inertial navigation system (INS) measurements, including velocity, attitude, and heave. The Veripos GNSS+INS technology is customized for hydrographic survey applications, ensuring accurate 3D positioning even during extended GNSS outages. The Veripos Quantum software is used for GNSS visualization, providing a suite of modules that can be operated independently without affecting the operational position computation.
2. Heading - Veripos LD900 (Attachment 6.2): This component, combined with the IMU-ISA-100C, offers high-rate, high-accuracy heading and motion output.
3. Motion - Veripos IMU (Attachment 6.3): The motion system contributes to providing accurate motion data during the survey operations.
4. USBL - Sonardyne Ranger2 with Lodestar GyroUSBL LMF Transceiver (see Attachment 6.4 and Attachment 6.5): The USBL system consists of a Sonardyne Ranger2, which is a 6th generation high-performance HPT USBL transceiver, and a Lodestar Attitude and Heading Reference System (AHRS) / Inertial Navigation System (INS) integrated into the same mechanical assembly. The Lodestar GyroUSBL combines power, communications, and highly accurate time-stamping capabilities for all motion and acoustic data.
5. USBL AvTrak Transponder (see Attachment 6.6): The AvTrak LMF transponder establishes the acoustic link between the SeaRaptor AUV and the surface vessel (Argeo Searcher).

Sonardyne USBL CASIUS Calibration

Before the commencement of the NPD Knipovich campaign, a crucial CASIUS calibration of the Sonardyne Ranger2 USBL system was performed by a Sonardyne engineer. This calibration ensures the accuracy and reliability of the USBL system during the survey operations. Results are shown in Attachment 6.9.

Furthermore, to address an observed depth offset, a second CASIUS check was conducted to validate the effectiveness of an amended Z offset. This step ensures that the corrected depth offset aligns with the required precision for accurate positioning of the AUV during the survey. Results from the second CASIUS test can be found in Attachment 6.10.

3.2.2 SVP casting

Valeport Midas SVX2 CTD probe, serial number 32138, was used to gather Sound Velocity Profile (SVP) data. This advanced instrument measures conductivity, temperature, and depth accurately. The SVP data helps correct acoustic signals and improves the precision of underwater measurements during surveys and marine research missions.

3.2.3 AUV operations on Argeo Searcher

The Argeo Searcher operates the SeaRaptor 6000 AUVs from a purpose-built installation on board the vessel. The AUVs are controlled via WiFi communications when on the surface, both after launch and before recovery. However, once the AUV begins its dive, all communication, positioning, and control are handled via the Sonardyne Ranger with gyroUSBL transceiver topside and the AvTrak 6 subsea transponder installed on the AUV.

Mission Planning and Operational Control

Mission planning and AUV operational control are carried out using the Teledyne Control Center application, which runs on a PC installed in an environmentally controlled Data/Server room. The operations room is adjacent to the Data/Server room.

Mission plans are prepared independently of the online operations. After the completion of the mission plans, an Online Operator conducts a Quality Control (QC) check to ensure accuracy and completeness. Once satisfied, the online operator uploads the mission plan to the AUV for execution.

AUV Launch and Control:

The Launch and Recovery System is a bespoke installation.

Prior to AUV launch, the on-line operator and deck technician follow detailed checklists and coordinate activities to efficiently prepare the AUV. Once the AUV is ready for a launch and a Toolbox Talk has been carried out, the AUV is driven down the rails and held while the Inertial Navigation reaches a fully aligned status. Once the INS is aligned, and the vessel is moving at 1.5 kts, the Online Operator gives the green light for the AUV to be released.

The Deck Technician uses Control Center on a rugged laptop to pilot the AUV, while the Online Operator carries out post-launch checks. Once these checks are completed, and the Deck Technician has piloted the AUV on a safe heading away from the ship, the Online operator executes the mission, and the AUV begins its dive.

Throughout the mission, the on-line station is continuously manned to monitor the AUV's progress and status.

Positioning and Navigation

The geographic position of the AUV is calculated by Sonardyne Ranger and through AvTrak SMS communications this position is fed to the AUV. The AUV integrates this measured USBL position into its Inertial Navigation solution to mitigate the natural tendency of INS systems to drift over time.

AUV Recovery

Upon completion of the mission, the AUV returns to the surface, and the Deck Technician pilots the AUV to a safe position. When ready for recovery, a float, attached to the AUV tow-line, is released from the AUV. A Pneumatic Line Thrower is then used to propel a grapnel with a painter line over the AUV tow-line, enabling the float to be pulled aboard and attached to the LARS winch. The AUV is winched up the cradle and returned to the preparation area.

Preparation Area and Maintenance

The aft preparation area is utilized for dive preparation, post-dive tasks, and battery changes. However, when required, the AUV cradle can be easily detached from the LARS trolley, allowing the AUV to be brought into the hangar for more extensive maintenance or safe stowage.

3.3 AUV spread

The SeaRaptor 6000 used for the survey are survey grade deep-water AUVs designed to operate at abyssal depths. A wide range of sensors allows the SeaRaptor 6000 to complete different types of missions including hydrographic survey with Multibeam Echosounder and Sub Bottom Profiler, high-resolution visual inspection survey with UHD Camera and Laser system and broad-area acoustic imaging with Synthetic Aperture Sonar, geophysical survey with Argeo Listen and Magnetometer, or environmental survey with various water-column measurements. These surveys support a variety of applications, such as inspection, search & recovery, salvage, marine mineral exploration, construction support, marine archaeology, and oceanography.

The vehicle offers several payload ports that provide serial communication, Ethernet, and power. These ports can be used for field-swappable sensors. In addition, removable batteries and data storage enable rapid turn-around to maximize operating time. The vehicle is equipped with all the necessary navigation sensors and support for acoustic aiding required for accurate deep-water navigation. Multiple safety systems, providing improved redundancy by including multiple devices both for recovery underwater and on the surface, are part of the AUV system.

An overview of the AUV sensors mounted on Argeo SeaRaptors is provided in Fig. 3.6. More details about the vehicle can be found in the following section and the 6.3 SeaRaptor AUV .

Navigation and environmental sensors

INS	iXblue Phins 6000 (0.01% Distance Travel)
DVL	RDI Tasman DVL (300 kHz w/ADCP)
CTD	Valeport uxSVP
Environmental sensors	RBR Maestro (CTD, Oxygen, Methane, pH, Turbidity, RedOx)

Payload sensors

Multibeam	Teledyne Reson T50 DF (200/400 kHz)
Sub-Bottom Profiler	Benthos Chirp III
Synthetic Aperture Sonar	Kraken minSAS 120 w/Real-Time onb. proc
Camera and Laser	CathX Hunter UHD system
Magnetometer	Applied Physics 3-axis fluxgate magnetometer
CSEM/SP	Argeo Robotics EM System
Onboard data processing	Caris Onboard and EIVA

Fig. 3.6 Searaptor 6000 specifications

3.3.1 Navigation and Positioning sensors

The SeaRaptor AUV is equipped with iXblue Phins 6000 INS unit for attitude and positioning of the AUV, with additional aiding sensors and systems:

- GPS: provides global position when AUV at surface. RTK-corrected GPS fixes provide centimetre accuracy at surface.
- DVL: tracks heading and speed over ground as long as seabed returns can be detected (maximum altitude is around 400 m).
- USBL: acoustic positioning system that tracks an AUV from the topside vessel. It can be used for both tracking and aiding the AUV. USBL fixes have been used both in real-time solution and during navigation post-processing.
- Pressure sensor: main input for the AUV depth logging. The data is later corrected for sea state (tides).

For speciations of the sensors for navigation, refer to Appendix 6.3.2 AUV navigations system specifications .

3.3.2 Multibeam Echosounder

For this project, Argeo utilized the Teledyne Reson SeaBat T50-S 200/400kHz multibeam echosounder sensor, which was installed on the SeaRaptor AUVs. The sensor system consists of two transmitters operating at different frequencies: 200 kHz and 400 kHz. The 400 kHz frequency provides superior resolution but comes with the trade-off of reduced range. As a result, the 400 kHz frequency is primarily employed at flight heights of 100 m or lower that aim to collect high-resolution data, whereas the 200 kHz frequency is recommended for higher altitudes due to its increased range capabilities.

Data are recorded into s7k files, including both bathymetry and backscatter data as standard. Optionally, water column data can also be recorded. To avoid a vast amount of data, water column data are normally compressed, by downsampling and only keeping amplitude information. During operations, data recording and sensor control for the Reson T50 sensor are conducted on a separate payload computer utilizing the SonarUI software. This software enables monitoring and modification of ping rates, swath width, and beam patterns. All settings are configured during mission planning in the Gavia Control Centre, and during the mission execution, the AUV control module updates the SonarUI settings based on the mission plan.

The SeaBat T50 is mounted on the same bracket as the INS, receiving real-time navigation and attitude data from it. The system's mounting is illustrated in Fig. 3.7. For detailed specifications of the T50-S system, refer to Attachment 6.16.

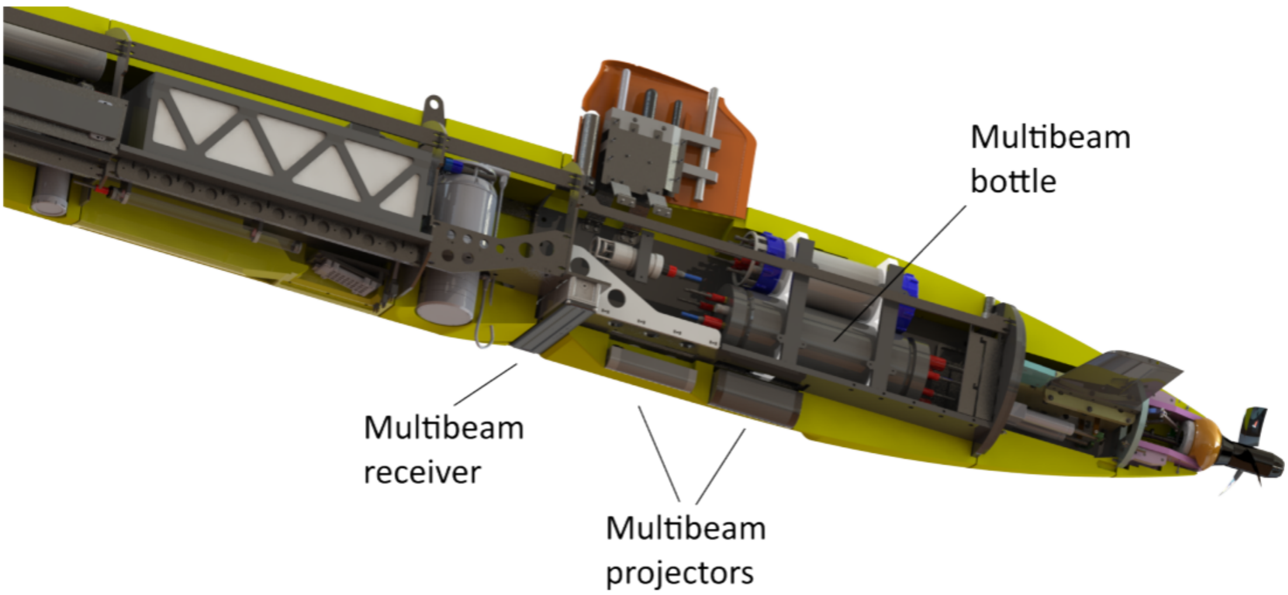

Fig. 3.7 SeaBat T50-S mount, SeaRaptor 6000

3.3.3 Sub-Bottom Profiler

For the acquisition of subsurface data, the SeaRaptors AUVs are equipped with the Benthos Chirp III LF (1.5-8kHz) sub-bottom profiler system. The system consists of a separate transmitter, and two receiver arrays located on each side of the AUV (see Fig. 3.8). The system operates using a chirp technique, where the transmitting signal is a frequency-modulated pulse with a frequency range of 1.5 - 8 kHz (a wider bandwidth allows for better resolution). The depth of penetration achieved by the system depends on the sediment lithology, with an anticipated performance of up to 80 m in clay and approximately 5-10 m in coarse calcareous sands.

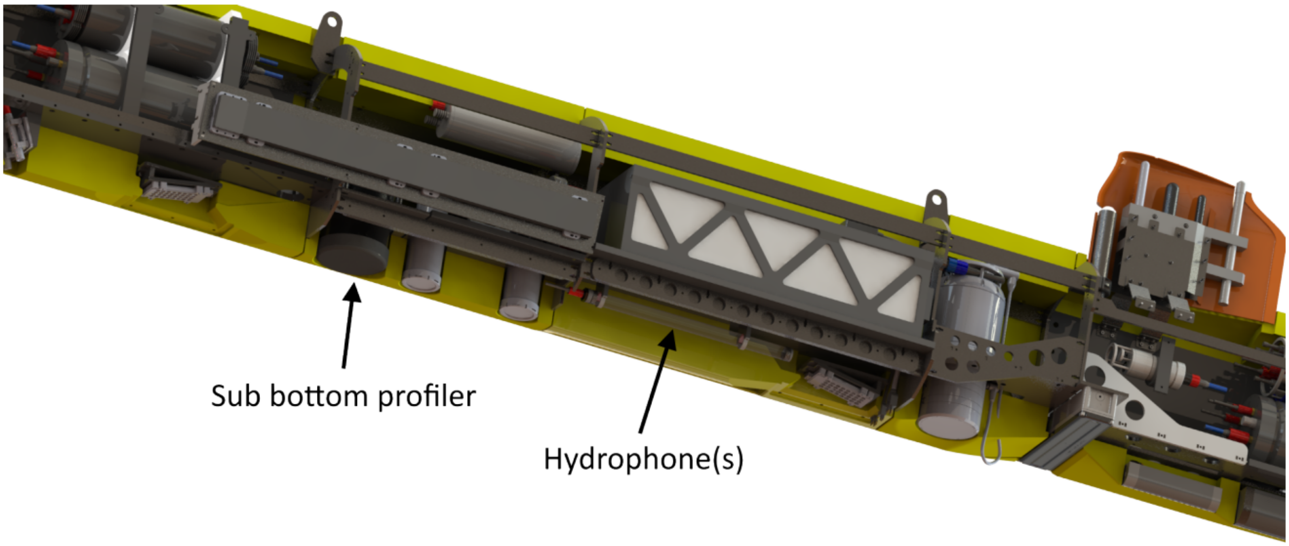

Fig. 3.8 SBP mount, SeaRaptor

The collected data is stored in both SEGY data formats, preserving the full waveform, which includes both amplitude and phase information. For more comprehensive details about the SBP system, please refer to Attachment 6.17

3.3.4 Electric Field sensor

The marine Self-Potential (SP) sensor system used in this project is the Argeo Listen system. Its primary purpose is to acquire electric field data in marine environments. The system is composed of 8 flush-mounted electrodes, arranged in set pairs along the hull of the AUV. These electrodes are strategically positioned to measure the potential difference between each pair of electrodes. The recorded potential differences are then processed to calculate three components of the Electric Field.

The flush-mounted electrode design ensures minimal protrusion from the AUV's hull, reducing the risk of damage to the system during launch and recovery operation, and minimise the turbulence around the sensors during the survey. This feature and other design considerations provide a significantly improved signal-to-noise ratio enabling accurate potential difference measurements, which are fundamental in determining the electric field's characteristics.

3.3.5 Magnetometer

The Applied Physics 1540 fluxgate magnetometer is an advanced sensing instrument used for measuring and analyzing magnetic fields in marine environments. The magnetometer is particularly designed for integration with marine Autonomous Underwater Vehicles (AUVs), being mounted inside the hull of the SeaRaptors (Fig. 3.9).

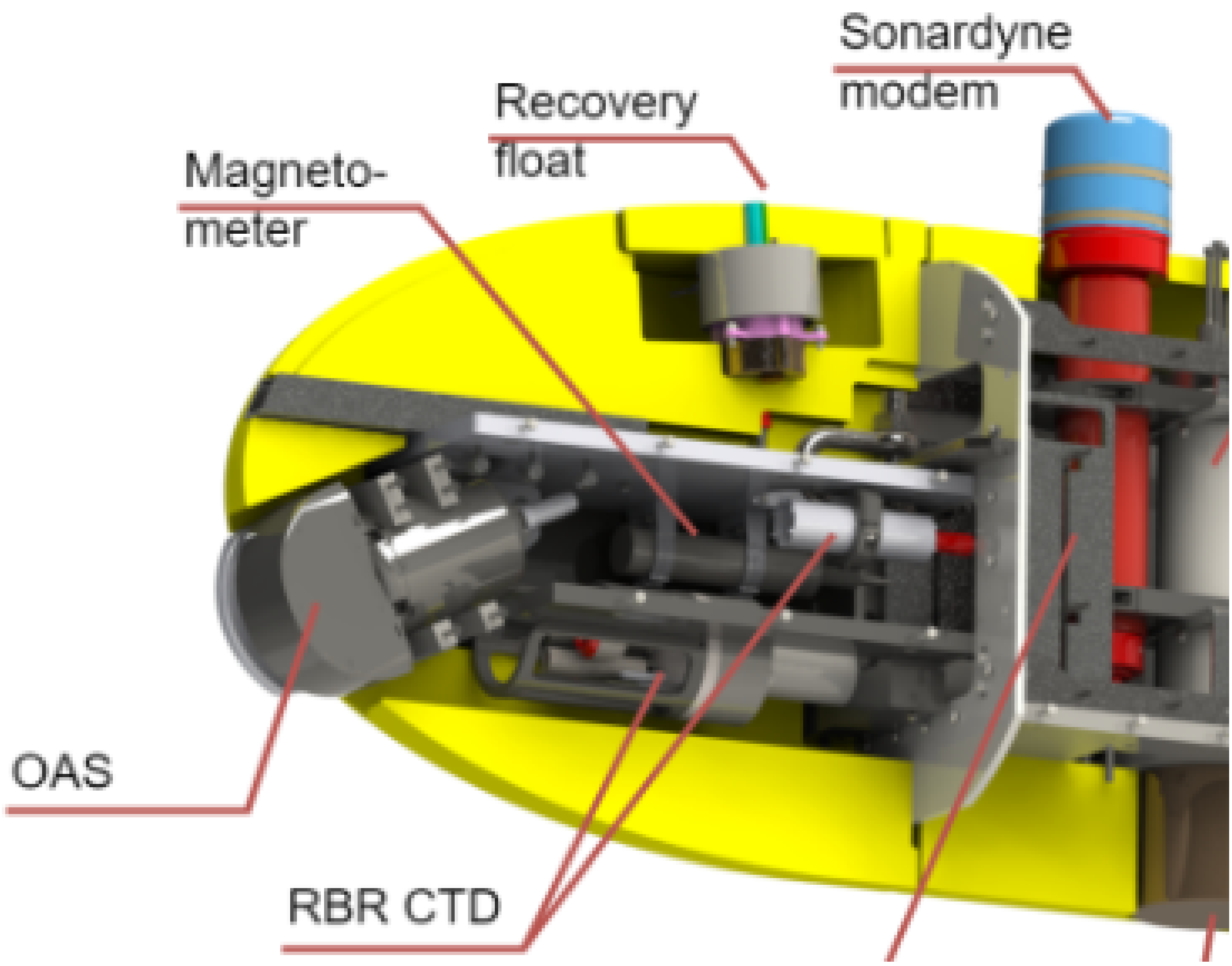

Fig. 3.9 Magnetometer, RBR systems mount, SeaRaptor

The fluxgate magnetometer operates based on the principle of magnetic induction. It consists of a core made of ferromagnetic material with two or more coils of wire wound around it. When exposed to an external magnetic field, the magnetic induction within the core changes, inducing an electrical current in the coils. This induced current is then processed and analyzed to determine the magnitude and direction of the ambient magnetic field.

The Applied Physics 1540 magnetometer is known for its high precision and sensitivity, allowing it to detect even subtle variations in magnetic fields. The data collected by the magnetometer can be used in a range of scientific applications, including marine geophysics, oceanography, and environmental monitoring. It aids in identifying magnetic anomalies associated with geological structures, mineral deposits, and hydrothermal vents, which is the objective of this project.

The sensor's datasheet can be found in 6.3.5 Magnetometer: Applied Physics 1540 specifications

3.3.6 Environmental sensors

In deep-sea exploration projects including the current project, environmental data refers to water physics and chemistry data collected in the water column. The SeaRaptors AUVs are equipped with several sensors designed to collect relevant environmental data, ensuring a comprehensive understanding of the underwater conditions:

1. RDI Tasman DVL: The Doppler Velocity Log (DVL) from RDI measures the vehicle's velocity relative to the seabed. While not a direct environmental parameter, the data from the DVL is crucial for navigation and understanding the AUV's movement in the water column, which is essential for accurately georeferencing the collected environmental data.

2. Valeport uxSVP: The Valeport sound velocity profiler (uvSVX) is designed to measure the speed of sound in the water column. This parameter is vital for accurately calculating other environmental properties, such as depth and conductivity. It provides essential information for understanding the variations in water properties, which in turn helps in identifying different water masses and understanding underwater currents.

3. RBR maestro (Fig. 3.9): The RBR maestro sensor is a versatile multi-sensor device that measures various water physics and chemistry parameters. It provides crucial data for the following environmental parameters:

- Pressure: The RBR maestro measures pressure, which is used to calculate depth.
- Conductivity: Conductivity data is used to determine salinity and specific conductivity.
- Temperature: The sensor measures temperature variations in the water column.
- ORP (Oxidation-Reduction Potential): The ORP data helps assess the water's oxidative capacity, which is relevant for understanding environmental conditions.
- pH: The sensor measures the acidity or alkalinity of the water, providing insight into water quality.
- Speed of Sound: As mentioned earlier, the speed of sound in water is measured directly by the Valeport uxSVP or calculated based on pressure and conductivity readings.
- Turbidity: Turbidity measurements help assess the clarity of the water and can provide indications of suspended particulate matter.
- Oxygen Concentration: Oxygen concentration is essential for understanding the dissolved oxygen levels in the water, which directly affect marine life and ecosystems.
- Oxygen Saturation: This parameter indicates the percentage of dissolved oxygen relative to the water's saturation point, providing valuable insights into the water's oxygen availability for marine organisms.

An overview of the environmental sensors and their key specifications and separate datasheets for the sensors can be found in 6.3.6 ENV: RBR maestro, Tasman DVL, uvSVX.

3.3.7 Synthetic Aperture Sonar

Although acquisition of SAS data was beyond the scope of this project, a short description of the AUV capabilities also including SAS data is included here.

The Searaptor 6000 AUV's are equipped with Kraken minSAS 120, which is a miniature Interferometric Synthetic Aperture Sonar (SAS) system. This advanced sonar system consists of two receiver arrays on each side of the AUV (Fig. 3.10). By combining the data from these arrays and processing it through SAS processing, the MINSAS 120 is capable of providing high-resolution side-scan images with an impressive resolution of 3x3 cm at a range of up to 200 meters on each side of the AUV.

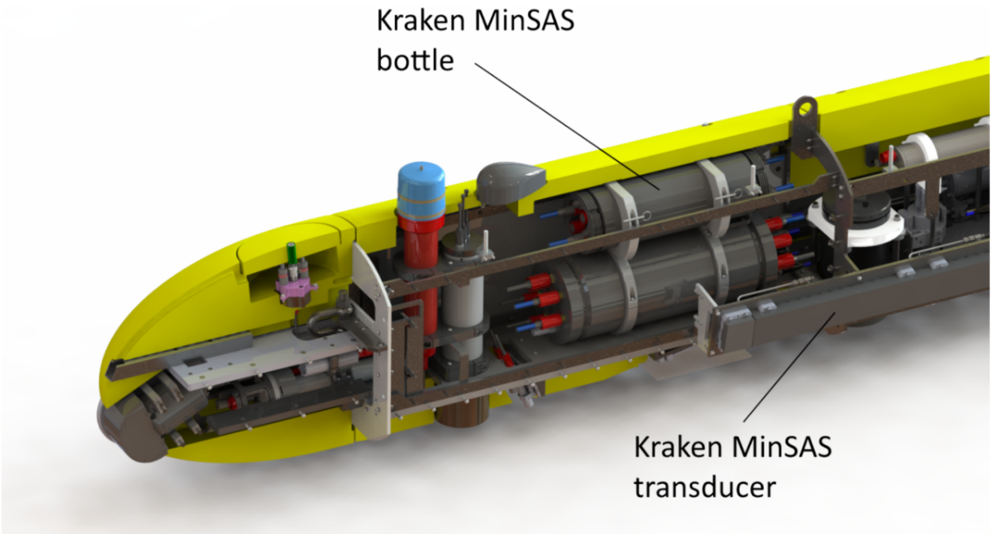

Fig. 3.10 minSAS mount, SeaRaptor

The MINSAS 120 utilises Krakens Real Time SAS (RTSAS) for real time processing of the SAS images, which are further processed in Krakens Insight software. The SAS technology utilizes synthetic aperture techniques by stitching together multiple swaths along a straight line, enabling the system to achieve a cm-level range independent resolution (as depicted in Fig. 3.11).

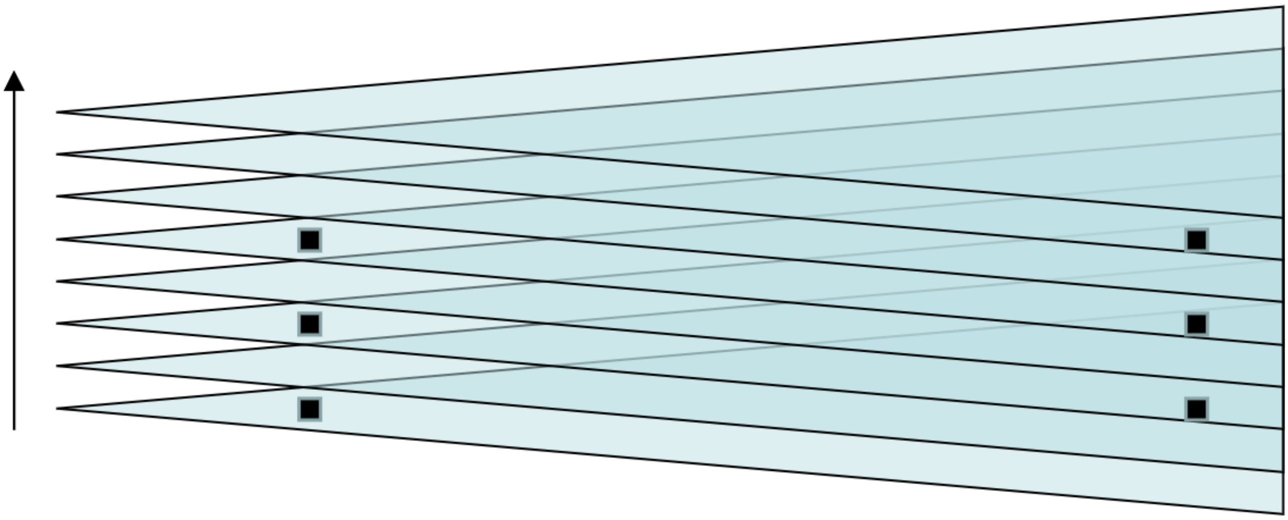

Fig. 3.11 SAS composition

The optimal performance of the MINSAS 120 is achieved when the AUV is operated at altitudes typically around 15-25 meters, with smooth and steady motions. However, rough terrain and frequent changes in the AUV's direction can negatively impact the quality of the SAS images, and in extreme cases, the SAS processing might fail. Nonetheless, as long as the seabed remains within the system's range, standard resolution side-scan images can still be generated and used if needed.

For more detailed information, see specification sheet provided as Attachment 6.23.

4 Data quality and processing

Data quality assurance process is a continuous feedback loop that is present across the full project value chain from project planning to final delivery, where the results of each mission inform the next one. It entails a pre-survey analysis of data requirements followed by thorough data acquisition planning. During the acquisition, data logging is ensured through AUV mission control and some processing is performed in near real-time. Immediately after data is retrieved from an AUV, systematic processing work begins.

Data management is another critical aspect of data quality control and data-supported decision-making, especially in complex DSM projects. For this project, in addition to standard offshore and onshore data storage and management systems, Argeo SCOPE - Argeo's new cloud-based solution for management, analysis, and interpretation of Ocean Space data - was utilised to allow for efficient communication of the results directly from the field.

Argeo SCOPE enables fast and performant 3D visualization of Ocean Space Data in a user-friendly browser-based interface, supporting collaborative data sharing and a smoother interpretation workflow. In this project, all fast-processed data was uploaded to SCOPE for internal immediate inspection and evaluation. Important findings in the acquired data were communicated through georeferenced annotations, that specified type of observations (e.g. hydrothermal vent field, pockmark, etc.) and additional comments.

4.1 Navigation data

Searaptor AUV, INS and positioning

The SeaRaptor AUV is equipped with iXblue Phins 6000 INS unit for attitude and positioning of the AUV, with additional aiding sensors and systems:

- GPS: provides global position when AUV at surface. RTK-corrected GPS fixes provide centimetre accuracy at surface.
- DVL: tracks heading and speed over ground as long as seabed returns can be detected (maximum altitude is around 400 m).
- USBL: acoustic positioning system that tracks an AUV from the topside vessel. It can be used for both tracking and aiding the AUV. USBL fixes have been used both in real-time solution and during navigation post-processing.
- Pressure sensor: main input for the AUV depth logging. The data is later corrected for sea state (tides).

Using the post-processing software (Delph INS), a forward and backward processing is performed to optimise the accuracy of the AUV navigation. To achieve stable solutions both good velocity estimates (DVL w/ bottom lock) and global position (GPS or USBL) were used in the processing. In deep waters like in this project, the high accuracy positioning achieved at surface is quickly reduced when diving without DVL bottom lock. The AUV is aided with USBL on the way down (and up), however, to ensure the best conditions for navigation processing, all dives start and end with the AUV moving in a square pattern with both DVL lock and USBL fixes proved from the topside. These manoeuvrers at the start and end of dive are referred to as racetrack manoeuvres.

4.1.1 Survey parameters and data quality

Accurate navigation is critical, in particular when working with high resolution data like MBES, SAS and camera data. Small navigation errors might not be visible on separate lines or tiles, however the relative position between adjacent lines can be noticeable and cause reduced data quality in the overlap. The real-time navigation solution is normally quite good, however we've seen the real time solution drift off after an avoidance behaviour have been triggered (brake, float and continue). Rough terrain can also case the DVL quality to drop intermittently and might case the solution to drift off. In the worst case, the DVL have to be turned off for a given period during prost-processing, and identifying the sections that need to be turned off can be quite time-consuming. Basically, we seek a stable solution for both the forward and backward solution before we settle for the final solution (forward and backward combined), and poor DVL might impact the forward and backward solution at different positions.

At times USBL data can be of lower quality than expected, with the post-processed navigation using high weights on the USBL input, the bathymetry data showed poorer quality compared to real-time solution. The final iterations were therefore completed using both real-time solution and USBL data as aiding data (low weights) and INS and DVL as the main input. This provided stable solutions, and the best MBES data quality. The final navigation solutions are associated with some uncertainties, and bathymetry data still show merge effects that likely are related error in horizontal positioning.

If for any reason an AUV aborts a mission and returns to surface before the final racetrack with DVL lock and USBL, it may take 10 - 20 minutes of the production line before the backward solution stabilises. Hence, in these situations, the positioning will be somewhat reduced at the end of the dive.

4.1.2 Processing workflow

During the data acquisition phase, the real-time navigation solution relies solely on the raw data obtained from the onboard sensors. Kalman filtering, which involves using current and past sensor readings to estimate the AUV's position and orientation, is also employed in real-time navigation.

After the data acquisition is complete, the navigation data is further refined and updated in the Delph INS software, which serves as a post-processing tool. During this post-processing stage, additional data, such as filtered or supplementary USBL (Ultra-Short Baseline) data recorded from the topside, can be incorporated. Both forward and backward simulations can be combined to improve the accuracy of the navigation solution.

The post-processing takes place in two stages. Initially, preliminary post-processing is carried out offshore. Subsequently, final iterations are performed onshore, allowing for more extensive data analysis and refinement.

Multiple iterations might be necessary during the post-processing to fine-tune the navigation solution and achieve the best results. The criteria for selecting the most optimal solution is based on the quality of overlapping bathymetry data. The solution that aligns the bathymetric data most accurately is considered the best. The iterative nature of the process allows for continuous improvement and ensures that the final navigation solution is highly reliable and precise. The incorporation of additional data during post-processing enhances the overall accuracy of the AUV's trajectory, enabling more accurate data analysis and interpretation during subsequent data analysis stages.

4.2 Multibeam echosounder data

Multibeam echosounder emits sound waves in a fan pattern to map the seabed. Bathymetry and backscatter are acquired simultaneously, and the water depth is then determined by the time it takes for the beam to return to the sonar given a known speed of sound in the water column while backscatter is measured by the strength of the returned signal. Backscatter can be used for seabed classification and object detection. Since the sound waves are emitted in a fan pattern, directional information can be derived from the returning sound waves, and a complete swath can therefore be produced from one single ping. The swath angle can be modified to adjust the swath width and beam density of the data. A Teledyne Reson T51 400/800 kHz MBES sensor was utilised for this project.

Following processing and finalising of the MBES data, bathymetry and backscatter grids were uploaded to Argeo Scope for further quality assurance and review. Fig. 4.1 shows an image of the bathymetry data in Scope.

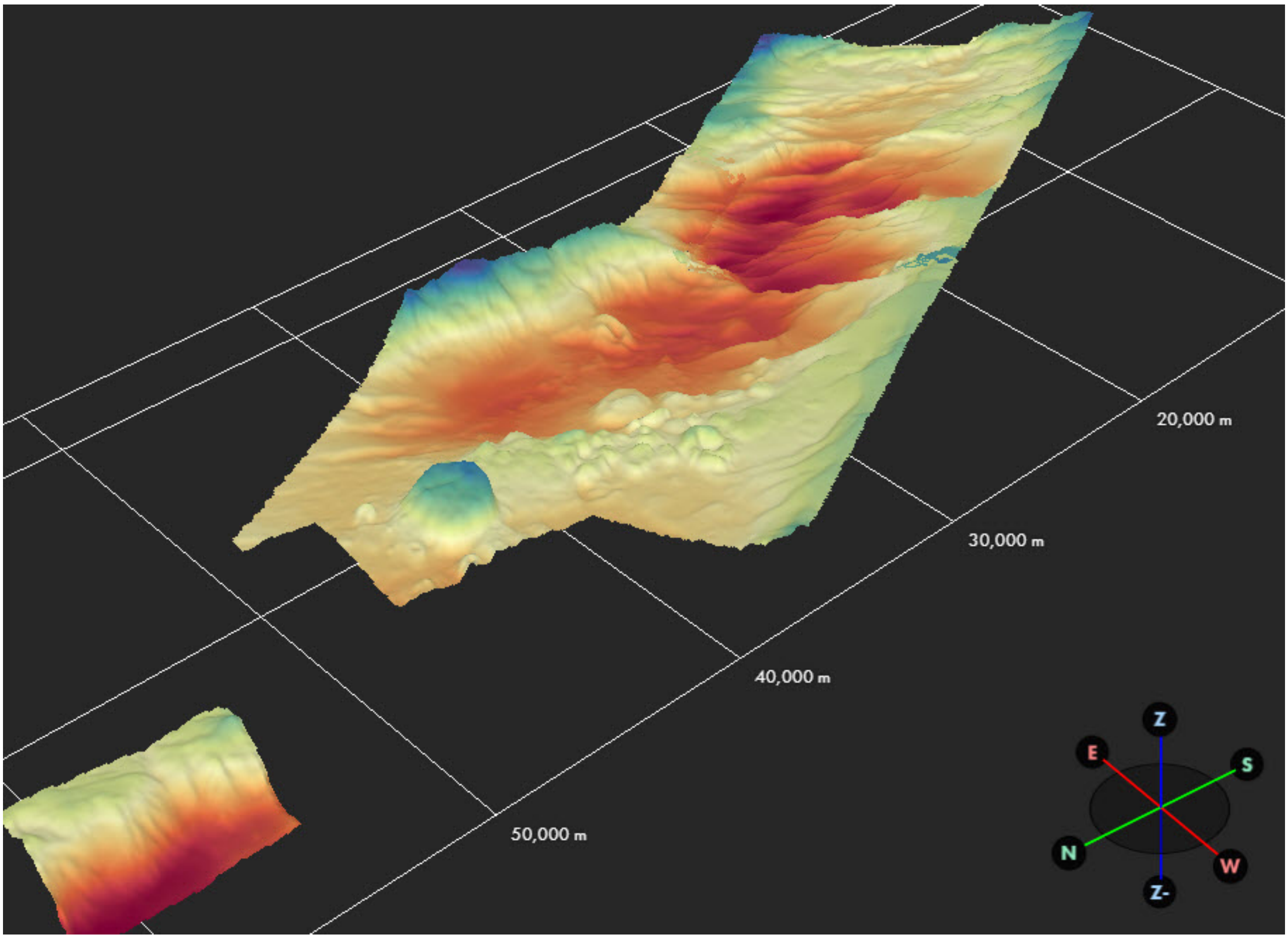

Fig. 4.1 Bathymetry grid in Argeo Scope

4.2.1 Survey parameters and data quality

The survey collected near-seafloor bathymetry data. All survey lines were carefully planned to ensure full MBES coverage. A summary of key survey parameters critical for coverage is presented in Table 4.1.

Table 4.1 Survey parameters summary

	Lokeslottet	Area A	Area B
Terrain factor: Percentage of area with slope exceeding 20°	26%	34%	70%
Nominal Altitude	70 m	75 m	100 m
Coverage angle	110 deg	110 deg	110 deg
Nominal Line Spacing	170 m (W-E lines) 120 m (N-S lines)	135 m	200 m

The AUV's ability to follow the terrain in steep slopes and rough areas was limited, leading to variations in the actual altitude along the survey lines. This, in turn, resulted in variable swath widths. When approaching steep up-hill slopes or peaks, the swath width became narrower, leading to potential lack of overlap with the adjacent lines. Additionally, when running up-hill along slopes steeper than the AUV's maximum pitch, the altitude decreased gradually until it reached the threshold for the AUV's avoidance behaviors, which prioritize safety. Moreover, when the AUV passed over a peak or cliff, the altitude could exceed the planned level, and in the worst case, exceed the detection range of the T50-S MBES source, resulting in missing seabed reflections and causing gaps in the Digital Terrain Model (DTM). Some gaps in the DTM were caused by altitudes beyond the range limit for the 400 kHz MBES source, and a proper seabed reflection was not recorded.

Due to variation in topography, survey parameters for each of the three survey areas and dives vary owing to safety considerations and vehicle control.

For more challenging parts of the survey areas with pronounced topography, the line spacing was significantly reduced to accommodate potential deviations from nominal flight altitude due to terrain avoidance of the AUV and to account for steep terrain.

To optimise data quality, fine-tune acquisition parameters using the SonarUI function called "Tracker" which allowed for auto-adjustment of parameters such as transmission power, pulse length, and receiver gain during acquisition.

To maximize data density, the T50-S system was capable of running with up to 1024 beams per ping, but due to the inclusion of water column data, the number of beams was limited to 512. To manage data volume effectively, a compressed version of the water column data was recorded.

The MBES data itself demonstrated high quality and appeared satisfactory when evaluating individual lines. However, when merging adjacent lines, a minor horizontal position error could lead to apparent vertical discrepancies between the lines, especially in steep and rough terrain. Numerous iterations of post-processing of the navigation solution were conducted using DelphINS to improve the merging effect, but some merge artifacts between lines persisted in the final composite DTM. Despite patch testing, some pitch misalignment between the INS and the T50-S persisted, particularly noticeable during the AUV's maximum pitch changes, potentially due to small movements in the AUV's tail section.

The water column data was inspected using Caris Hips/Sips software, which identified several potential anomalies. However, some of these anomalies were likely false positives related to DVL (Doppler Velocity Log) noise. The DVL noise appeared in specific sectors in the data, pointing towards the AUV. Although some anomalies seemed real in individual pings, when examined in stacked sections (multiple pings), some aligned within the DVL sectors. Further work and 3D plotting were required to validate and interpret these anomalies accurately.

The MBES T50-S acquisition parameters for the Knipovich survey are provided in Fig. 3.2.

4.2.2 Processing workflow

Bathymetry

For the processing of the hydrographic MBES data, the professional software package *Teledyne Caris HIPS* was utilised. Other software, like Eiva navipac and navimodel may also used for QC and inspection.

Water column data

Water column inspection is conducted by loading the s7k files into Hips files, allowing access to the water column through the swath editor and/or subset editor in Caris Hips/Sips. Each line is replayed and visually inspected, and points of interest are marked and added to an "additional bathymetry" CSAR file, highlighting the water column points. To examine the 3D shape of the data, these points can be displayed in 3D alongside or on top of the bathymetry, color-coded by reflection intensity. This manual process is time-consuming but essential for data assessment.

Backscatter

To process the MBES backscatter data, CARIS HIPS & SIPS was used to create a mosaic from intensity values in dB. Backscatter processing is performed after bathymetry as the bathymetry surface is used as a reference when in the production of the beampattern and subsequently the backscatter mosaic.

4.3 Sub-bottom profiler data

Sub-bottom profiler (SBP) is a data type used for imaging the sub-surface. Unlike MBES data, which provides information about the seafloor topography, the SBP data represent penetrative acoustic signals in the form of a 2D vertical profile of the subsurface layers along the track lines. The SBP method relies on acoustic reflectivity, making it sensitive to changes in the acoustic impedance, which is determined by the velocity and/or density of the subsurface materials. This sensitivity allows SBP to map out different sediment layers, interpretation of deposition environments (and possible lithology), and in some cases also to determine the depth to the bedrock. The observed penetration of the SBP signals varies with sediment type and lithology due to the use of high frequencies. Different sediment types and lithologies respond differently to the acoustic energy, affecting the depth to which the SBP signals can penetrate. The SBP data was acquired using the Benthos Chirp 3 SBP system (1.5-8 kHz) and the Searaptor AUV platform.

Following processing and finalising of the SBP data, the SEGY files were uploaded to Argeo Scope for further quality assurance and review. Fig. 4.2 shows images of the SBP data in Scope, both combined with bathymetry (Upper inset A) and as single SBP line (lower inset B).

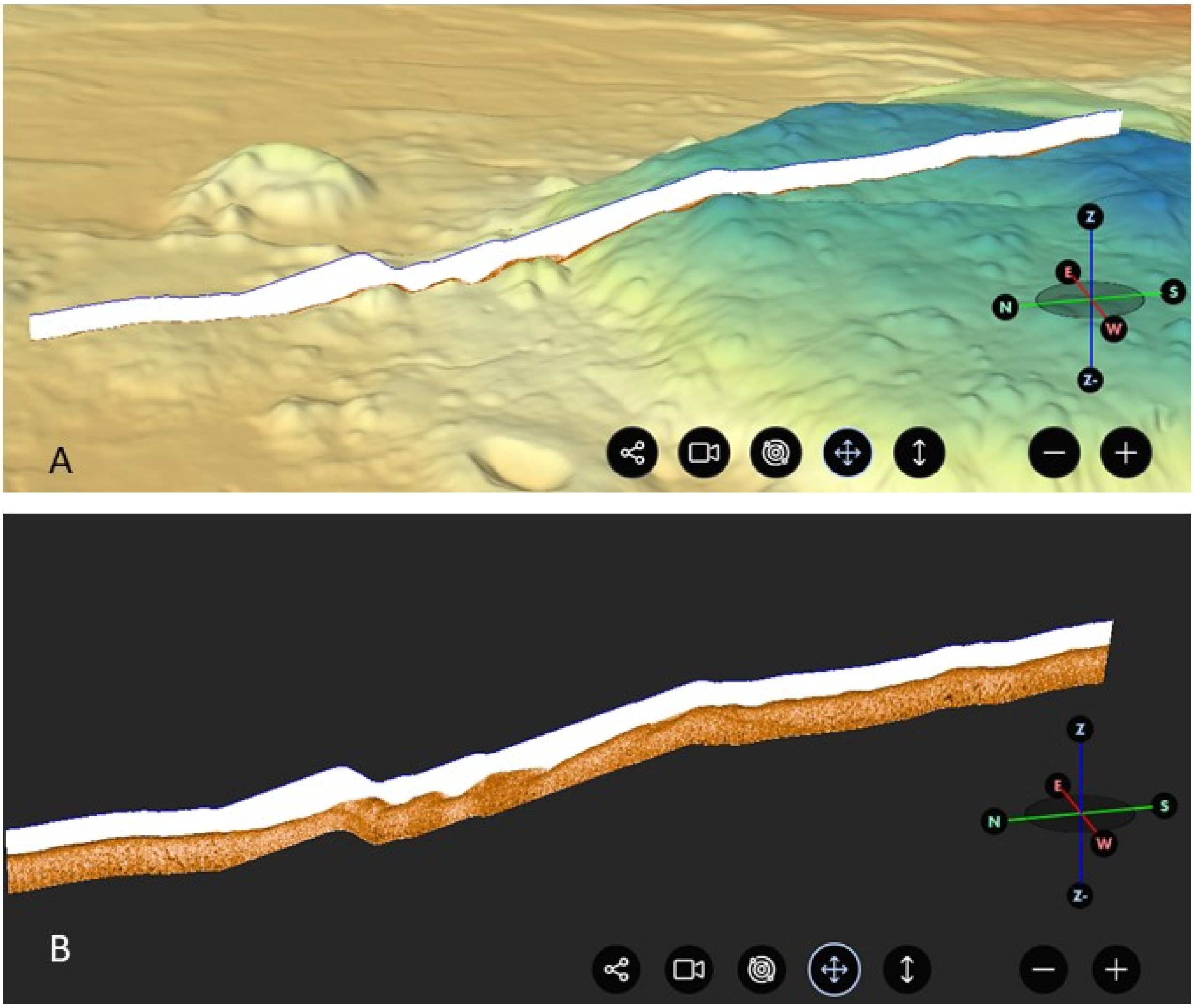

Fig. 4.2 SBP data exemplified from Scope.
A: SBP data combined with bathymetry
B: single SBP line

4.3.1 Survey parameters and data quality

SBP data was collected throughout all dives. All sensors deployed share key survey parameters with the ones outlined in Table 4.1 that were guided by MBES coverage goals. In addition to these survey parameters, each sensor has been set up to acquire respective data of the best quality. The SBP settings used to collect SBP data is shown in Table 4.2:

Table 4.2 SBP settings

Survey parameters	Phase-I (70-100 m altitude)
Frequency range	1.5 - 8 kHz
Bandwidth	6.5 kHz
Pulse length	30 ms
Record length	400 ms

Range or vertical resolution (theoretical)	About 11-12 cm
Horizontal resolution (fresnel zone)	About 4.2 m
Ping rate	2.5 Hz

The settings for the SBP system was kept the same throughout the project. Due to the relatively high operation altitudes, the pulse length was increased 30 ms to improve the S/N ratio and possibly improved penetration. Record length was kept relatively long, to ensure to capture all potential reflectors, even if altitude increased. The ping rate is linked to the record length, and was kept at 2.5 Hz, with nominal speed of 1.6-1.7 m/s that provides the pinging density of about 0.7 m between each ping.

The recorded de-chirped full waveform data shows a wide bandwidth where most of the energy is within the expected bandwidth.

The overall quality of the acquired SBP data is very good in areas with sediment coverage, for example see Fig. 4.3. However, in rugged volcanic terrain, the data quality is somewhat reduced. Seabed reflections are less clear in areas with a significant amount of exposed bedrock at sea floor where the seabed is hard and uneven. In such areas, thin layers of sediments can be present but may not be recorded in the SBP data. It is therefore recommended to combine the data analysis with bathymetry data from a multibeam echo sounder (MBES). Due to the rough terrain and steep slopes, abundant side effects can be observed, especially when sailing in the strike direction of the seabed trend.

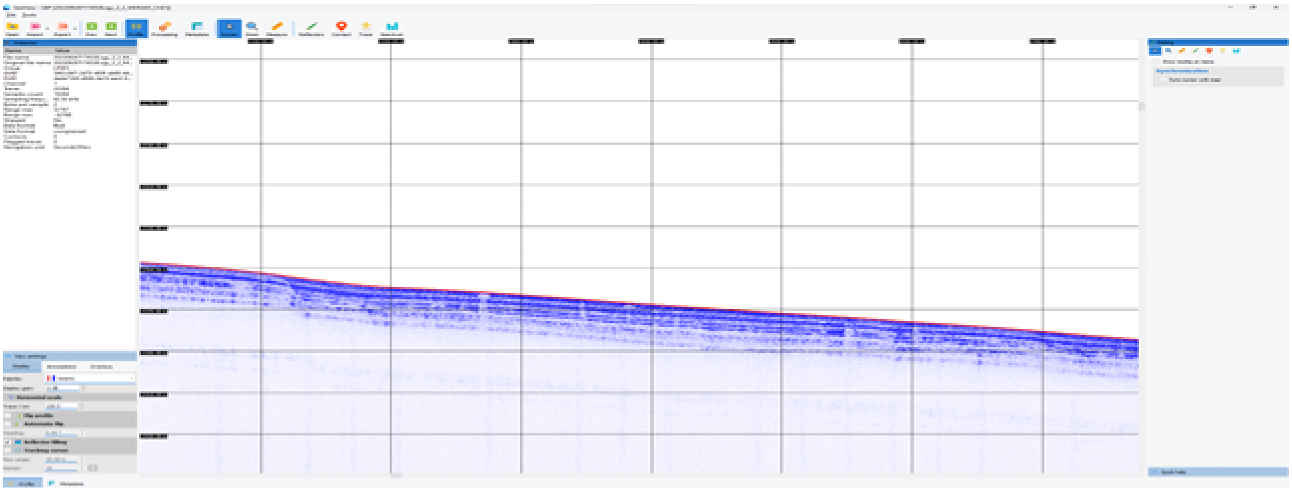

Fig. 4.3 SBP data example

The degree of penetration of the SBP system is primarily controlled by the physical properties of the sediments in the surveyed area. In regions with soft seabed sediment, our system is expected to achieve significant penetration, up to 80 meters. However, in areas with harder sediment, the penetration depth will be reduced, with an expected range of 5-15 meters in calcareous sands.

The SBP system also records the water column, but we have applied a Time-Varying Gain (TVG) correction from the seabed, which effectively mutes most of the water column reflectors. However, the water column data from SBP can potentially complement water column observations obtained from MBES data. To achieve this, separate processing is required to enhance water column reflections in the SBP data. At QC stage, no obvious anomalies were observed in the data.

Seabed multiples are data artefacts generated from energy bouncing between the sea floor and the sea surface. These multiples manifest as deeper reflections mirroring the seabed. The depth to these multiples depends on the water depth and the AUV depth. No issues with multiples have been observed in the data, likely due to the large water depths.

4.3.2 Processing workflow

During the data acquisition, raw data was recorded into *.SEGY files, including the full wave form of the time series and header information for each ping. For QC and processing, the recorded SEGY data underwent several steps using various software tools to enhance data quality and prepare them for interpretation.

4.4 Environmental data

The SeaRaptor AUVs are equipped with several sensors designed to gather water physics and chemistry data (referred to as ENV data in this report), enabling a comprehensive understanding of underwater conditions. These sensors include the RDI Tasman DVL for measuring velocity, the Valeport uxSVP for sound velocity profiling, and the versatile RBR maestro sensor for various parameters such as pressure, conductivity, temperature, ORP, pH, turbidity, methane, oxygen concentration, and oxygen saturation.

4.4.1 Survey parameters and data quality

ENV data was collected throughout all dives. All sensors deployed during this phase share key survey parameters with the ones outlined in Table 4.1 that were mainly guided by MBES coverage goals. All ENV sensors have standard settings that were not changed throughout the project.

To ensure best data quality, all sensors are maintained according to the manufacturer's recommendations and are subject to regular calibration.

Sensor drift, however, can be expected in the data throughout a long survey.

4.4.2 Processing workflow

ENV data processing consists of pre-processing conducted in the bottle and post-processing performed after the data was retrieved from an AUV.

For more details about the methods and calculations please refer to the manufacturer's guide: Standard Loggers instrument guide (rbr-global.com).

4.5 SAS data

Synthetic Aperture Sonar (SAS) data is a cutting-edge technology used in underwater imaging and mapping. Unlike traditional sonar systems, SAS employs sophisticated signal processing techniques to synthesize an aperture as the sonar moves along its trajectory. This technique allows for high-resolution, high-quality imagery of the seafloor. SAS data provides unparalleled details of underwater features, enabling the detection of small objects, intricate seabed topography, and megafauna with remarkable clarity. The data processing involves coherent integration of multiple pings to create a single, focused image, resulting in improved signal-to-noise ratio and enhanced target detection capabilities. Kraken minSAS 120 was used to collect SAS data for this project.

4.5.1 Survey parameters and data quality

To acquire SAS data an optimal speed of 1.6-1.8 knots with an altitude of 20-25 m is utilised. This range provides optimal resolution and the widest swath. Due to unique properties of the technique, the resolution of SAS data is range-independent and will only vary with the speed of the vessel.

Table 4.3 MINSAS 120 survey parameters

Survey Parameter	Value
Altitude	20 m
Nominal Speed	1.6 m/s
Pulse Interval	272 ms
Pulse Length	9 ms
Center Frequency	337 kHz
Pulse Bandwidth	40 kHz
Pulse Type	FM

Quality considerations relevant to this project

The performance of the minSAS system is indeed exceptional in flat terrain; however, there are certain limitations associated with the SAS method and the minSAS sensor, particularly when surveying areas with rough topography. In regions with rough terrain, characterized by excessive variability in topography and subsequently AUV behavior if flown in the follow-terrain mode, the quality of the processed SAS images can be significantly compromised, and in the worst cases, the SAS processing may fail altogether. This issue becomes especially pronounced in mid-ocean ridge settings, where terrain is highly irregular and elevation changes are dramatic.

During these pioneering surveys conducted using minSAS in such challenging settings, we have encountered equipment and method limitations. In areas with rough topography and high seabed slope angles, synthetic aperture sonar interferometry may produce inconsistent coverage due to the complex terrain and the AUV's inconsistent altitude response to rapidly changing topography.

To achieve the required high resolution and optimal coverage, it is recommended that the SAS survey is conducted at relatively low altitudes. The maximum SAS survey altitude recommended is 25 meters, with the optimal altitude being 20 meters. Such low altitudes necessitate careful survey planning and impose limitations on surveying areas with particularly high elevation gradients.

Based on the identified limitations, it is important to avoid conducting SAS surveys in seabed areas with slope angles exceeding 20 degrees and significant topography variability, primarily due to safety concerns. It is crucial to recognize that such areas may experience inconsistent data coverage. Addressing these considerations is essential to ensure the reliability of the survey results, prevent potential data gaps and inconsistencies, and achieve successful SAS data acquisition in challenging underwater environments.

4.5.2 Processing workflow

To achieve the high resolution of Synthetic Aperture Sonar (SAS), multiple swaths are combined, typically in 50 m along-track chunks. During data processing, straight-line movement is assumed along these chunks. Any deviation from this straight-line movement may lead to positional uncertainty and image smearing. If the AUV has sufficient movement along the 50 m segment the section can not be processed.

SAS image processing takes place onboard the AUV using the Real Time SAS processing unit. After the AUV surfaces, the SAS data undergoes quality assurance (QA) and further processing. This includes adding post-processed navigation data and recomputing any failed tiles if necessary. The resulting output consists of 50 m tiles with 3x3 cm resolution. For compiled surfaces, these tiles are imported into Hips & Sips software, where they can be exported in the desired size and resolution.

5 Summary

The project aimed to acquire high-resolution geophysical and environmental data for identifying SMS (seafloor massive sulfide) and hydrothermal venting occurrences, along with baseline mapping of the environment. This was achieved through the deployment of two autonomous underwater vehicles (AUVs) known as SeaRaptor 6000, equipped with a suite of sensors. Launch of the AUV is exemplified in Fig. 5.1.

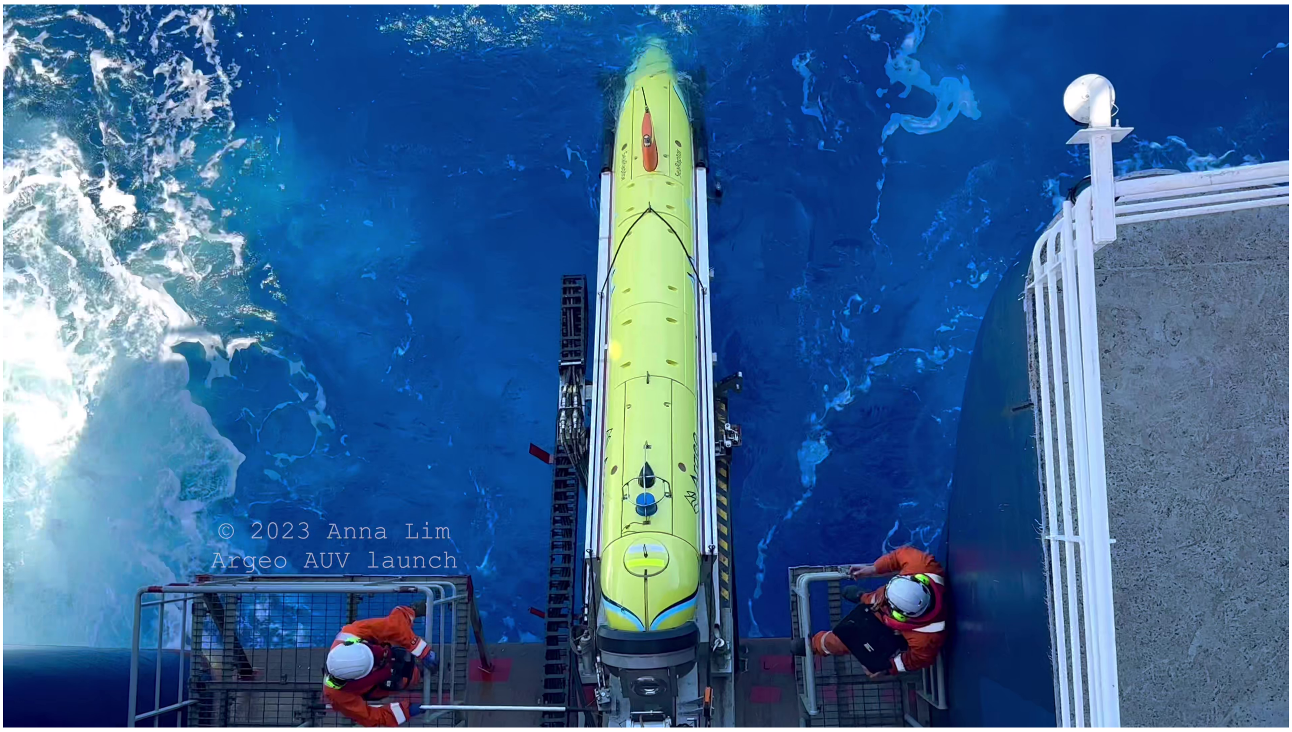

Fig. 5.1 AUV Launch in the survey area

The AUVs collected data across three pre-identified areas of interest - Lokeslottet, Area A and Area B.

The project's primary focus was on successful data acquisition, and the subsequent analysis of the collected data was not part of the scope for Argeo.

6 Appendix

6.1 HSEQ

Fig. 6.1

Argeo

ESG Policy

ESG stands for Environment, Social and Governance. ESG is often used synonymously for sustainability. For Argeo, sustainability is about our business model, which means how our projects contribute to sustainable development and what impact we have on all the three components in ESG.

Environmental

Environmental criteria include i.e., a company's use of renewable energy sources, its waste management, how it handles potential problems of air or water pollution arising from its operations, deforestation issues (if applicable), and the company's attitude and actions in relation to climate change issues.

We are all committed to:

- Prevent harm to the environment
- Identify, develop, maintain, and advise Argeo employees on environmental policy standards
- Create measurable goals
- Comply with relevant laws and regulations
- Strive to achieve corporate environmental goals set forward

Social

Companies have a responsibility for their employees as well as their impact on the societies in which they operate – for instance in terms of working conditions, labor rights and diversity.

We are all committed to:

- Create measurable goals
- Ensure equal treatment and opportunity for all staff members
- Promote diversity and maintain an inclusive workplace
- Keep our workplace harassment-free
- Comply with relevant laws and regulations
- Strive to achieve corporate social goals set forward

ESG Policy   Version: 1   Uncontrolled if printed

Fig. 6.1 Argeo's ESG policy

Fig. 6.2

Governance

Governance can serve as a control mechanism in relation to bribery and corruption, tax, executive remuneration, shareholders' voting possibilities and internal control. We believe active corporate governance is important to the development of companies and provides long-term benefits for shareholders, employees, and society.

We are all committed to:

- Create a healthy and safe working place for both employees and contractors
- Create measurable goals
- Strive to achieve corporate environmental goals set forward
- Comply with relevant laws and regulations
- Promote a culture in which all employees share this commitment
- Promote responsible purchasing
- Develop and communicate a Company Code of Conduct
- Respect and promote human rights of all individuals potentially affected by our operations. We respect the fundamental principles set forth in the Universal Declaration of Human Rights and related UN documents

ESG mission

Our Mission is that Argeo will be a sustainable company with a "green growth" business model, enabling the green transition, as well as being responsible in all our operations and promote diversity. To achieve this, we will work together and take personal responsibility to reach our common goals.

Trond Erling Figenschou Crantz
Chief Executive Officer, Argeo AS
08.04.2022

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Fig. 6.2 Argeo Governance

6.2 MV Argeo Searcher

In this section Argeo Searcher specifications and calibration reports are given in the following order:

- Argeo Searcher, vessel specifications
- Topside GNSS and USBL positioning specification
- Dimensional Control Survey and Heading Pitch Roll Calibration
- Sonardyne USBL CASIUS Calibration

AUV & ROV SURVEY & INSPECTION VESSEL

Argeo Searcher is an effective multipurpose AUV/ROV survey vessel with an excellent track record for several O&G clients worldwide since built in 2001/2006

Argeo

Argeo Searcher

Vessel info

- Length 108,6m x breath 18m
- Class: DNV, 1A1 HELDK DYNPOS -DPS2
- Long endurance diesel electric propulsion
- OSM Vestland Management
- Capacity for 65 persons onboard
- FRC: Norsafe with diesel waterjet propulsion
- Helideck for Super Puma 9.3t

Survey Spread

- AUV: 1 x SeaRaptor 6000 (option 2x SeaRaptor)
- ROV: 1 x WROV/Observation/Survey (option)
- Instrumentation and acoustic positioning (SON/HIPAP)
- Dedicated instrument/operations room
- Computerized onboard data processing center
- Client office space and conference room
- Marlink VSAT communication

M/V Argeo Searcher

Machinery and propeller plants

Main propulsion system	Diesel Electric—Double Stern Aquamaster Azimuth, FPP 2 x Aquamaster US 2001, 1600 KW, 0-1200 rpm,
Diesel Engines:	2x Stork –Wartsila 6GL28 , 1800 KW, 900 rpm 2x Wartsila Vasa 6R32, 2430 KW, 720rpm
Forward Tunnel Thusters	3 x Ulstein (Rolls Royce) 375 TV, 1275 KW, CPP
Emergency Generator	Cummins 6BT 5.9G, 87 KW
Seismic compressors	2 x LMF type 138/62, 62m3/min (2200 cfm) frequency converter controlled

Deck machinery

Deck Crane	2x ABAS Knuckle Boom 4t at 16 meter
Deck Crane	1x Palfinger Marine PS 22000m/10 S2.5SWL2t

Navigation Equipment

Auto Pilot	"SIMRAD AP9 MK3"
DGPS	"MX MARINE 420"; FUGRO SEA STAR 9205 GNSS; C-NAV 3050
Radars	FAR – 2117 BB FAR – 2137S BB:
Gyro	2 x " SG Brown TS" 1 x "Alphatron-Alphaminicourse":
Magnetic compass "PLATH"	
El. Chart	"TelChart ECS" – C-Map database
DP System	DP2 MT Bridge Mate, installed 2013
Navigation Echo Sounder	"STN ATLAS"
GMDSS	SAILOR A1, A2, A3
Simplified VDR	DANALEC MARINE"
AIS	"JOTRON"
Speed Log	"BEN MARINE- ANTHEA"
Fac-Simile	"ICS Electronics"
ECDIS	TECDIS
DP System	Marine Technologies LLC Bridge Mate DP2 System
Gyrocompass with repeaters	2 x " SG Brown TS", 1 x "Alphatron-Alphaminicourse"

Seismic Equipment

Manufacturer	N/A
Node type	N/A
Max On-board Node Capacity	5,226 (Handling System Owners equipment
Charging Capacity	630 units (Charterers equipment)
Deployment/Retrieval Method	WROV
On-line Navigation System	EIVA
Primary Navigation	Veripos LD6 w/Ultra2 Corrections
GPS receiver	C-NavigatorIII
Secondary navigation:	C-Nav 305000000 Sstarfire w/SF2 Corr
GPS receiver	N/A
Acoustic/USBL	Sonardyne Ranger Pro v2.02

Energy source

Compressors	2x LMF62/138-207 E60
Drive Engine	El. Motor ABB AMA 450L6L BAFTMH
Cubic ft. per minute	2,200 cfm
Total Volume per Source	Source not onboard
Source Controller	Not onboard

Speed and fuel consumption

Transit speed	10 knots
Range	120 days at economic speed
Endurance operation	240 days in operation
Fuel consumption transit	~15t @ 10kn (dependant on weather conditions)
Fuel consumption operations	6-8t @ 3-4 kn (dependant on weather conditions)

Capacities

Fuel	1671 M3
Fresh water	610 M3
Lube oil	32.0 M3
Sewage	27.0M3
Fresh water generator	1 x Alfa Laval evaporator: 15 m3 1 x ENWA Inverse Osmosis: 25 m3
Sewage treatment plant:	Aquamar GmbH, Bio-Unit model MSP 60 10.5 m3/Day
Incinerator:	Saniterm SH 20-SR,400000Kcal/h

Life saving equipment

Lifeboat	2x 65 persons—Greben
Life Rafts	2x 25, 4x 20, 1x 6—Viking
Rescue Boat:	FRC—Norsafe 655M
Fire Suits (BA-sets	6x Drager PA91 Plus
Air Compressor	1x Bauer U II W
Smoke Hoods	48 x HKMASK
Line Thrower	3x Comet, 1x Ikaros
Survival Suits	69x Helly Hansen 130
Life Vests	130
Life Rings	10
Work Floating Vest	13x Helly Hansen, 14x Crewsaver
Gas Monitor	2x portable sets-Drager
Medical Equipment	ALS Medical Kit, 2 spine boards, traction splint, KED/Stokes Basket
Resuscitators	1x Heart-Start AED, 1x Heart-Start
Cardiac	Monitor with AED
Galley System	1x CO2 HP System
Emergency Fire Pump	1x 70 m3/h
Fire Extinguisher:	137/ CO2, Powder/Foam
CO2 System:	1x Fixed ER 38 cyl x 45 kg 1x Fixed Galley 1 x 9 kg

Communication

Fixed satellite line (Fleet77):	
VSAT Number	Sealink SCPC/Vados
Inmarsat C	Sailor – H23095 C
Emergency Radios	3x VHF ICOM GM 1600E
Life Boat Radios	3x Portable VHF
M/F and H/F	Sailor - TT – 6301A
VHF stationary	Sailor – RT - 4822
VHF portable	Sailor C4901
UHF portable	Motorola – GP340; GP360
Internal communication	Automatic Telephone System "VINGTOR" Amplified Battery less Telephone System "STENTO" Public Address System "STENTO AS
Handheld GMDSS/VHF Radio:	Sailor C4901
Satellite – Inmarisat Type 'C':	Sailor – H23095 C
NavTex	ICS, Nav5
Telex	Sailor C4901
Echo Probe	STN ATLAS
Satellite com. Equipment	Sealink SCPC
Inmarsat:	Sailor – H23095 C
Max capacity (personnel)	65 persons

Accommodation

Accommodation	65 persons
1M Cabins	13x 1M Cabins with Bathrooms
2M Cabins	26x2M Cabines with Bathrooms
Mess	30 person
Day room	3xconfortable outfitted on Deck No6
Exercise room	1 x fully equiped GYM on Deck No2
Office	3 x Client offices on Deck No6
Conference room	1 x Equipped for 10 person on Deck No6

sales@argeo.no
Argeo.no

Argeo

LD900 Receiver

Quad-Band GNSS receiver delivers precise positioning for demanding marine operations.

LD900 Receiver

Maximum performance

The LD900 is a quad-band GNSS receiver capable of tracking GPS, GLONASS, BeiDou, Galileo and QZSS constellations to provide reliable and accurate positioning. Access to multiple GNSS signals allows for better satellite availability and reduces the impact of satellite masking or blockage.

Robust L-band reception

LD900 receives L-band signals on multiple channels providing access to the worldwide independent correction links and services supplied by Hexagon | VERIPOS. Correction data available simultaneously from up to three correction satellites minimizes the impact of satellite masking to ensure reliable reception of signals.

Maximum accuracy

VERIPOS provides accurate and reliable positioning for all marine applications via their redundant positioning and multi-frequency Precise Point Positioning (PPP) Apex and Ultra services. The Apex5 correction service utilizes all GNSS constellations delivering 5cm positioning accuracy for use in the most demanding offshore applications.

GNSS+INS integration

SPAN GNSS+INS technology combines GNSS positioning with inertial navigation system (INS) measurements like velocity, attitude and heave. In a solution optimized for hydrographic survey applications, the 3D positioning provides accurate measurements even through extended GNSS outages.

Simple to configure and operate

The intuitive colour display and navigation menu make setup, configuration and system status monitoring simple, and the LD900 can also be configured remotely through the VERIPOS Quantum software.

Designed for marine operations

The receiver has been designed, manufactured and delivered specifically for marine operations. Marine certification allows the LD900 to be interfaced with Dynamic Positioning systems, assuring accurate and reliable positioning for critical marine operations.

Benefits

- Supports decimeter-level multi-constellation positioning with VERIPOS Apex and Ultra PPP correction services
- Compatible with VERIPOS Quantum visualization software
- EN60945 Marine Certified
- OGP 373-19 and IMCA S015 QC compliant
- Designed for marine operations such as seismic exploration, offshore construction, survey and dynamic positioning
- Advanced signal filtering mitigates the effects of interference from other transmitters

Features

- 555 channel, all-constellation, multi-frequency positioning solution
- Simultaneously track up to 3 VERIPOS correction service satellites
- Independent L-band RF input
- Intuitive color display for configuration and monitoring
- Multiple communication options for interfacing with marine systems
- Optional SPAN GNSS+INS functionality
- Optional ALIGN GNSS heading solution
- Optional MSK Beacon receives corrections from IALA marine radio beacon network
- Automatic 72-hour rolling data log for incident support
- 19” Rackmount option providing additional serial port expansion & UHF receiver availability
- Spoofing and interference detection provided by GRIT (GNSS Resilience and Integrity Technology)

Primary GNSS module[1]

Channel configuration

555 Channels

Signal tracking

GPS	L1 C/A, L1C, L2C, L2P, L5
GLONASS[2]	L1 C/A, L2 C/A, L2P, L3, L5
BeiDou	B1I, B1C, B2I, B2a, B3I
Galileo[3]	E1, E5 AltBOC, E5a, E5b, E6
NavIC (IRNSS)	L5
SBAS	L1, L5
QZSS	L1 C/A, L1C, L2C, L5, L6

Horizontal position accuracy (RMS)

Single Point L1	1.5 m
Single Point L1/L2	1.2 m
SBAS[4]	1 m
VERIPOS DGNSS[5]	1 m
VERIPOS PPP[5]	5 cm
RTK	1 cm + 1 ppm
Initialization time	< 10 s
Initialization reliability	> 99.9%

Maximum data rate

Measurements	up to 20 Hz
Position	up to 20 Hz

Time to first fix

Cold start[6]	< 39 s (typical)
Hot start[7]	< 20 s (typical)

Signal reacquisition

L1	< 0.5 s (typical)
L2	< 1.0 s (typical)

Time accuracy[8]	20 ns RMS
Velocity accuracy	< 0.03 m/s RMS
Velocity limit[9]	515 m/s

Secondary GNSS module[1]

Channel configuration

555 Channels

Signal tracking[10]

GPS	L1 C/A, L1C, L2C, L2P, L5
GLONASS[2]	L1 C/A, L2C, L2P, L3, L5
BeiDou	B1I, B1C, B2I, B2a
Galileo[11]	E1, E5 AltBOC, E5a, E5b
NavIC (IRNSS)	L5
SBAS	L1, L5

Time to first fix

Cold start[6]	< 39 s (typical)
Hot start[7]	< 20 s (typical)

Signal reacquisition

L1	< 0.5 s (typical)
L2	< 1.0 s (typical)

Time accuracy[8]	20 ns RMS
Velocity accuracy	< 0.03 m/s RMS
Velocity limit[9]	515 m/s

L-band module

Channels	5 Channels
Frequency range	1525 to 1560 MHz

Beacon module (option)

Channels	2 Channels
Frequency range	283.5 to 325.0 kHz
Channel spacing	500 Hz
Demodulation	Minimum Shift Keying (MSK)

Communication ports

3 RS-232/RS-422	up to 460,800bps
3 RS-232/RS-422 (expansion)	up to 460,800bps
1 USB 2.0 (host)	HS
2 Ethernet	10/100 Mbps
1 PPS output	pulsewidth 1 to 500ms

Physical and electrical

Dimensions	300 x 200 x 80 mm
with mounting plate	300 x 220 x 80 mm
Weight	3.8 kg
with mounting plate	4.8 kg
Power[12]	
Power consumption	13 W (typical)
Input voltage	+12 to 24 VDC
Antenna LNA power outputs	
Output voltage	12 VDC ±5%
Maximum current	300mA
Connectors	
GNSS RF	TNC
L-band RF	TNC
IALA	TNC
Serial	DB9
Serial (expansion)	DB15
USB (host)	Type A
Ethernet	RJ45
PPS	BNC
Power	M12, 4 pin
Display	
3.5” QVGA TFT Color Display	

ALIGN® GNSS heading accuracy

Baseline	**Accuracy (RMS)**
2 m	0.08 degrees
4 m	0.05 degrees

SPAN technology

GNSS+INS integration with marine profile for hydrographic survey applications.

Supported IMUs:

IMU-ISA-100C
IMU-uIMU-IC

Attitude & velocity performance

Refer to IMU product sheets for values

Heave performance[13]

Instantaneous Heave	5 cm or 5%
Delayed Heave	3.5 cm or 3.5%
Post-Processed Heave	2.5 cm or 2.5%[14]

Environmental

Temperature	
Operating	-15°C to +55°C
Humidity	EN60945

Compliance

FCC, CE, UKCA, RoHS, REACH , WEEE, EN60945 (Protected Equipment), EN/IEC62368

Features

- NovAtel® OEM7® marine positioning engine
- Standard 32 GB internal storage
- Automatic 72 hour rolling data log for incident support
- Simultaneously track up to 3 VERIPOS correction service satellites
- Independent L-band RF input
- SPAN GNSS+INS option
- ALIGN® GNSS Heading (option)
- Built in WiFi support
- OGP 373-19 and IMCA S015 (July 2011) QC compliant

1 Typical values. Performance specifications subject to GNSS system characteristics, Signal-in-Space (SIS) operational degradation, ionospheric and tropospheric conditions, satellite geometry, baseline length, multipath effects and the presence of intentional or unintentional interference sources. 2 Hardware ready for L3 and L5. 3 E1bc and E6bc support only. 4 GPS only. 5 Requires a subscription to a data service. 6 Typical value. No almanac or ephemerides saved and no approximate position or time. 7 Typical value. Almanac or ephemerides and no approximate position and time entered. 8 Time accuracy does not include biases due to RF or antenna delay. No almanac or ephemerides and no approximate position or time. 9 Export licensing restricts operation to a maximum of 515 meters per second, message output impacted above 500 m/s. 10 Model-configurable to track L5/E5a (all / Galileo) through L2 (GPS) or L3/E5b/B2 (GLONASS / Galileo / BeiDou) through L2 (GLONASS). 11 E1bc support only. 12 Typical value. Consult the user documentation for power supply considerations. 13 Requires SPAN Marine Profile. 14 Post-processing results using Waypoint Inertial Explorer.

Contact Hexagon | VERIPOS

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For the most recent details of this product visit veripos.com

REV 3 | August 2022 | Printed in Canada

IMU-ISA-100C

High Performance Tactical Grade IMU Combines With SPAN Technology to Deliver 3D Position, Velocity and Attitude Solution

World-Leading GNSS+INS Technology

SPAN technology brings together two different but complementary technologies: Global Navigation Satellite System (GNSS) positioning and inertial navigation. The absolute accuracy of GNSS positioning and the stability of Inertial Measurement Unit (IMU) gyro and accelerometer measurements are deeply coupled to provide an exceptional 3D navigation solution that is continuously available, even through periods when satellite signals are blocked.

Overview

The IMU-ISA-100C features Northrop-Grumman Litef GMBH's proven inertial measurement technology offering exceptional performance when paired with SPAN technology. A near navigation grade sensor, the IMU-ISA-100C contains fiber optic gyros and fully temperature compensated Micro Electromechanical Systems (MEMS) accelerometers. The IMU-ISA-100C operates from 10-34 VDC and interfaces with GNSS receivers through a highly reliable IMU interface. IMU measurements are used by SPAN technology to compute a blended GNSS+INS position, velocity and attitude solution at rates up to 20 Hz.

Advantages Of IMU-ISA-100C

The IMU-ISA-100C offers extremely high performance and precise accuracy at an affordable price point. It is commercially exportable and offers an ideal solution for marine applications SPAN technology with Hexagon | VERIPOS receivers provide your choice of accuracy and performance, from decimeter to RTK-level positioning.

Benefits

- Premium performance IMU
- Optimized for hydrographic survey and marine applications
- Easy integration with the LD900 receiver from VERIPOS and Quantum visualization software
- Commercially exportable

Features

- Low noise fiber optic gyros and MEMS accelerometers
- SPAN GNSS+INS capability for marine applications
- Non-ITAR IMU

SPAN Technology Performance[1]

Horizontal Position Accuracy (RMS)

Single point L1/L2	1.2 m
SBAS[2]	60 cm
VERIPOS DGPS	1 m
VERIPOS PPP	5 cm
RTK	1 cm +1 ppm

Data Rate[5]

IMU Raw Data Rate	20 Hz
INS Solution	Up to 20 Hz

Time Accuracy[6] 20 ns RMS

Max Velocity[7] 515 m/s

IMU Performance[8]

Gyroscope Performance

Input range	±495 deg/sec
In-run bias stability	≤0.05 deg/hr
Scale factor repeatability	≤100 ppm
Scale factor non-linearity	≤100 ppm
Angular random walk	0.012 deg/√hr

Accelerometer Performance

Range[9]	±10 g
In-run bias stability	≤100 µg
1 year scale factor repeatability	≥1250 ppm
Scale factor non-linearity	≤100 ppm
Velocity random walk	≤100 µg/√Hz

Physical and Electrical

Dimensions 180 x 150 x 137 mm

Weight 5.0 kg

Power

Power consumption	18 W (typical)
Input voltage	+10 to +34 V

Connectors

Power	SAL M12, 5 pin, male
Data	SAL M12, 4 pin, female

Environmental

Temperature

Operating	-40°C to +55°C
Storage	-40°C to +85°C

Humidity MIL-STD-810G, Method 507.5

Random Vibe MIL-STD-810G, Method 514.6 (2.0 g)

MTBF >46,100 hrs

Environment IEC 60529 IP67

Compliance

FCC, ISED, CE

Included Accessories

- Power cable
- Communication cable

Performance During GNSS Outages[1,10]

Outage Duration	Positioning Mode	Position Accuracy (M) RMS		Velocity Accuracy (M/S) RMS		Attitude Accuracy (Degrees) RMS		
		Horizontal	Vertical	Horizontal	Vertical	Roll	Pitch	Heading
0 s	RTK[11]	0.02	0.03	0.008	0.008	0.006	0.006	0.010
	PPP	0.06	0.15					
10 s	RTK[11]	0.08	0.08	0.013	0.013	0.008	0.008	0.013
	PPP	0.12	0.20					
60 s	RTK[11]	0.92	0.53	0.048	0.023	0.009	0.009	0.018
	PPP	0.96	0.65					

1. Typical values. Performance specifications subject to GNSS system characteristics, Signal-in-Space (SIS) operational degradation, ionospheric and tropospheric conditions, satellite geometry, baseline length, multipath effects and the presence of intentional or unintentional interference. 2. GPS-only. 3. Requires a subscription to Apex[5] Correction Service. Subscriptions available from VERIPOS. 4. Correction service available depends on the GNSS receiver used. See the receiver product sheet for details. 5. 20 Hz data is an optional configuration. Contact NovAtel for details. 6. Time accuracy does not include biases due to RF or antenna delay. 7. Export licensing restricts operation to a maximum of 515 meters/second. 8. Supplied by IMU manufacturer. 9. GNSS receiver sustains tracking up to 4 g. 10. Ground Mobile Operating Environment. 11. 1 ppm should be added to all values to account for additional error due to baseline length.

Contact Hexagon | VERIPOS

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For the most recent details of this product visit veripos.com

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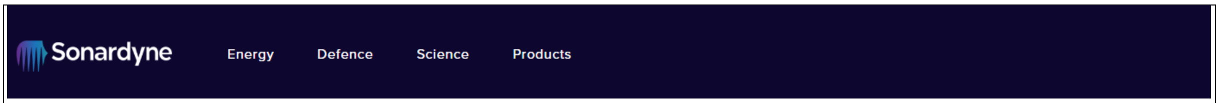


Sonardyne Ranger 2 USBL

Overview

Ranger 2 has the versatility you need, at the investment level you can afford to get your project completed fast and efficiently. It's engineered like no other USBL on the market.

Every survey, research, recovery, construction and data collection project is different; different water depths, different vessels – manned and unmanned – and different targets to track and communicate with. But whatever you're doing and wherever your working, investing in Ranger 2 – the most capable USBL technology available on the market – means your organisation can meet any operational requirement.

Ranger 2 comes with an impressive list of standard features, our award-winning 6G (sixth generation) acoustic hardware platform and Sonardyne Wideband 2 digital signal architecture. It provides stable and repeatable acoustic position referencing for your ship's DP system, including those from GE, Kongsberg, MT, Navis, Thrustmaster and Wärtsilä.

As your needs grow and become more complex, bolt-on software packs unlock additional capability and protect your investment. Take the DP pack; it enables acoustic ranging to be aided by our inertial navigation technology (DP-INS).

But Ranger 2 is more than just an acoustic tracking and DP reference system. It also supports robust two-way data telemetry allowing you to command our range of seafloor deployed long-endurance sensors and recover the logged data inside them.

The system is made up of software, a vessel-mounted transceiver and in-water transponders. Ranger 2 software brings together all the features surveyors, scientists and DPOs told us they wanted to see. The transceiver, called HPT, is available in a range of different designs to suit your operations; deep, shallow and long layback. If you need a solution for a vessel of opportunity, our pre-calibrated, all-in-one Gyro USBL transceiver is perfect.

The flexibility of the Ranger 2 family is further extended by our range of transponders to support a wide variety of applications. WMT is a high power transponder capable of operations to 7,000 m, while AvTrak 6 is our most capable acoustic vehicle instrument, combining the functions of a USBL transponder, LBL transceiver and modem for demanding applications such as AUV operations.

Datasheet

Gyro USBL 7000 LMF

Gyro USBL combines a Sonardyne 6th (6G®) generation high performance HPT Ultra-Short BaseLine (USBL) LMF transceiver and a Lodestar Attitude and Heading Reference System (AHRS) / Inertial Navigation System (INS) in the same mechanical assembly.

With the AHRS / INS in fixed mechanical alignment to the USBL's acoustic array, and 'in-water' pre calibrated at the factory, Gyro USBL can be quickly deployed without need for a USBL calibration. This enables significant savings in vessel time and operational costs. Depending on the array type, Gyro USBL can offer precision of better than 0.1% of slant range out of the box.

The HPT LMF transceiver component of the instrument utilises the latest Sonardyne Wideband®2 signal processing and is fully compatible with other products in the Sonardyne 6G equipment range.

Lodestar is tightly integrated with the HPT transceiver, providing highly accurate time-stamped motion and acoustic data. This enables unparalleled precision and accuracy of position estimation by removing many of the sources of error associated with all USBLs such as lever arm offsets, pole bending, and ship flexing.

Two accuracy versions of Lodestar are available. A cost-effective version for standard USBL operations and a "plus" variant optimised for long layback tracking and touch-down monitoring.

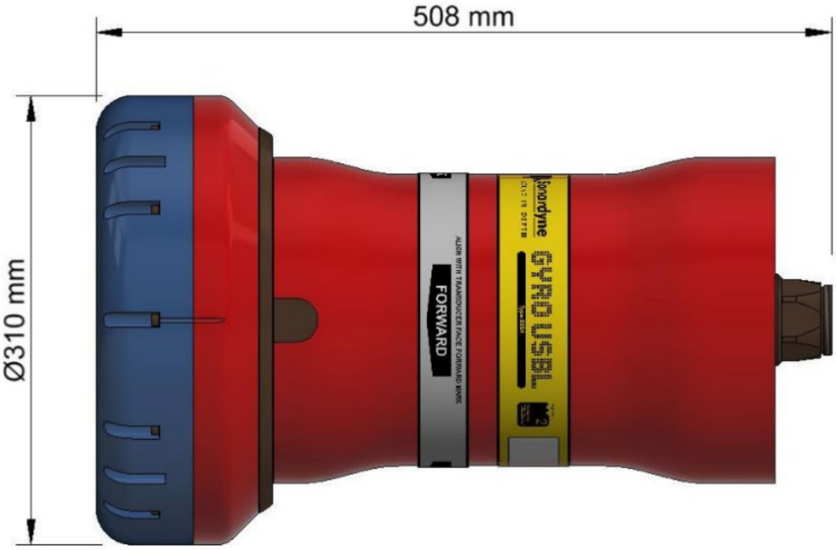
Manufactured in aluminium bronze the Gyro USBL is ideally suited for installations on vessels of opportunity using through-hull or over-the-side poles. It is also ideal for permanent installation on flexible stem tubes and on very small vessels such as USVs.

Key features

- Integrated Sonardyne 6G Wideband 2 USBL transceiver and Lodestar AHRS / INS offering high performance
- Small form factor
- Available in two inertial performance versions; standard for typical top down operations and "plus" optimised for long layback tracking and touch-down monitoring.
- Calibration free offering rapid deployment
- Class leading system precision and accuracy.
- Sonardyne Marksman LUSBL, DP-INS (plus variant) and Ranger 2 USBL compatible
- Compatible with Sonardyne's through-hull, over-the-side and stem tube deployment systems
- Ethernet and RS485 connectivity

Specifications

Gyro USBL 7000 LMF



Feature			Gyro USBL 7000 LMF 8084-0426 Gyro USBL 7000+ LMF 8084-0456
Operational frequency			LMF (14–19 kHz)
Transceiver performance	Operating range		Up to 12,000 m
	Acoustic coverage		Up to ±90° optimised for deepwater
	Range accuracy		Better than 15 mm
	Expected system slant range accuracy 1 drms (20 dB)[1]		All transceivers tested to better that 0.12% of slant range 1 drms
Transmit source level (dB re 1 μPa @ 1 m)			200 dB
Tone equivalent energy (TEE)[2]			206 dB
Heading	Accuracy	Plus variant	0.1° secant latitude
		Standard variant	0.2° secant latitude
	Settle time		<5 minutes in dynamic conditions
Pitch & roll (accuracy)			0.01°
Heave	Range		±99 m
	Accuracy (real time)		5 cm or 5% (whichever the greater)
Electrical			+48 V dc maximum 160 W
Connector			AGP-2716
Communication			RS485, baud rate switchable, Ethernet 100 Mbps
Operating temperature			-5 to 40°C
Storage temperature			-20 to 45°C
Dimensions (length x diameter)			508 x 310 mm
Weight in air/water[3]			55/35 kg

Note: The absolute accuracy of the system is dependent upon the beacon source level, vessel noise, water depth, mechanical rigidity of the transceiver deployment machine, SV knowledge and proper calibration of the total system using CASIUS

[1] System performance is directly affected by frequency of operation. These figures are taken at top end of the band of operation, i.e. 33.5 kHz for MF band.
[2] WBv2+ signals are 4x the duration of Sonardyne tone signals (WBv1 & WBv2 are 2x). The TEE figure shows the operational performance when comparing wideband and tone systems.
[3] Estimated weights.

AvTrak Overview

AvTrak 6 has been designed to form part of an integrated AUV tracking and navigation system. Built on our 6G hardware platform running secure Wideband 2 spread-spectrum signal processing, AvTrak 6 combines the functions of transponder, transceiver and telemetry link in one low power unit that meets the requirements of a wide variety of AUV mission scenarios and vehicle types.

The unit is fully compatible with our family of survey quality LBL and USBL navigation systems. AvTrak 6 supports Sonardyne Messaging Service (SMS) allowing USBL position fixes to be sent to the vehicle or for status messages to be retrieved from the topside system.

AvTrak 6 is available in a variety of configurations to help meet a range of mission profiles. A popular option is an omni-directional unit with integral or remote transducer options. For operations at depth, an integral directional transducer option is common. AvTrak 6's flexible configuration is intended both to assist the AUV manufacturer with the mounting of the instrument within the AUV and to ensure the highest levels of acoustic performance. Low-medium frequency (LMF) and high-power (HP) versions of AvTrak 6 are also available.

An AUV equipped with AvTrak 6 can receive navigation updates from any 6G compatible USBL or LBL system, send status updates to multiple 6G instruments including other AUVs and synchronise clocks with other 6G instruments to better than 50 microseconds as standard.

Anko Maritime AS

REPORT

Argeo Searcher

Full Vessel Survey

Surveyed in Las Palmas, Spain 5th - 6th of February 2023 and 27th - 29th of March 2023

Client
Argeo

Document reference
2306007-004

0	FOR USE	2306007-004	26.04.2023	CW	AD	RH
REV. NO	REASON FOR ISSUE	DOC. NO.	REV. DATE	WRITTEN	VERIFIED	APPROVED

Anko Maritime AS

Enclosure 1
Coordinate reference system
IMU
Pole Gyro USBL - STB
Pole Gyro USBL - Port
Veripos1 Pri
Veripos 1 Slave
Veripos 2
GNSS Repeater 1
GNSS Repeater 2
Wind Sensor 1
Wind Sensor 2
Vessel Trimble
GPS 1 Vessel
GPS 2 Vessel
GPS 3 Vessel
AUV Stern
AUV STB Recovery Point

Enclosure 2
Coordinate reference system
Fix points for future use

ANKO

Anko Maritime AS

1 Introduction

Anko Maritime AS has been awarded a job by Argeo to perform an offset survey onboard Argeo Searcher Surveyed in Las Palmas, Spain 5th – 6th of February 2023 and 27th – 29th of March 2023.

1.1 General

The report details the results and describes the work performed.

1.2 Health Safety Environment

Our personnel worked through a safe job analysis prior to work commencement.
The work conditions on site were acceptable and seem to us to be safe.
No dangerous situation, near accident or accident occurred during our site visit.
No actions were done by us that could harm or pollute the environment as well as no valuable materials were spilled.

2 Scope of Work

Surveyed at Las Palmas, Spain 5th - 6th February 2023:

- Coordinate reference system	
- IMU	Position, Pitch, Roll, Yaw
- Veripos1 Pri	Position, Yaw
- Veripos 1 Slave	Position, Yaw
- Veripos 2	Position
- GNSS Repeater 1	Position
- GNSS Repeater 2	Position
- Wind Sensor 1	Position
- Wind Sensor 2	Position
- Vessel Trimble	Position
- GPS 1 Vessel	Position
- GPS 2 Vessel	Position
- GPS 3 Vessel	Position
- AUV Stern	Position
- AUV STB Recovery Point	Position
- Fix points for future use	Position

Surveyed at Las Palmas, Spain 27th – 29th of March 2023:

- Pole Gyro USBL - STB	Position, Pitch, Roll
- Pole Gyro USBL - Port	Position, Pitch, Roll

3 Results

3.1 Summary offset results

Item	X (+Stb)	Y (+Fwd)	Z (+Up)	Description
CRP	0.000	0.000	0.000	Vessel CL, Frame 57, Deck 4
Veripos1 Pri	8.218	-23.812	14.035	Geometric Center
Veripos 1 Slave	8.263	-15.964	13.827	Geometric Center
Veripos 2	8.466	-23.077	14.042	Geometric Center
IMU	6.189	6.163	0.145	Sensor Point
AUV Stern	1.638	-46.869	-5.758	Center Edge
AUV STB Recovery Point	9.028	2.824	0.062	Center Kicklist
USBL Ref Point	-4.606	13.300	-4.073	Teip Placed on Hatch
GNSS Repeater 1	8.019	-23.069	13.983	Geometric Centre
GNSS Repeater 2	7.620	-23.457	13.974	Geometric Centre
Wind Sensor 1	-2.402	39.174	22.461	Geometric Centre
Wind Sensor 2	-0.624	38.847	23.292	Geometric Centre
Vessel Trimble	-0.917	37.835	22.393	Geometric Centre
GPS 1 Vessel	7.937	-24.369	14.015	Geometric Centre
GPS 2 Vessel	0.103	37.187	22.095	Geometric Centre
GPS 3 Vessel	1.211	39.248	22.051	Geometric Centre
Gyro USBL - STB	-3.712	13.305	-13.776	Bottom Centre (Fully extracted)
Gyro USBL - Port	-4.293	13.311	-15.159	Bottom Centre (Fully extracted)

3.2 Summary results Yaw, Pitch and Roll

Item	Roll (+Stb Down)	Pitch (+ Bow Up)	Yaw(+Clockw)	Description
IMU	-0.18	0.38	-0.14	IMU Plate
Veripos	N/A	N/A	0.33	From Pri to Slave
Gyro USBL - STB	0.38	-0.08	N/A	Fully extracted
Gyro USBL - Port	0.22	-1.05	N/A	Fully extracted

3.3 Survey results

The results of the survey are presented in Enclosure 1

Anko Maritime AS

4 General comments

4.1 Coordinate Reference System

All coordinates herein are with reference to that system.
This system is defined as follows:

- Reference plane is a best fit plane through many points on Deck 4.
- Coordinate reference point (CRP, where X=0, Y=0, Z=0) is at Centreline from X-axis, Frame 57 at Y-axis and at Deck 4 for Z-axis.
- Positive X-axis is towards Starboard.
- Positive Y-axis is Forward.
- Positive Z-axis is Upwards.

4.2 Convention

- All angles/bearings in degree (360deg.system).
- Positive Pitch is Fore Up.
- Positive Roll is Starboard Down.
- Positive Yaw is Clockwise.

5 Work Procedure

Generally, all positions were obtained by measuring bearings and distances from the instrument (Totalstation) to a receiver target placed on the point to be measured. Several set ups with the instrument at different locations were necessary in order to have sight to all points that were measured.

From each set up, it was measured to several common points that could be measured to from at least one other set up. All points of relevance were measured to at least two times.

Afterwards, all measured points from all set ups were calculated into a common coordinate reference system for the vessel.

6 Survey accuracy

Probable angular determination accuracy is +/- 0.025 deg.
Probable position determination accuracy is +/- 2mm.

Anko Maritime AS

7 Personnel

The survey work was performed by the following personnel:

Surveyed at Las Palmas, Spain 5th - 6th February 2023:
Senior Surveyor Anders Dalerhaug

Surveyed at Las Palmas, Spain 27th – 29th of March 2023:
Surveyor Camilla Waage

DAK-Operator: Katarzyna Rozum-Urbaniak

8 Equipment

The following equipment and software were used:

Equipment:
- Leica TS11 Totalstation.
- Javad Sigma (4 antennae GPS+Glonass attitude system produced by Javad Navigation Systems)

Software:
- SC4W 3D coordinate calculation software, version no 1.195.0.114
- Innhouse Tools version 1.13.34.3:
  - AttCon
- AttCon Log Monitor version no 1.13.13

Various minor survey equipment (e.g. tripod, rulers, prisms etc.)

Anko Maritime AS

ENCLOSURE 1

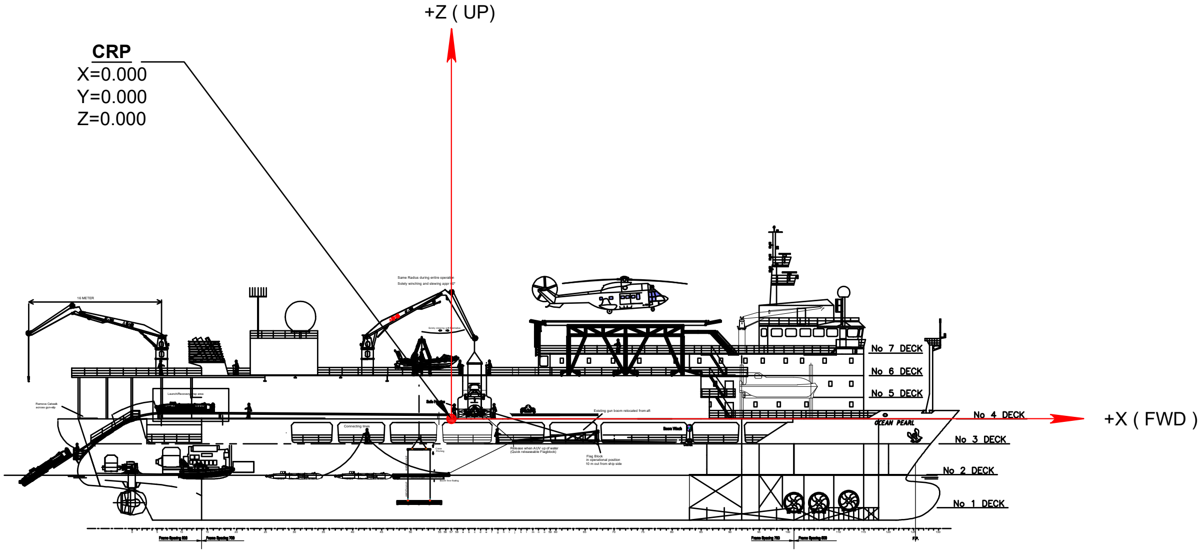
Argeo Searcher

Surveyed at Las Palmas, Spain 5th - 6th February 2023 and 27th – 29th of March 2023:

- Coordinate reference system	
- IMU	Position, Pitch, Roll, Yaw
- Pole Gyro USBL - STB	Position, Pitch, Roll
- Pole Gyro USBL - Port	Position, Pitch, Roll
- Veripos1 Pri	Position, Yaw
- Veripos 1 Slave	Position, Yaw
- Veripos 2	Position
- GNSS Repeater 1	Position
- GNSS Repeater 2	Position
- Wind Sensor 1	Position
- Wind Sensor 2	Position
- Vessel Trimble	Position
- GPS 1 Vessel	Position
- GPS 2 Vessel	Position
- GPS 3 Vessel	Position
- AUV Stern	Position
- AUV STB Recovery Point	Position

General comments

- All dimensions in metres U.N.O.
- All angles/bearings in degree (360deg.system).
- Sketches not to scale.
- Probable general position survey accuracy is +/- 2mm.
- Probable general angle survey accuracy is +/- 0.025deg.



SIDE VIEW

NOTES:

THE COMMON COORDINATE REFERENCE SYSTEM IS DEFINED AS FOLLOWS:
- REFERENCE PLANE IS A BEST FIT THROUGH SEVERAL POINTS ON 4 DECK
- CENTERLINE STRUCTURE IS DEFINED FROM MAIN STRUCTURE
- COORDINATE REFERENCE POINT (CRP, WHERE X=0.000, Y=0.000, Z=0.000) IS AT CENTERLINE FROM X-AXIS, FRAME 57 AT Y-AXIS AND AT DECK 4 FOR Z-AXIS
- POSITIVE X-AXIS IS TOWARDS STARBOARD
- POSITIVE Y-AXIS IS FORWARD
- POSITIVE Z-AXIS IS UPWARDS

- SKETCH NOT TO SCALE
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE: **COORDINATE REFERENCE SYSTEM**

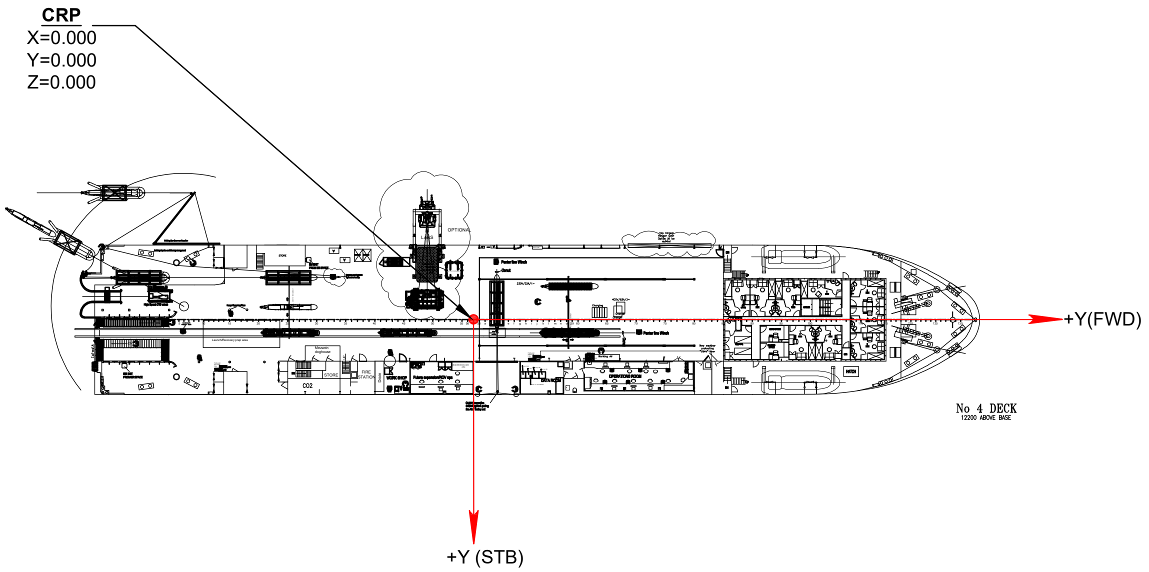
CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004 | ENCL: 1

REF. DRAWING NO. 100-1 Rev.4 | PAGE: 1



TOP VIEW

NOTES:

THE COMMON COORDINATE REFERENCE SYSTEM IS DEFINED AS FOLLOWS:
- REFERENCE PLANE IS A BEST FIT THROUGH SEVERAL POINTS ON 4 DECK
- CENTERLINE STRUCTURE IS DEFINED FROM MAIN STRUCTURE
- COORDINATE REFERENCE POINT (CRP, WHERE X=0.000, Y=0.000, Z=0.000) IS AT CENTERLINE FROM X-AXIS, FRAME 57 AT Y-AXIS AND AT DECK 4 FOR Z-AXIS
- POSITIVE X-AXIS IS TOWARDS STARBOARD
- POSITIVE Y-AXIS IS FORWARD
- POSITIVE Z-AXIS IS UPWARDS

- SKETCH NOT TO SCALE
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

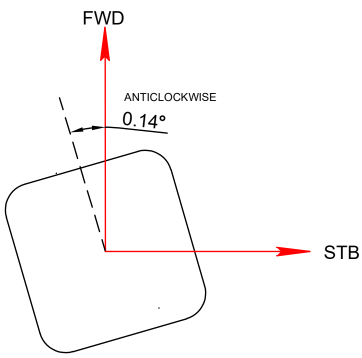
ANKO MARITIME AS

DIMENSIONAL CONTROL

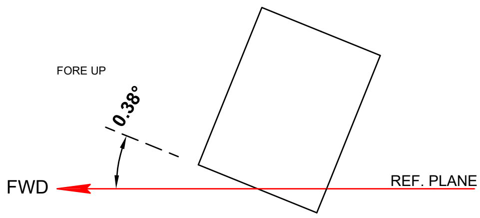
TITLE:

COORDINATE REFERENCE SYSTEM

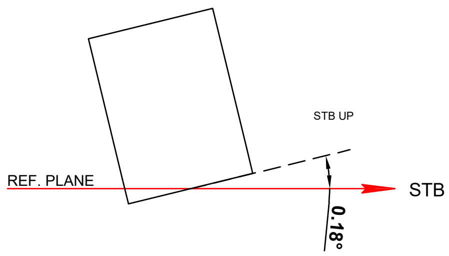
CLIENT:	**ARGEO**
PROJECT:	**Argeo Searcher**
LOCATION:	Spain, Las Palmas
DOC. REF.:	2306007-004
ENCL:	1
REF. DRAWING NO.	100-1 Rev.4
PAGE:	2



YAW
PLAN VIEW



PITCH
LOOKING TOWARDS STARBOARD



ROLL
LOOKING FORWARD

SENSOR POINT
X = 6.189
Y = 6.163
Z = 0.145

IMU

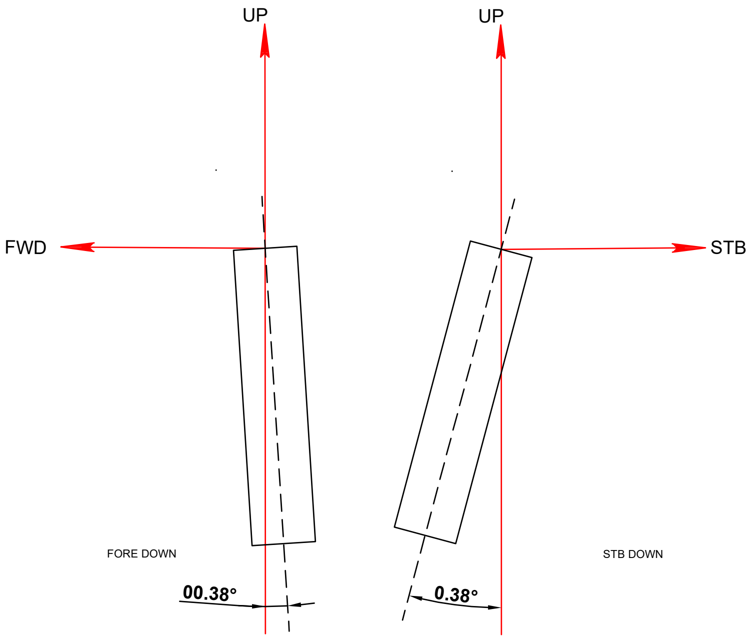
NOTES:
- ALL COORDINATES IN METERS
- ALL ANGLES IN 360 DEGREE SYSTEM

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS
DIMENSIONAL CONTROL

TITLE:
IMU
POSITION, YAW, PITCH AND ROLL

CLIENT: **ARGEO**
PROJECT: **Argeo Searcher**
LOCATION: Spain, Las Palmas
DOC. REF.: 2306007-004
ENCL: 1
REF. DRAWING NO.
PAGE: 3



PITCH
LOOKING TOWARDS STARBOARD

ROLL
LOOKING FORWARD

CALCULATED POSITION OF U/S HEAD, AS FULLY EXTENDED
BOTTOM CENTER
X = -3.712
Y = 13.305
Z = -13.776

GYRO USBL - STB
LOOKING FORWARD

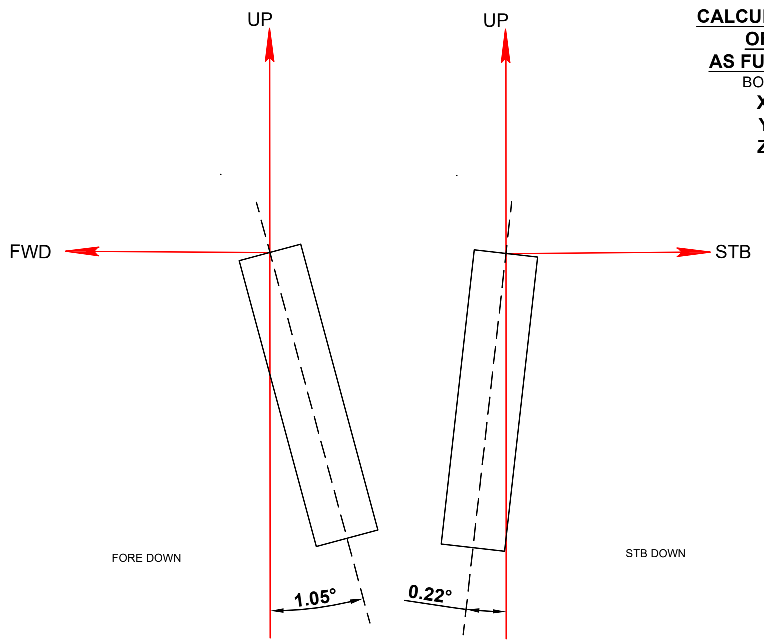
NOTES:
- ALL COORDINATES IN METERS
- ALL ANGLES IN 360 DEGREE SYSTEM

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS
DIMENSIONAL CONTROL

TITLE:
GYRO USBL - STB
POSITION, PITCH AND ROLL

CLIENT:	**ARGEO**
PROJECT:	**Argeo Searcher**
LOCATION:	Spain, Las Palmas
DOC. REF.:	2306007-004
ENCL:	1
REF. DRAWING NO.	
PAGE:	4



PITCH
LOOKING TOWARDS STARBOARD

ROLL
LOOKING FORWARD

CALCULATED POSITION OF U/S HEAD, AS FULLY EXTENDED
BOTTOM CENTER
X = -4.293
Y = 13.311
Z = -15.159

GYRO USBL - PORT
LOOKING FORWARD

NOTES:
- ALL COORDINATES IN METERS
- ALL ANGLES IN 360 DEGREE SYSTEM

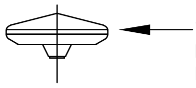
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS
DIMENSIONAL CONTROL

CLIENT: **ARGEO**
PROJECT: **Argeo Searcher**
LOCATION: Spain, Las Palmas
DOC. REF.: 2306007-004
ENCL: 1
REF. DRAWING NO.
PAGE: 5

TITLE:
GYRO USBL - PORT
POSITION, PITCH AND ROLL

LOOKING FWD\UP



Wind Sensor 1	-2.402	39.174	22.461	Geometric Centre
Wind Sensor 2	-0.624	38.847	23.292	Geometric Centre
Vessel Trimble	-0.917	37.835	22.393	Geometric Centre
GPS 2 Vessel	0.103	37.187	22.095	Geometric Centre
GPS 3 Vessel	1.211	39.248	22.051	Geometric Centre

NOTES:
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE: **ANTENNA AND WIND SENSOR** POSITION

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

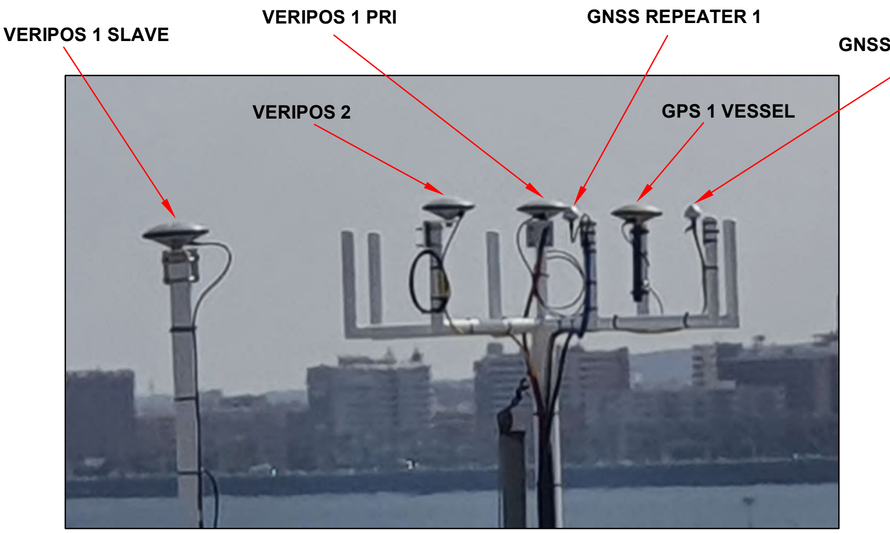
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

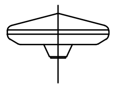
ENCL: 1

REF. DRAWING NO.

PAGE: 6



LOOKING AFT\STB



Veripos1 Pri	8.218	-23.812	14.035	Geometric Center
Veripos 1 Slave	8.263	-15.964	13.827	Geometric Center
Veripos 2	8.466	-23.077	14.042	Geometric Center
GNSS Repeater 1	8.019	-23.069	13.983	Geometric Centre
GNSS Repeater 2	7.620	-23.457	13.974	Geometric Centre
GPS 1 Vessel	7.937	-24.369	14.015	Geometric Centre

NOTES:

- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

TITLE: **ANTENNA** POSITION

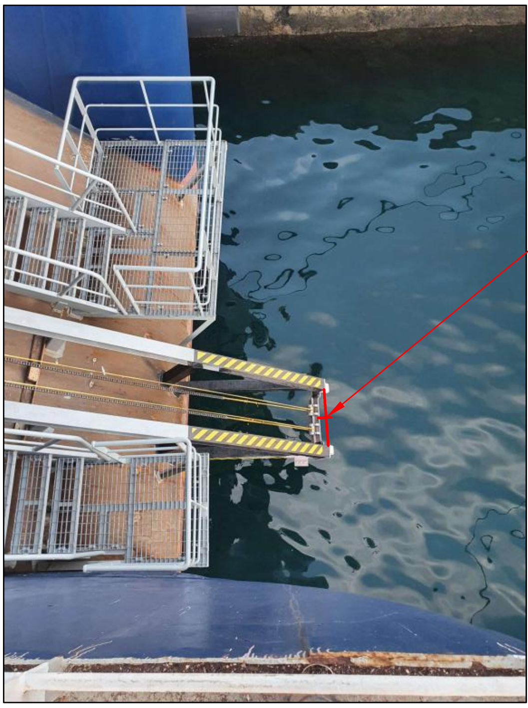
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 1

REF. DRAWING NO.

PAGE: 7



AUV STERN
CENTER EDGE
X = 1.638
Y = -46.869
Z = -5.758

LOOKING DOWN\STB

NOTES:
- ALL COORDINATES IN METERS

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO MARITIME AS
DIMENSIONAL CONTROL

TITLE:
AUV STERN
POSITION

CLIENT: **ARGEO**
PROJECT: **Argeo Searcher**
LOCATION: Spain, Las Palmas
DOC. REF.: 2306007-004
ENCL: 1
REF. DRAWING NO.
PAGE: 8

LOOKING STB

LOOKING DOWN

AUV RECOVERY POINT
(PUNCH MARK)
CENTER KICKLIST
X = 9.028
Y = 2.824
Z = 0.062

NOTES:
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS
DIMENSIONAL CONTROL

TITLE:
AUV RECOVERY POINT
POSITION

CLIENT: **ARGEO**
PROJECT: **Argeo Searcher**
LOCATION: Spain, Las Palmas
DOC. REF.: 2306007-004
ENCL: 1
REF. DRAWING NO.
PAGE: 9

ENCLOSURE 2

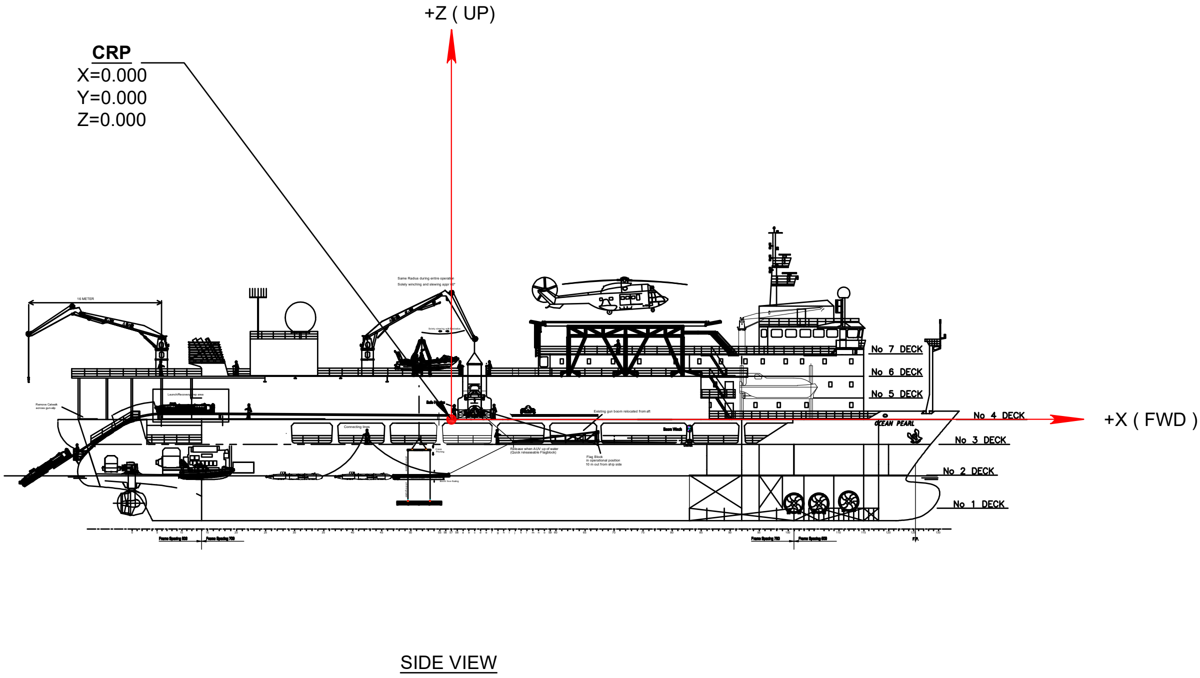
Argeo Searcher

Surveyed at Las Palmas, Spain 5th - 6th February 2023:

- Coordinate reference system
- Fix points for future use

General comments

- All dimensions in metres U.N.O.
- Sketches not to scale.
- Probable general position survey accuracy is +/- 2mm.



NOTES:

THE COMMON COORDINATE REFERENCE SYSTEM IS DEFINED AS FOLLOWS:
- REFERENCE PLANE IS A BEST FIT THROUGH SEVERAL POINTS ON 4 DECK
- CENTERLINE STRUCTURE IS DEFINED FROM MAIN STRUCTURE
- COORDINATE REFERENCE POINT (CRP, WHERE X=0.000, Y=0.000, Z=0.000) IS AT CENTERLINE FROM X-AXIS, FRAME 57 AT Y-AXIS AND AT DECK 4 FOR Z-AXIS
- POSITIVE X-AXIS IS TOWARDS STARBOARD
- POSITIVE Y-AXIS IS FORWARD
- POSITIVE Z-AXIS IS UPWARDS

- SKETCH NOT TO SCALE
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

COORDINATE REFERENCE SYSTEM

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

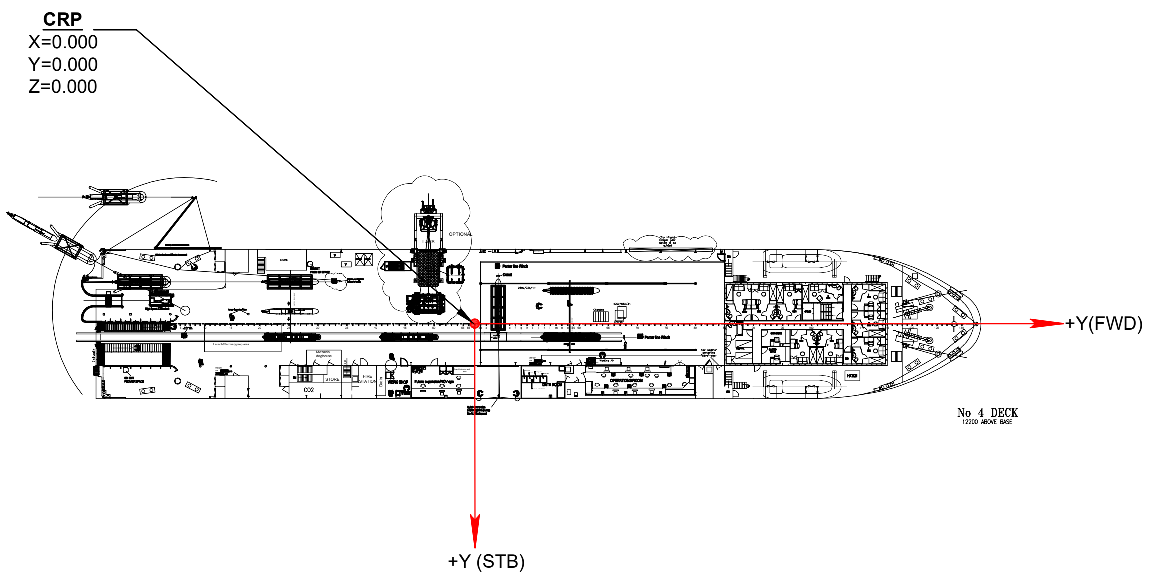
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO. 100-1 Rev.4

PAGE: 1



TOP VIEW

NOTES:

THE COMMON COORDINATE REFERENCE SYSTEM IS DEFINED AS FOLLOWS:

- REFERENCE PLANE IS A BEST FIT THROUGH SEVERAL POINTS ON 4 DECK
- CENTERLINE STRUCTURE IS DEFINED FROM MAIN STRUCTURE
- COORDINATE REFERENCE POINT (CRP, WHERE X=0.000, Y=0.000, Z=0.000) IS AT CENTERLINE FROM X-AXIS, FRAME 57 AT Y-AXIS AND AT DECK 4 FOR Z-AXIS
- POSITIVE X-AXIS IS TOWARDS STARBOARD
- POSITIVE Y-AXIS IS FORWARD
- POSITIVE Z-AXIS IS UPWARDS

- SKETCH NOT TO SCALE
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

COORDINATE REFERENCE SYSTEM

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO. 100-1 Rev.4

PAGE: 2

Point ID	X (+Stb)	Y (+ Fwd)	Z (+Up)	Description
F1	1,403	27,107	-2,035	Punch Mark Deck 3
F2	-4,718	15,504	-2,161	Punch Mark Deck 3
F3	-6,893	20,195	-1,133	Punch Mark Deck 3
F4	5,138	13,724	-3,131	Punch Mark Deck 3
F5	1,377	12,590	-2,064	Punch Mark Deck 3
F6	-6,886	7,077	-1,132	Punch Mark Deck 3
F7	-4,226	0,532	-2,185	Punch Mark Deck 3
201	-1,537	28,693	-1,410	Reflective teip Deck 3
202	2,289	26,742	-2,289	Reflective teip Deck 3
203	-7,299	20,262	-1,241	Reflective teip Deck 3
204	-6,853	13,706	-1,646	Reflective teip Deck 3
205	-1,888	12,424	-3,019	Reflective teip Deck 3
206	4,660	1,568	-2,315	Reflective teip Deck 3
207	3,121	-2,177	-1,830	Reflective teip Deck 3
208	-7,282	2,819	-1,277	Reflective teip Deck 3
101	7,234	20,282	-1,686	40 MM targets Deck 3
102	7,174	4,929	-1,603	40 MM targets Deck 3
103	-1,206	13,280	-0,890	40 MM targets Deck 3
104	-7,190	4,958	-1,657	40 MM targets Deck 3
105	-1,361	-2,471	-1,687	40 MM targets Deck 3
106	-7,229	-7,728	-1,683	40 MM targets Deck 3
107	-4,673	-9,185	-1,652	40 MM targets Deck 3
108	-5,937	-5,276	-2,372	40 MM targets Deck 3

NOTES:

- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 3
COORDINATES

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

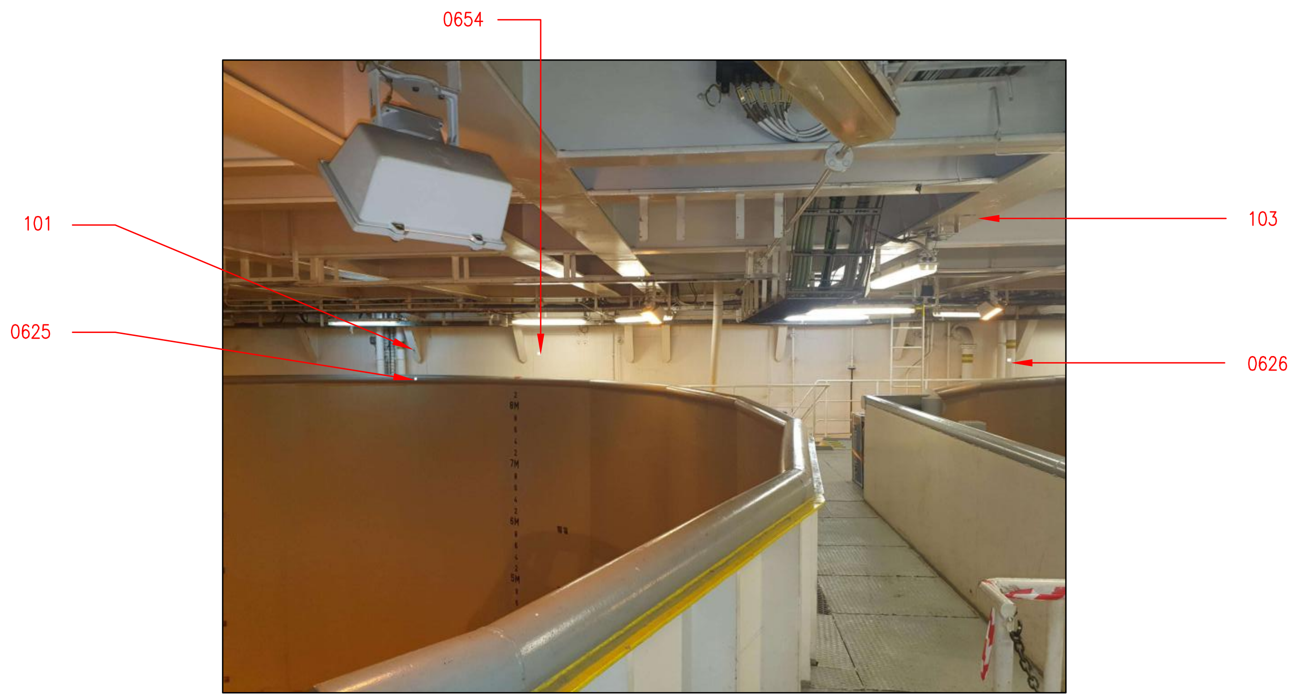
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 3



LOOKING STB

NOTES:	

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 3
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

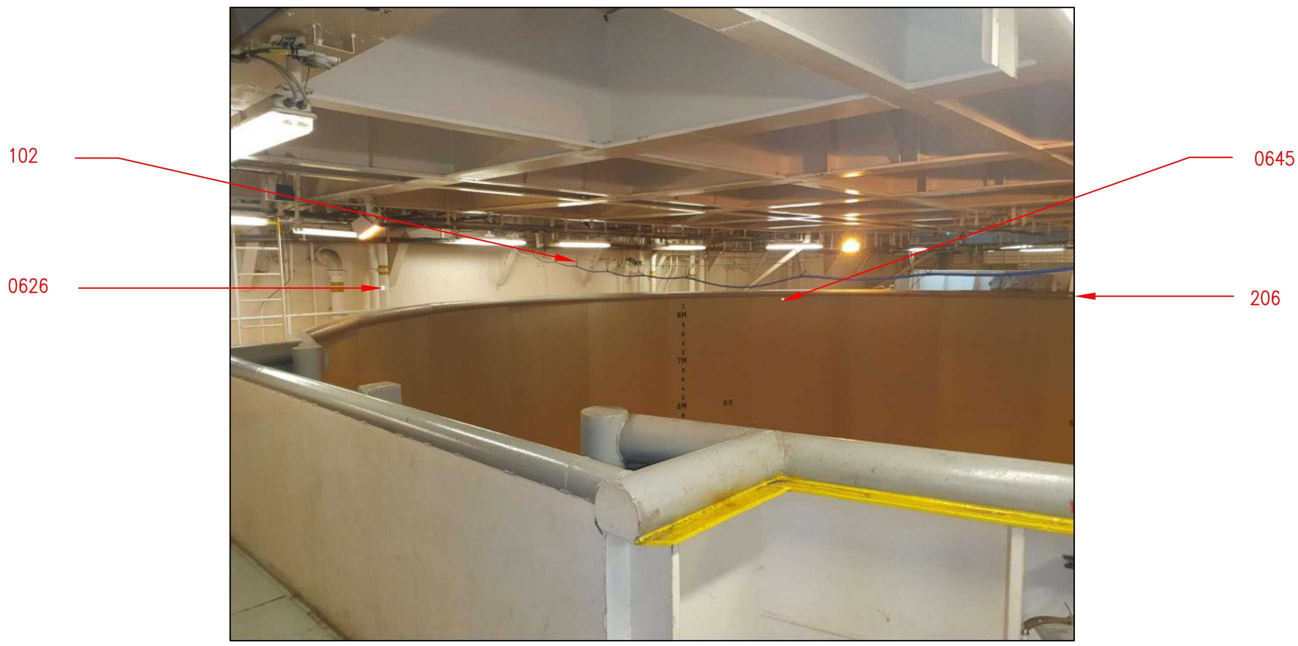
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 4



LOOKING STB/AFT

NOTES:

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 3
POSITION AND OVERVIEW

CLIENT: **ARGEO**	
PROJECT: **Argeo Searcher**	
LOCATION: Spain, Las Palmas	
DOC. REF.: 2306007-004	ENCL: 2
REF. DRAWING NO.	PAGE: 5

LOOKING AFT

NOTES:

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

TITLE:

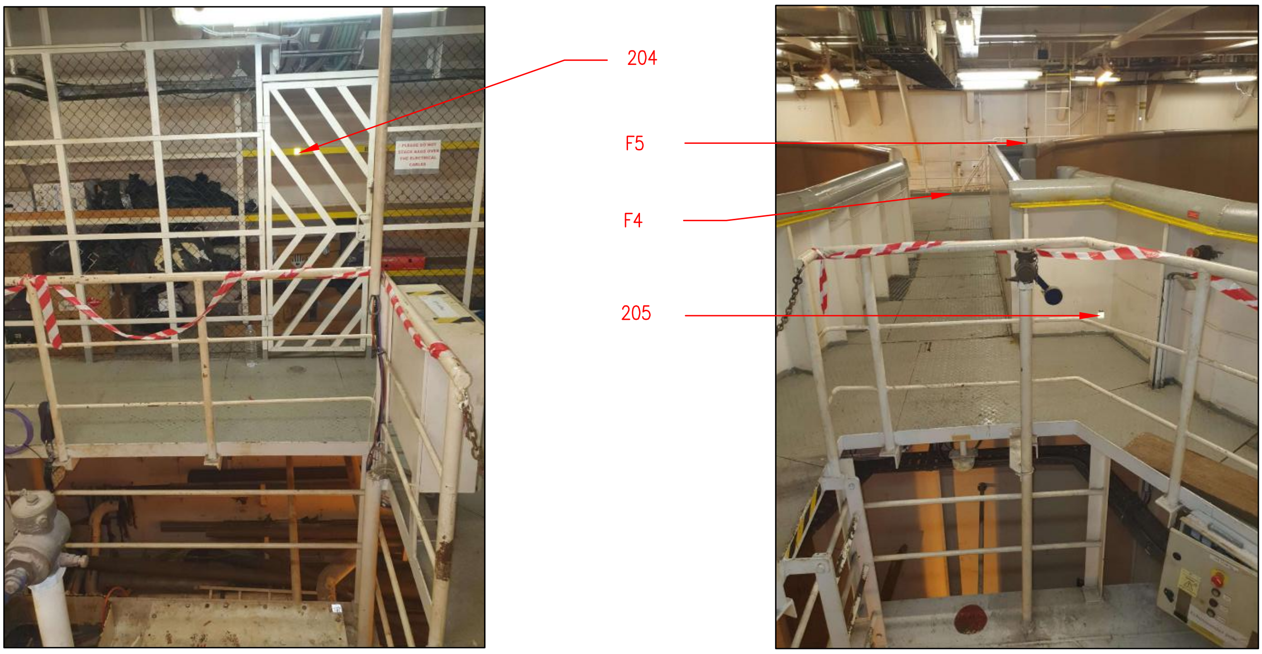
FIX POINTS
Deck 3
POSITION AND OVERVIEW

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 6



LOOKING PORT

LOOKING STB

NOTES:

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 3
POSITION AND OVERVIEW

CLIENT: **ARGEO**	
PROJECT: **Argeo Searcher**	
LOCATION: Spain, Las Palmas	
DOC. REF.: 2306007-004	ENCL: 2
REF. DRAWING NO.	PAGE: 7

LOOKING FWD

LOOKING DOWN

NOTES:

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 3
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

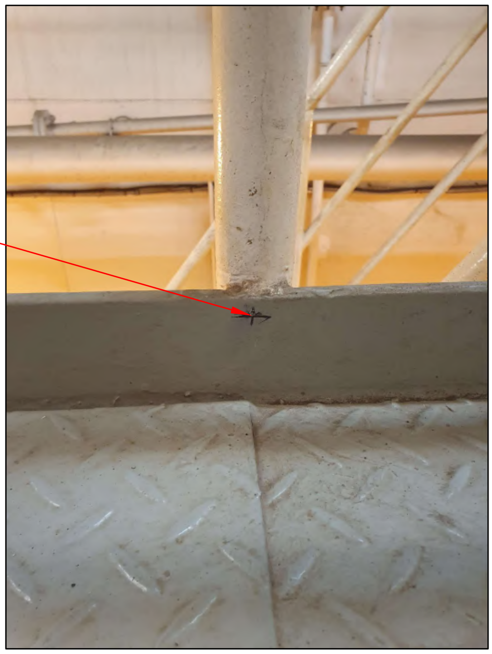
DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 8

LOOKING AFT



LOOKING STB

NOTES:

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 9

TITLE:

FIX POINTS
Deck 3
POSITION AND OVERVIEW

LOOKING FWD

NOTES:

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 3
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 10

LOOKING AFT

LOOKING AFT

NOTES:

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 3
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

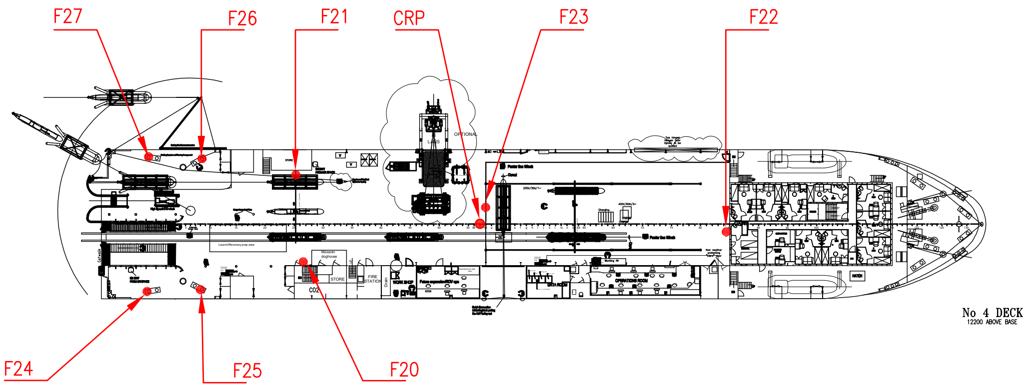
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 1

REF. DRAWING NO.

PAGE: 11



Point ID	X (+Stb)	Y (+Fwd)	Z (+Up)	Description
CRP	0,000	0,000	0,000	Punch Mark on Deck
F20	4,913	-20,255	2,246	Punch Mark - Deck 4
F21	-6,236	-10,776	2,081	Punch Mark - Deck 4
F22	2,593	30,044	2,030	Punch Mark - Deck 4
F23	-2,744	0,687	0,244	Punch Mark - Deck 4
F24	8,110	-39,815	0,806	Center bollard
F25	7,637	-33,238	0,800	Center bollard
F26	-7,778	-33,247	0,802	Center bollard
F27	-8,071	-39,634	0,815	Center bollard

NOTES:
- SKETCH NOT TO SCALE
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:
FIX POINTS
Deck 4
POSITION, OVERVIEW AND COORDINATES

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 12

LOOKING FWD

LOOKING FWD

NOTES:

ANKO MARITIME AS

DIMENSIONAL CONTROL

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

TITLE:

FIX POINTS
Deck 4
POSITION AND OVERVIEW

CLIENT: **ARGEO**	
PROJECT: **Argeo Searcher**	
LOCATION: Spain, Las Palmas	
DOC. REF.: 2306007-004	ENCL: 2
REF. DRAWING NO.	PAGE: 13

NOTES:

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 4
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 14

LOOKING FWD

NOTES:

0	FOR USE	05.05.23	KRU	CW	AD	RH
REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Deck 4
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

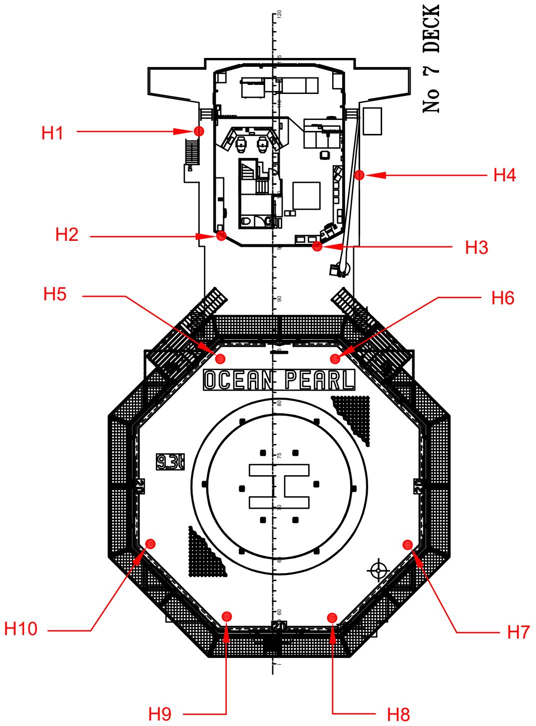
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 15



Point ID	X (+Stb)	Y (+Fwd)	Z (+Up)	Description
H1	-4,525	48,066	12,035	Punch Mark On Helideck
H2	-2,195	37,020	12,404	Punch Mark On Helideck
H3	1,422	37,021	12,908	Punch Mark On Helideck
H4	4,289	44,341	12,045	Punch Mark On Helideck
H5	-3,945	30,407	11,787	Punch Mark On Helideck
H6	3,944	30,444	11,793	Punch Mark On Helideck
H7	9,595	17,253	11,815	Punch Mark On Helideck
H8	3,935	11,521	11,784	Punch Mark On Helideck
H9	-3,936	11,518	11,769	Punch Mark On Helideck
H10	-9,578	17,196	11,783	Punch Mark On Helideck

NOTES:
- SKETCH NOT TO SCALE
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

TITLE:

FIX POINTS
Helideck
POSITION AND OVERVIEW

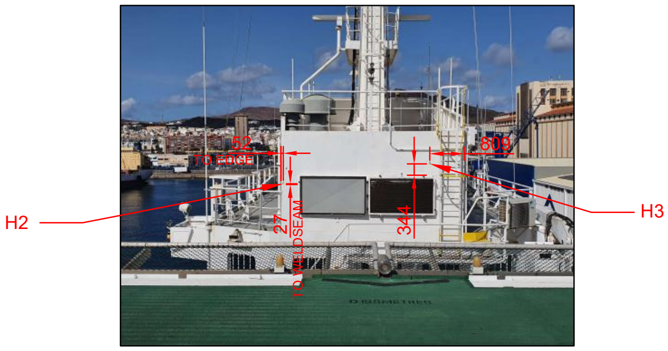
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 16



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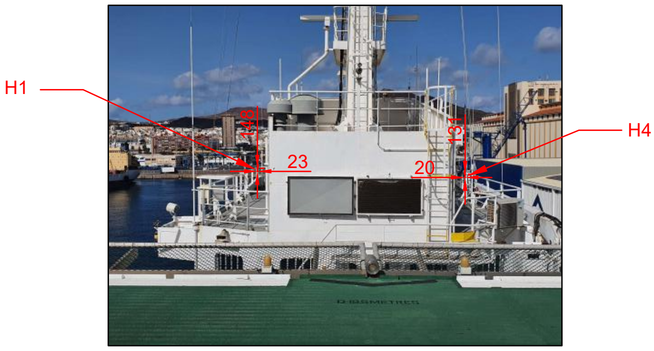

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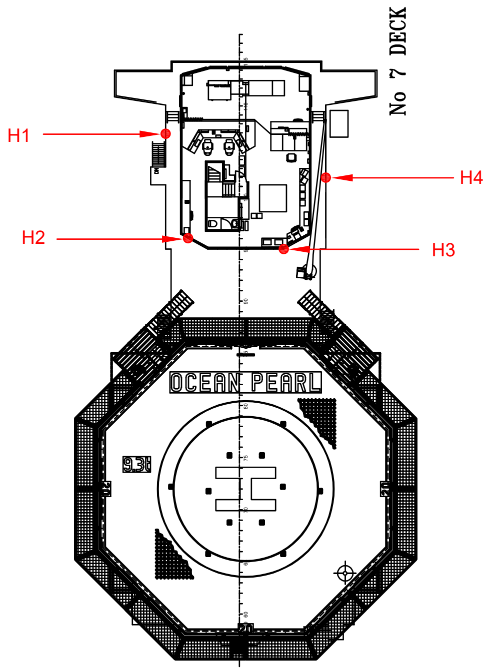


NOTES:

- SKETCH NOT TO SCALE
- ALL COORDINATES IN METERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

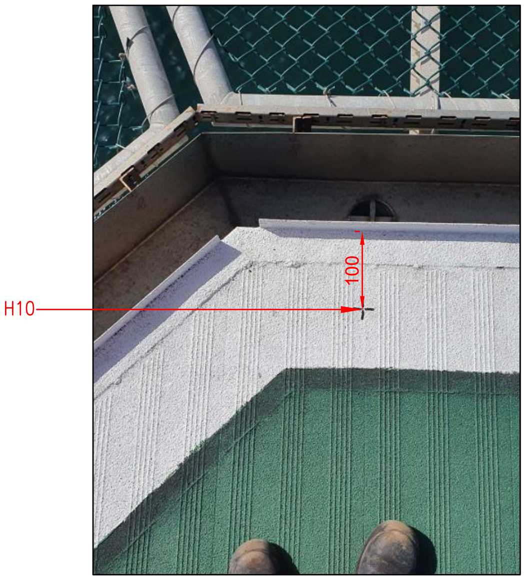
ANKO MARITIME AS

DIMENSIONAL CONTROL

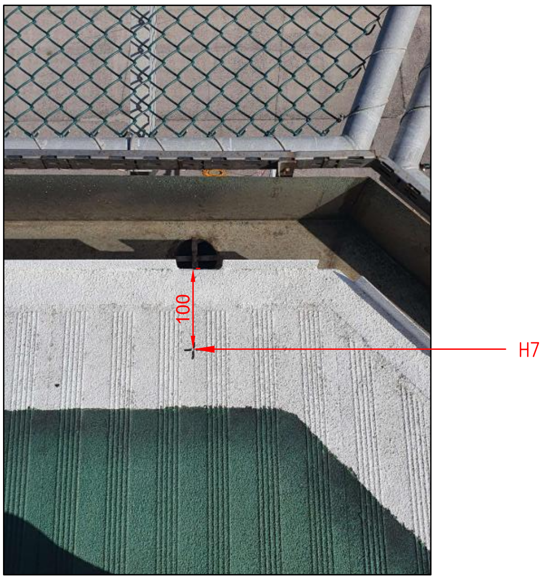
CLIENT:	**ARGEO**
PROJECT:	**Argeo Searcher**
LOCATION:	Spain, Las Palmas
DOC. REF.:	2306007-004
ENCL:	2
REF. DRAWING NO.	
PAGE:	17

TITLE:

FIX POINTS
Helideck
POSITION AND OVERVIEW



LOOKING DOWN\PORT



LOOKING DOWN\STB

NOTES:
- SKETCH NOT TO SCALE
- ALL DIMENSIONS IN MILLIMETERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

TITLE:
FIX POINTS
Helideck
POSITION AND OVERVIEW

LOCATION: Spain, Las Palmas

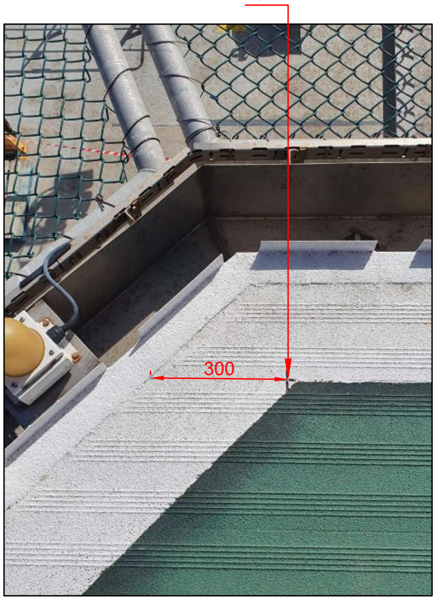
DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

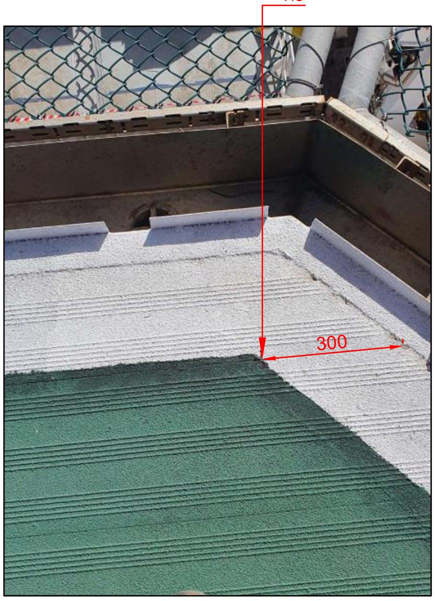
PAGE: 18

H8



LOOKING DOWN\AFT

H9



LOOKING DOWN\AFT

NOTES:
- SKETCH NOT TO SCALE
- ALL DIMENSIONS IN MILLIMETERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Helideck
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

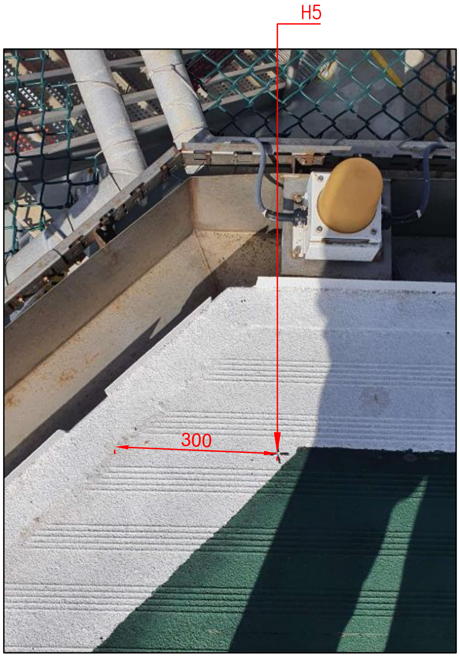
LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

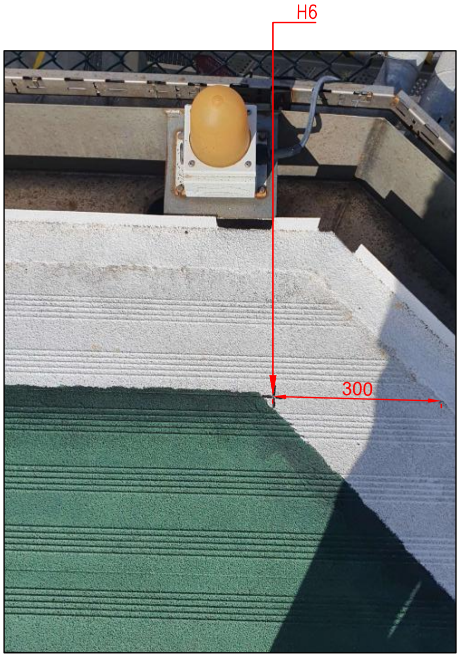
ENCL: 2

REF. DRAWING NO.

PAGE: 19



LOOKING DOWN\FORE



LOOKING DOWN\FORE

NOTES:
- SKETCH NOT TO SCALE
- ALL DIMENSIONS IN MILLIMETERS

REV.NO.	REASON FOR ISSUE	DATE	DRAWN	PREPARED	CHECKED	APPROVED
0	FOR USE	05.05.23	KRU	CW	AD	RH

ANKO MARITIME AS

DIMENSIONAL CONTROL

TITLE:

FIX POINTS
Helideck
POSITION AND OVERVIEW

CLIENT: **ARGEO**

PROJECT: **Argeo Searcher**

LOCATION: Spain, Las Palmas

DOC. REF.: 2306007-004

ENCL: 2

REF. DRAWING NO.

PAGE: 20

Anko Maritime AS

CALIBRATION REPORT

Argeo Searcher

Surveyed at Las Palmas, Spain 27th - 29th of March 2023

Client
Argeo

Document reference
2306007-003

0	FOR USE	2306007-003	11.04.2023	CW	AD	RH
REV. NO	REASON FOR ISSUE	DOC. NO.	REV. DATE	WRITTEN	VERIFIED	APPROVED

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1 Introduction

Anko Maritime AS has been awarded a job by Argeo to perform heading/pitch/roll calibration onboard Argeo Searcher. The work was performed at Las Palmas, Spain 27th – 29th of March 2023.

1.1 General

This report details the results and describes the work performed.

1.2 Health Safety Environment

The work conditions on site were acceptable and seem to us to be safe.
No dangerous situation, near accident or accident occurred during our site visit.
No actions were done by us that could harm or pollute the environment as well as no valuable materials were spilled.

2 Scope of Work

Heading/Pitch/Roll Calibration:

- Lodestar LMF
- Lodestar
- Veripos
- Vessel

Anko Maritime AS

3 Summary Results

3.1 Lodestar

Lodestar

Name	Average C-O
Average: Lodestar Pitch	**-0.09**
Average: Lodestar Roll	**-0.11**
Average: Lodestar Heading	**-14.27**

Ref. Chapter 8 for more details.

3.2 Veripos

Veripos

Name	Average C-O
Average: Veripos Pitch	**0.06**
Average: Veripos Roll	**-0.04**
Average: Veripos Heading	**-0.63**

Ref. Chapter 8 for more details.

3.3 Vessel

Vessel

Name	Average C-O
Average: Vessel Pitch	**-1.07**
Average: Vessel Roll	**-0.81**
Average: Vessel Heading	**-1.35**

Ref. Chapter 8 for more details.

3.4 Lodestar LMF

Lodestar LMF

Name	Average C-O
Average: Lodestar LMF Pitch	-0.10
Average: Lodestar LMF Roll	0.90
Average: Lodestar LMF Heading	-1.41

Ref. Chapter 8 for more details.

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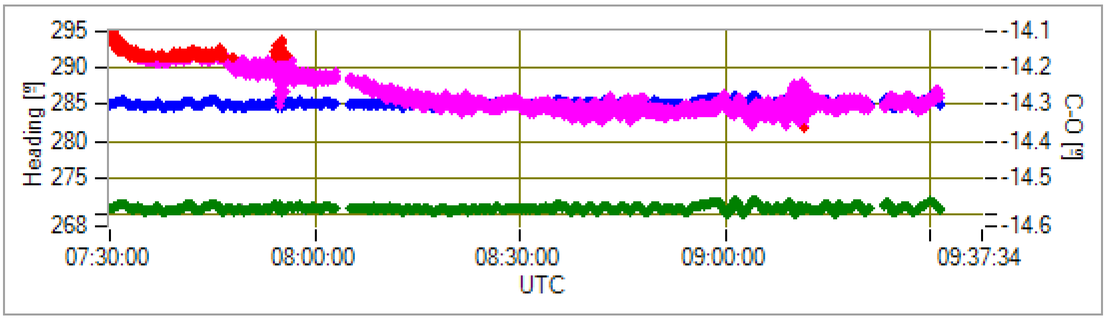
4 Heading/Pitch/Roll Calibration

4.1 Lodestar

Lodestar
Verification of heading data:
Lodestar Heading

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	-14.28	0.05	-14.28 to -14....	6456	5738
V	2023.03.29 07:30	2023.03.29 09:31	-14.28	0.04	-14.28 to -14....	6456	5741
L	2023.03.29 07:30	2023.03.29 09:31	-14.26			6456	6456
Avg			-14.27				



Heading by Vector   Heading from Q-matrix   Client Lodestar Heading   C-O Q
Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

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Anko Maritime AS

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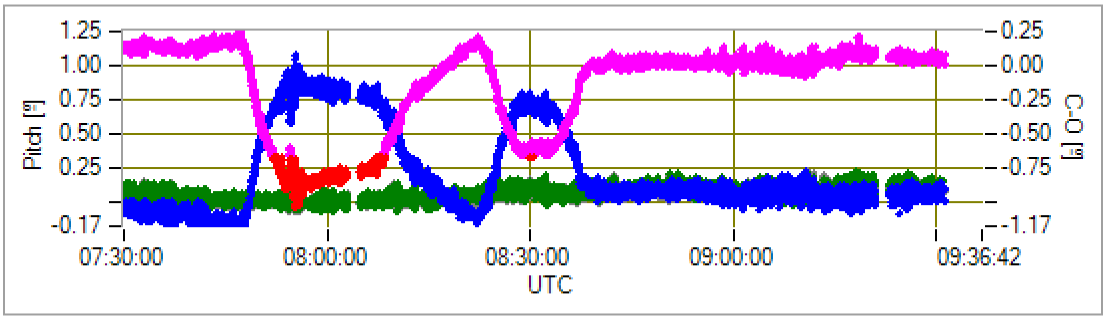
Lodestar
Verification of pitch data:
Lodestar Pitch

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	-0.06	0.23	-0.07 to -0.05	6456	5734
V	2023.03.29 07:30	2023.03.29 09:31	-0.07	0.23	-0.07 to -0.06	6456	5732
L	2023.03.29 07:30	2023.03.29 09:31	-0.15			6456	6456
Avg			-0.09				



Pitch by Vector | Pitch from Q-matrix | Client Lodestar Pitch | C-O Q | Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

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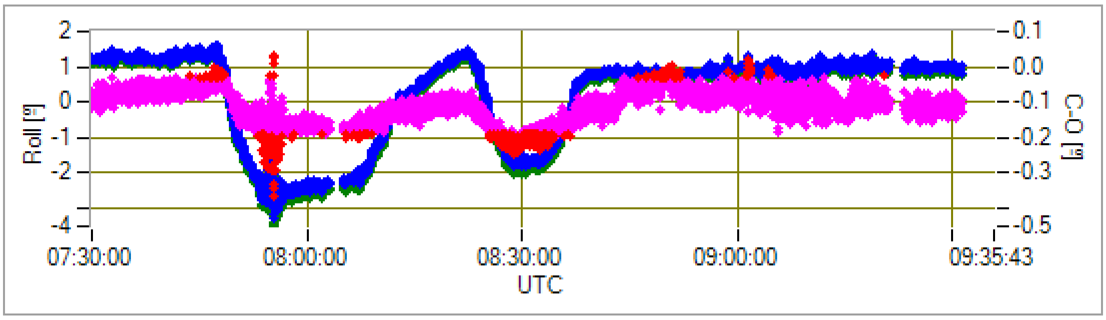
Lodestar
Verification of roll data:
Lodestar Roll

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	-0.10	0.04	-0.11 to -0.10	6456	5932
V	2023.03.29 07:30	2023.03.29 09:31	-0.10	0.04	-0.11 to -0.10	6456	5929
L	2023.03.29 07:30	2023.03.29 09:31	-0.11			6456	6456
Avg			-0.11				



Roll by Vector   Roll from Q-matrix   Client Lodestar Roll   C-O Q   Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

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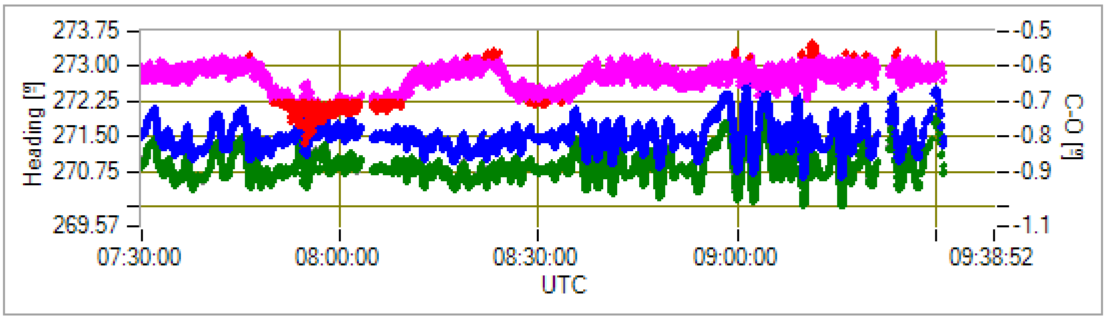
4.2 Veripos

Veripos
Verification of heading data:
Veripos Heading

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	-0.63	0.03	-0.63 to -0.63	6456	5793
V	2023.03.29 07:30	2023.03.29 09:31	-0.63	0.03	-0.63 to -0.63	6456	5766
L	2023.03.29 07:30	2023.03.29 09:31	-0.64			6456	6456
Avg			-0.63				

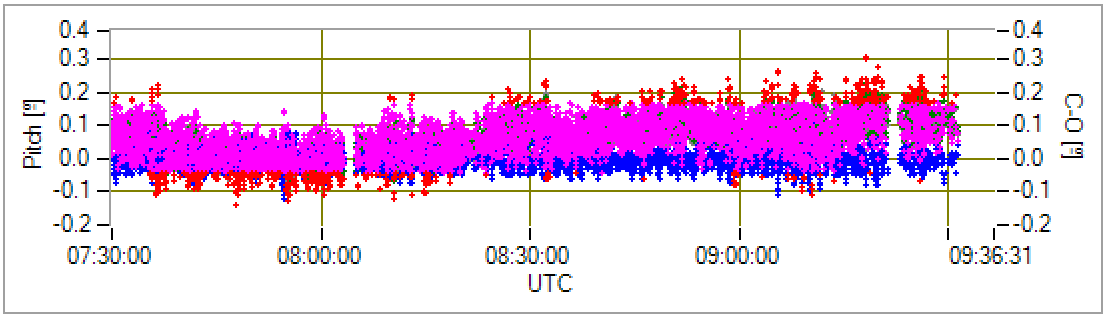


Heading by Vector Heading from Q-matrix Client Veripos Heading C-O Q
Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

Veripos
Verification of pitch data:
Veripos Pitch

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	0.06	0.05	0.06 to 0.06	6456	5823
V	2023.03.29 07:30	2023.03.29 09:31	0.06	0.05	0.06 to 0.06	6456	5805
L	2023.03.29 07:30	2023.03.29 09:31	0.06			6456	6456
Avg			0.06				



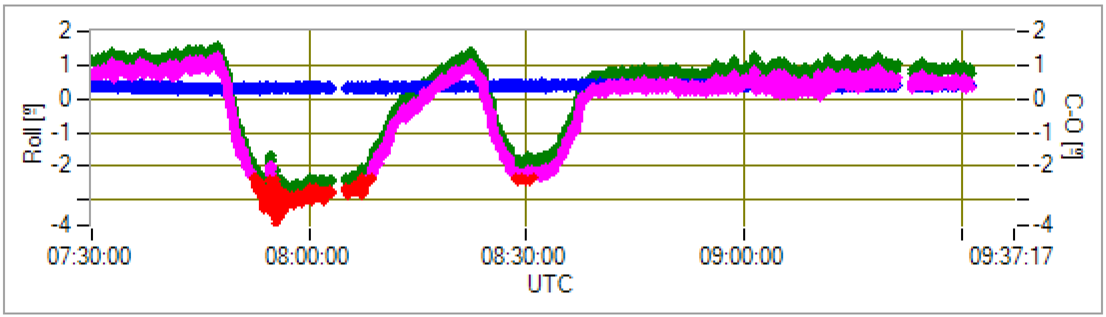
Pitch by Vector   Pitch from Q-matrix   Client Veripos Pitch   C-O Q   Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

Anko Maritime AS

Veripos
Verification of roll data:
Veripos Roll

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	0.08	0.92	0.05 to 0.10	6456	5708
V	2023.03.29 07:30	2023.03.29 09:31	0.08	0.92	0.05 to 0.10	6456	5708
L	2023.03.29 07:30	2023.03.29 09:31	-0.26			6456	6456
Avg			-0.04				



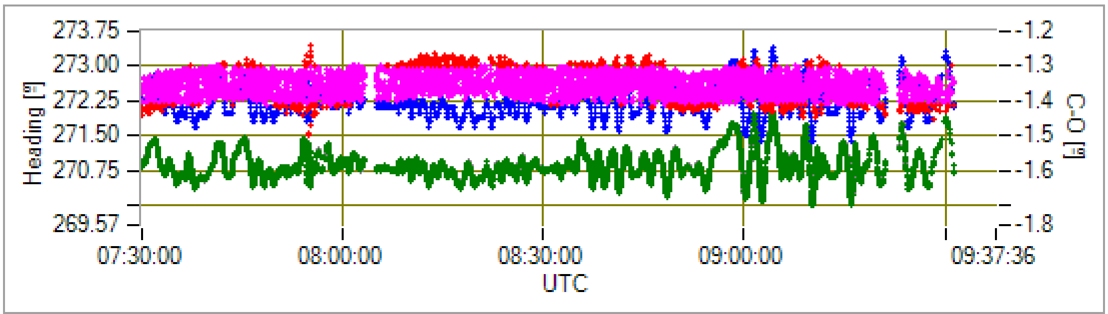
Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

Anko Maritime AS

4.3 Vessel

Vessel
Verification of heading data:
Vessel Heading

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	-1.35	0.03	-1.36 to -1.35	6456	5876
V	2023.03.29 07:30	2023.03.29 09:31	-1.35	0.03	-1.35 to -1.35	6456	5899
L	2023.03.29 07:30	2023.03.29 09:31	-1.35			6456	6456
Avg			-1.35				



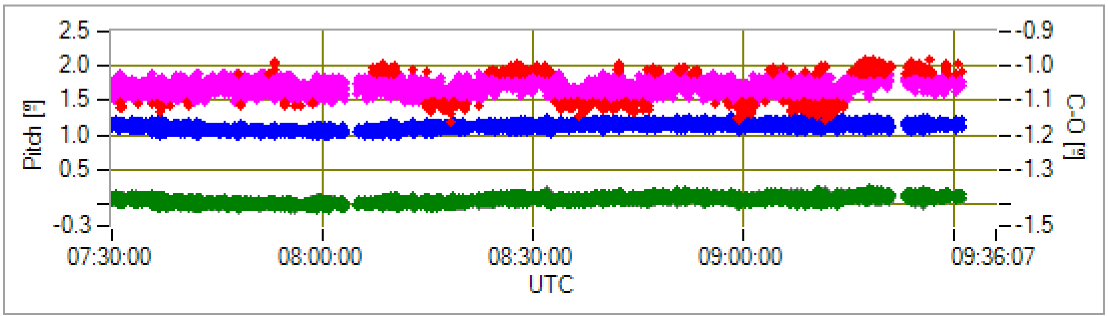
Heading by Vector   Heading from Q-matrix   Client Vessel Heading   C-O Q
Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
- Max difference between calculated and observed antenna separation allowed: 0.025
- Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
- GNSS vector length and C-O are normalized and tested with T-test value 0.95

Anko Maritime AS

Vessel
Verification of pitch data:
Vessel Pitch

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	-1.06	0.02	-1.06 to -1.06	6456	5817
V	2023.03.29 07:30	2023.03.29 09:31	-1.07	0.02	-1.07 to -1.07	6456	5805
L	2023.03.29 07:30	2023.03.29 09:31	-1.07			6456	6456
Avg			-1.07				



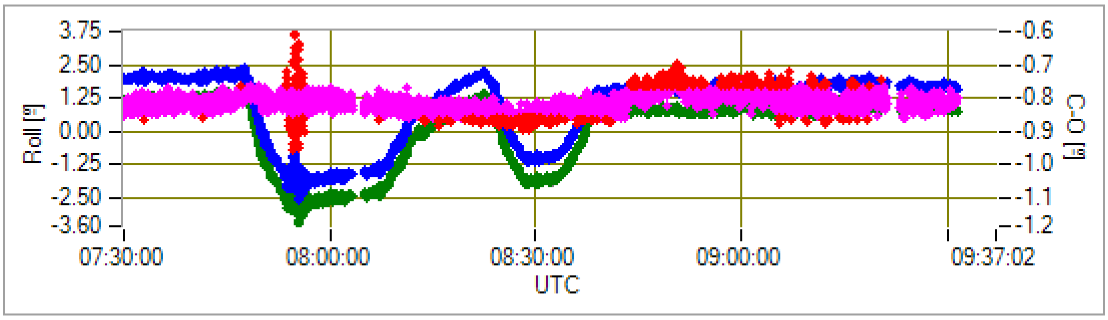
Pitch by Vector Pitch from Q-matrix Client Vessel Pitch C-O Q Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

Anko Maritime AS

Vessel
Verification of roll data:
Vessel Roll

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 07:30	2023.03.29 09:31	**-0.81**	0.02	-0.82 to -0.81	6456	5844
V	2023.03.29 07:30	2023.03.29 09:31	**-0.81**	0.02	-0.82 to -0.81	6456	5842
L	2023.03.29 07:30	2023.03.29 09:31	**-0.81**			6456	6456
Avg			**-0.81**				



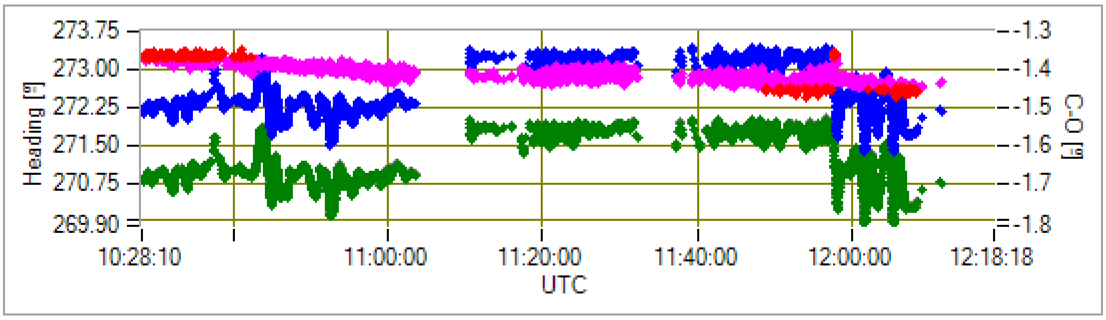
Roll by Vector   Roll from Q-matrix   Client Vessel Roll   C-O Q   Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

4.4 Lodestar LMF

Lodestar LMF
Verification of heading data:
Lodestar LMF Heading

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 10:28	2023.03.29 12:11	-1.41	0.02	-1.41 to -1.41	3752	3366
V	2023.03.29 10:28	2023.03.29 12:11	-1.41	0.02	-1.41 to -1.41	3752	3402
L	2023.03.29 10:28	2023.03.29 12:11	-1.41			3752	3752
Avg			-1.41				



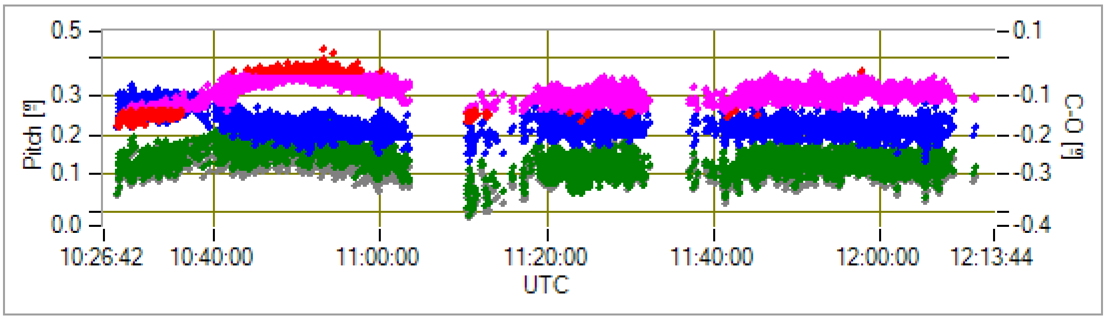
Heading by Vector Heading from Q-matrix Client Lodestar LMF Heading C-O Q
Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

Anko Maritime AS

Lodestar LMF
Verification of pitch data:
Lodestar LMF Pitch

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 10:28	2023.03.29 12:11	-0.09	0.02	-0.09 to -0.09	3752	3331
V	2023.03.29 10:28	2023.03.29 12:11	-0.10	0.02	-0.10 to -0.10	3752	3334
L	2023.03.29 10:28	2023.03.29 12:11	-0.10			3752	3752
Avg			-0.10				



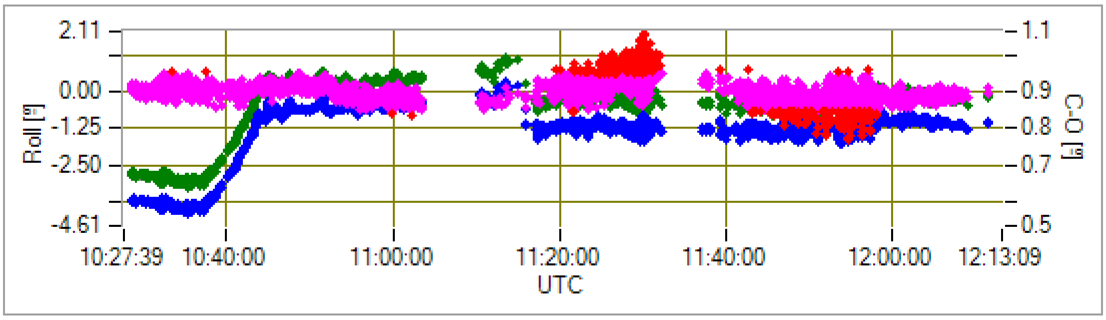
Pitch by Vector Pitch from Q-matrix Client Lodestar LMF Pitch C-O Q
Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

Anko Maritime AS

Lodestar LMF
Verification of roll data:
Lodestar LMF Roll

Id	Start UTC	Stop UTC	C-O	SD	Confidence Interval	No. of Matches	No. Used
Q	2023.03.29 10:28	2023.03.29 12:11	**0.90**	0.02	0.90 to 0.90	3752	3391
V	2023.03.29 10:28	2023.03.29 12:11	**0.90**	0.02	0.90 to 0.90	3752	3389
L	2023.03.29 10:28	2023.03.29 12:11	**0.90**			3752	3752
Avg			**0.90**				



Roll by Vector Roll from Q-matrix Client Lodestar LMF Roll C-O Q Rejected C-O Q

Q: Q-matrix (receiver rotation matrix), V: Average of vectors from Helmert transformation, L: Least Squares Estimation of vectors from Helmert transformation. The confidence interval is computed with 95% confidence level.
Data snooping:
Max difference between calculated and observed antenna separation allowed: 0.025
Max HDOP allowed: 3.0, Max VDOP allowed: 3.0
GNSS vector length and C-O are normalized and tested with T-test value 0.95

5 Work Procedures

5.1 Calibration

The calibration observations were made with the JNS Gyro - 4 GNSS attitude sensors manufactured by Javad Navigation System. This sensor utilizes 4 antennas, each connected to its separate receiver. All receivers are contained in the same physical box and they are all using the same oscillator.

The misalignment between vessel centreline and the Javad antennae was surveyed by means of a total station.

Simultaneous logging with the online navigation system was carried out for 1,5 hours. The C-Os were established on basis of comparisons (subtractions) between these data sets.
Verification logging was carried out for 30 minuets.

5.1.1 Description of JNS Gyro – Javad Sigma

The GNSS compass relies on RTK technology, resolving the phase ambiguities of the same set of satellites tracked by the two antennas/receivers. A minimum of 5 common satellites with a good geometry should be tracked on the 4 antennas in order to provide a heading, pitch and roll in accordance with specifications.

5.1.2 Survey Accuracy

The real time attitude accuracy estimates obviously depend on the distances between the antennae, and the following RMS values are given by the manufacturer:

Heading RMS: $\frac{0.004}{L}$ [rad] = $\frac{0.229}{L}$ [º],

Roll/Pitch RMS: $\frac{0.008}{L}$ [rad] = $\frac{0.458}{L}$ [º],

where L = Distance between antennae [m].

The GNSS compass used by Anko Maritime has inbuilt multipath rejection software. The receivers are continuously tracking possible reflected satellite signals and will throw out observations that are found not to have followed the direct trajectory between satellite and antenna. Thus, the system normally needs a certain redundancy in the number of satellites tracked in order to always deliver good, (RTK fix) solutions.

Whenever the GNSS satellite system itself is not supporting a good coverage, and the environment of use is affected by reflecting surfaces and objects obstructing the clear sky, the instrument is likely to give degraded heading information (float solutions).
More satellites availed will normally increase the potential for achieving, RTK fix, solutions.

Only fix solutions are used in the alignment verifications. The “No. used” compared to the “No. of matches” in the heading calculations normally show less observations used, due to quality filtering based on a normalized t-test, actual distance between the two antennae and HDOP of the solution.

5.1.3 AttCon (Heading and Attitude Control)

The AttCon program is developed for use when doing attitude control with the Javad Sigma (4 antennae GNSS attitude system produced by Javad Navigation Systems) GNSS attitude system onboard client vessels.

AttCon parses the JNS logs file the client file, finds pertaining records, performs data snooping and computes C-O values of the selected data.

The data were processed using 3 different methods with software modules made by Anko Maritime and NHS, which are implemented in AttCon.

5.1.4 Processing methods and results

The results are derived using three different methods:
Method 1 uses the pitch, roll, and heading angles that are derived from the rotation matrix (Qmatrix) components output from the Javad Sigma.
Method 2 uses the vectors between the 4 GPS antennas. These geocentric vectors are transformed to a local geodetic system on the vessel. The pitch, roll, and heading angles are then derived by performing a Helmert's transformation using these vectors and the antenna coordinates in the vessel's reference system. The estimated C-O is obtained by averaging the C-O for each record.

Method 3 uses same vector derived pitch, roll, and heading angles as for method 2. The estimated C-O is obtained using a least square estimation (LSE). The main difference between the 3 methods is that in Method 1 it is the Javad Sigma that computes the angles, and in Method 2 and 3 the angles are computed using external algorithms. (Under some circumstances the z- axis VRU rotation can be estimated using Method 3). All the filters except the t-testing of the CO results are applied to all the three methods. The C-O testing does not apply to the LSE method. The user setup of the system and the quality of the Javad Sigma output is controlled by comparing the results from these 3 methods.

5.1.5 Data Snooping (filtering method using statistics)

The sample values, that may be C-O or vector length, are normalized to achieve a Normal distribution with expected mean = 0 and standard deviation = 1. Each normalized C-O is tested against the T distribution that is recommended to be used when the standard deviation is unknown, as in our case. We have to estimate the standard deviation.

We compute the one-sided probability $P(T \leq t)$ where T is a random variable from the T-distribution with the specified degrees of freedom, and t is the normalized C-O. If the absolute value of $P(T \leq t)$ is less than the selected test value, the C-O value is accepted and the flag for this test and record is set to 0. Otherwise it is set to 1. The recommended test value is 0.95 (which is 2 σ).

Anko Maritime AS

6 Personnel

The survey work was performed by the following personnel:

Surveyor	Camilla Waage

7 Equipment

The following equipment was used:

- Leica TS11 Totalstation.
- Javad Sigma (4 antennae GPS+Glonass attitude system produced by Javad Navigation Systems)

Software:

- SC4W 3D coordinate calculation software, version no 1.195.0.114
- Innhouse Tools version 1.13.34.3:
  - AttCon
- AttCon Log Monitor version no 1.13.13

Various minor survey equipment (e.g. tripod, rulers, prisms etc.)

Average Fix Report

Vessel(s): Argeo Searcher **Date/Time (UTC):** 2023-03-31 19:56:38

Transceiver Settings:

Name	Transceiver Starboard Offset	Transceiver Forward Offset	Transceiver Depth Offset	Transceiver Pitch Offset	Transceiver Roll Offset	Transceiver Heading Offset
Transceiver 1	-5.193m	12.890m	21.010m	-0.09º	-0.02º	1.35º

GNSS Settings:

Name	Forward Offset	Starboard Offset	Height Offset
GNSS 1	8.218m	-23.812m	21.010m

Pitch, Roll & Heading Settings:

Name	Usage	Pitch Offset	Roll Offset	Heading Offset
GNSS Hdg	Heading	0.0º	0.00º	0.00º

Beacon Settings:

Name	Received Signal
CAS 2012	IRS 2012

Sound Speed:

	Surface	Average (Initial)
Sound Speed	1524.1m/s	1513.9m/s

Results:

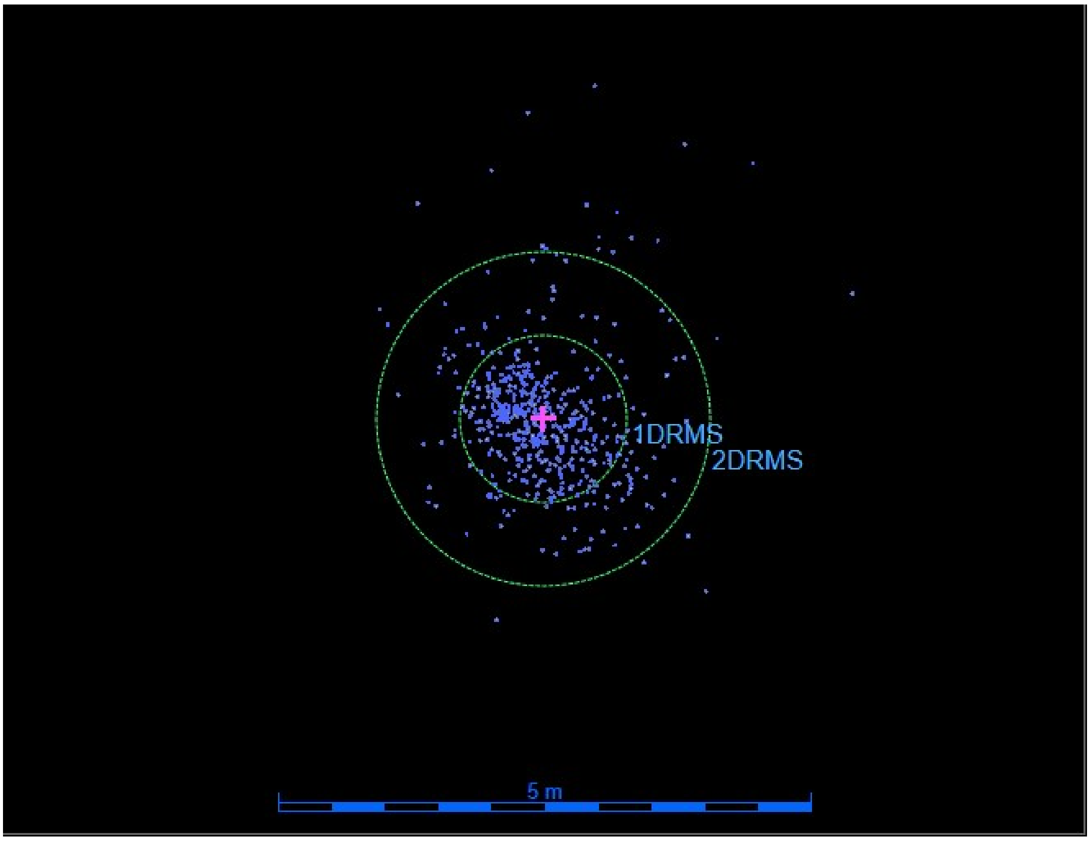
Name	Latitude	Longitude	Depth	Eastings	Northings
CAS 2012	28.05451999º	-15.34084483º	510.445m	466504.047m	3103288.712m

Name	Use / Reject	1DRMS (m / % Depth)	2DRMS (m / % Depth)
CAS 2012	1052 / 0	0.78m / 0.15	1.57m / 0.31

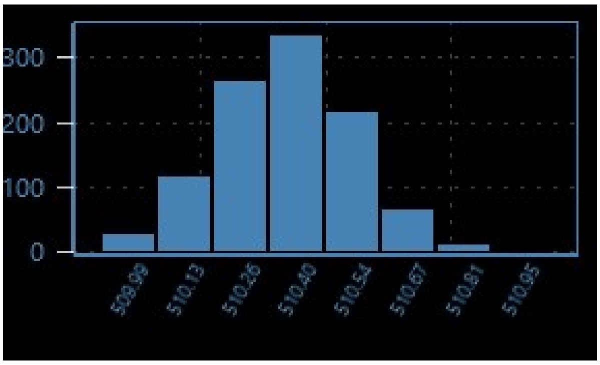
Selected Fix Point Legs:

From	To	Minimum Fixes
2023-03-31 01:25:09	2023-03-31 01:42:26	526

CAS 2012: Fix Point X-Y Chart



Depth Histogram



Average Fix Report

Vessel(s): Argeo Searcher **Date/Time (UTC):** 2023-05-09 18:48:07

Transceiver Settings:

Name	Transceiver Starboard Offset	Transceiver Forward Offset	Transceiver Depth Offset	Transceiver Pitch Offset	Transceiver Roll Offset	Transceiver Heading Offset
Transceiver 1	-5.193m	12.890m	15.159m	-0.09º	-0.02º	1.35º

GNSS Settings:

Name	Forward Offset	Starboard Offset	Height Offset
GNSS 1	8.218m	-23.812m	14.035m

Pitch, Roll & Heading Settings:

Name	Usage	Pitch Offset	Roll Offset	Heading Offset
GNSS Hdg	Heading	0.0º	0.00º	-0.25º

Beacon Settings:

Name	Received Signal
Spin 2012	IRS 2012

Sound Speed:

	Surface	Average (Initial)
Sound Speed	1519.9m/s	1515.5m/s

Results:

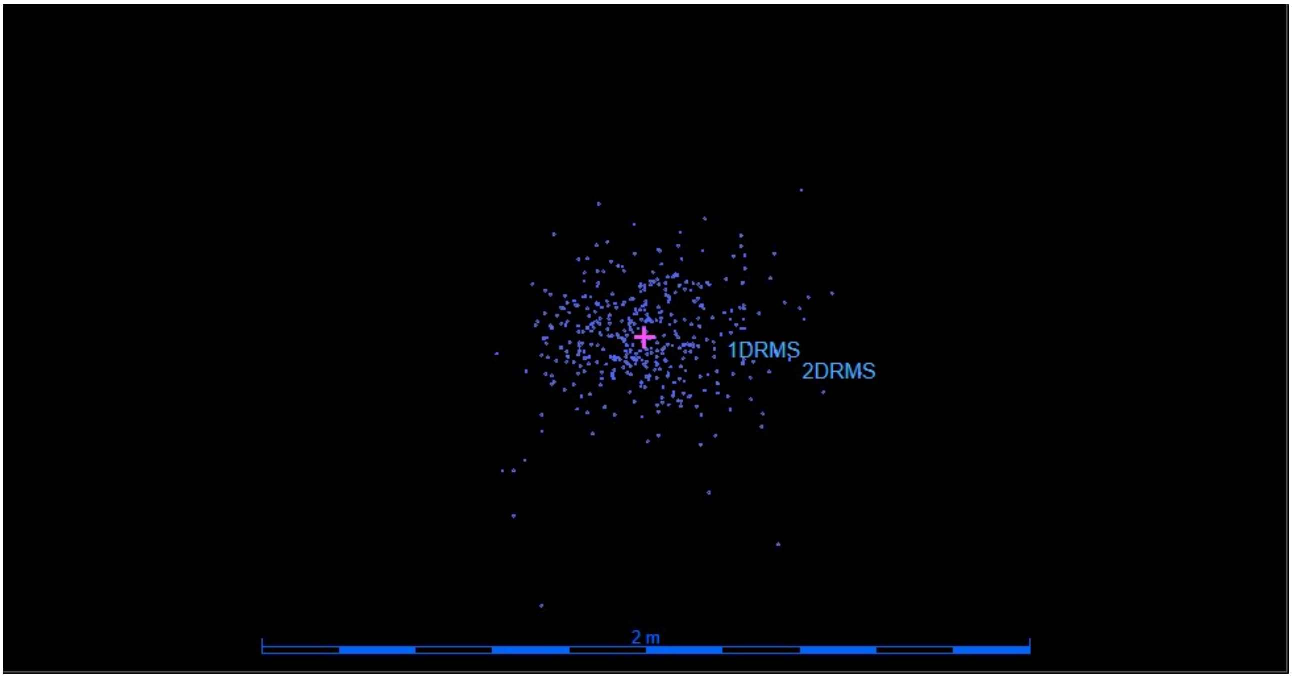
Name	Latitude	Longitude	Depth	Eastings	Northings
Spin 2012	34.09416665º	-30.22559603º	292.600m	755964.589m	3776072.576m

Name	Use / Reject	1DRMS (m / % Depth)	2DRMS (m / % Depth)
Spin 2012	403 / 0	0.20m / 0.07	0.41m / 0.14

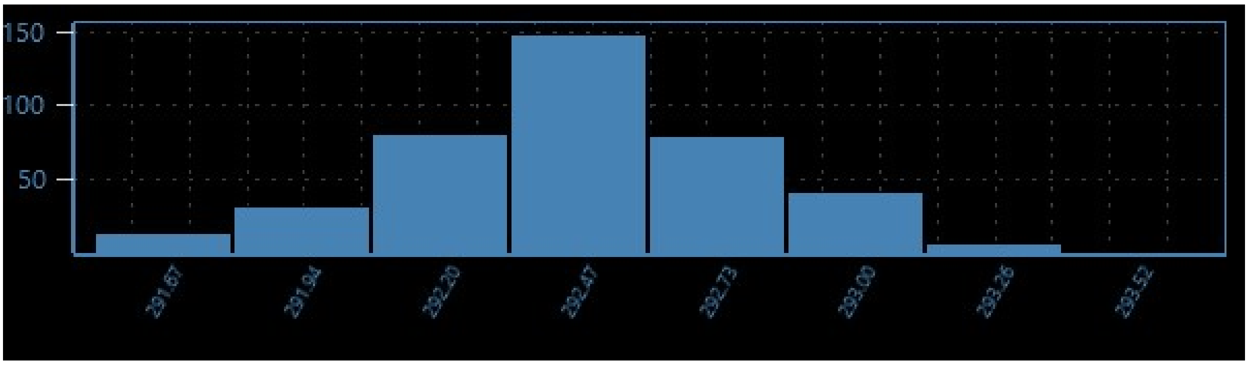
Selected Fix Point Legs:

From	To	Minimum Fixes
2023-05-09 05:57:37	2023-05-09 06:00:59	103
2023-05-09 06:06:17	2023-05-09 06:09:33	100
2023-05-09 06:17:43	2023-05-09 06:21:06	100
2023-05-09 06:28:59	2023-05-09 06:32:16	100

Spin 2012: Fix Point X-Y Chart



Depth Histogram

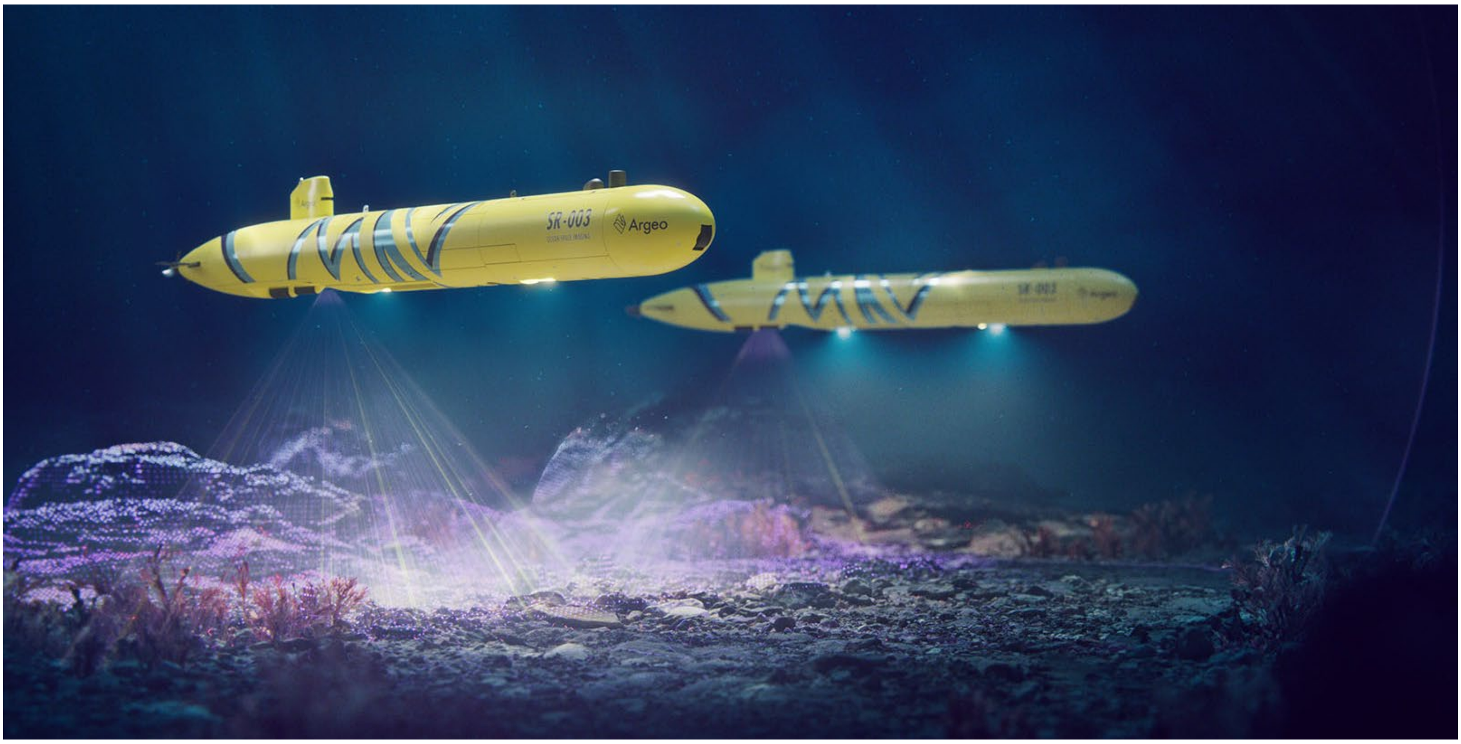


6.3 SeaRaptor AUV

6.3.1 SeaRaptor 6000

Autonomous Underwater Vehicle

SEARAPTOR 6000



High performance, deep rated AUV

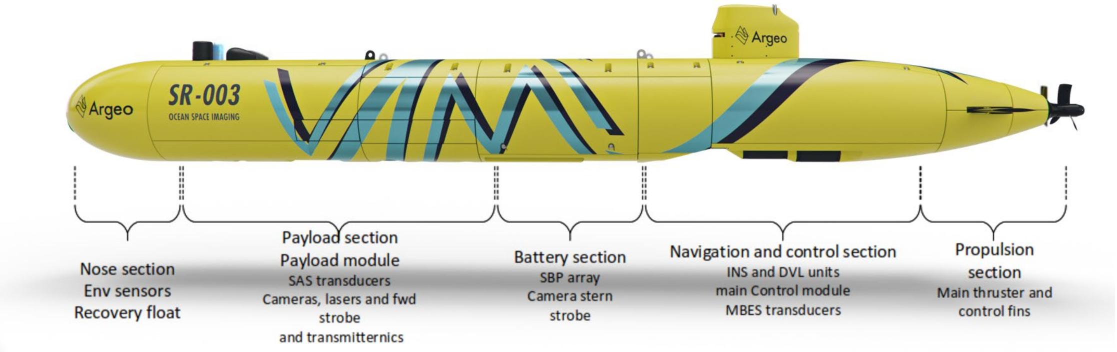
The SeaRaptor 6000 is a survey grade deep water autonomous underwater vehicle (AUV) designed to operate at abyssal depths. A wide range of sensors allow the SeaRaptor 6000 to complete several types of missions including broad area search with Synthetic Aperture Sonar, hydrographic survey with Multibeam and Sub Bottom Profiler, and high-resolution inspection survey with camera and acoustic sonar. These surveys support a variety of applications, such as inspection, search & recovery, salvage, exploration, construction support, marine archaeology, and oceanography

Key features

- Depth rated to 6,000m
- Modular payload ports
- Estimated endurance: > 50 hrs. @ nominal speed

Key benefits

- Wide range of available sensor integrations
- Custom sensor integration possible
- State of the art navigation sensors and acoustic aiding



Argeo

Safety and communication sensors

Collision avoidance sonar	Blueview MB450
Acoustic communication	Sonardyne AvTrack 6
Underwater locator	RJE ULB-362-B
Emergency release	Benthos acoustics
Surface communication	RF, Iridium and WLAN

Navigation and environmental sensors

INS	IXblue phins 6000 (0.01% Distance Travel)
DVL	RDI Tasman DVL (300 kHz w/ADCP)
CDT	Valeport uxSVP
Environmental pack	RBR Maestro (CDT, Oxygen, Methane, pH, Turbidity, Redux)

Payload sensors

Multibeam	Teledyne Reson T50 DF (200/400)
Sub-Bottom Profiler	Benthos Chirp III
Synthetic Aperture Sonar	Kraken minSAS 120 w/Real-Time onb. proc
Camera and Laser	CathX Hunter twin laser UHD
Cathodic Protection Inspection	Argeo Robotics EM Tool pack
Onboard data processing	Caris Onboard and EIVA

- RBR maestro
  - CTD
  - Oxygen
  - Methane
  - pH
  - Turbidity
  - Redux
- Valeport uxSVP
  - Pressure (depth)
  - Sound velocity
  - Temperature
- OFG magnetometer
  - 3 axis magnetic field measurement

Depth rating, speed and power

Depth Rating	6000 m
Useful Speed	2.5-4.5 knots
Operating Speed	3-4 knots

Weight and dimensions

Length	6.8 m
Weight	1600 kg
Diameter:	0,665 m

Required utilities

Power requirement (vehicle container)	400V/63A 3-phase

Container information

Vehicle container	Standard 40ft ISO container

6.3.2 AUV navigations system specifications

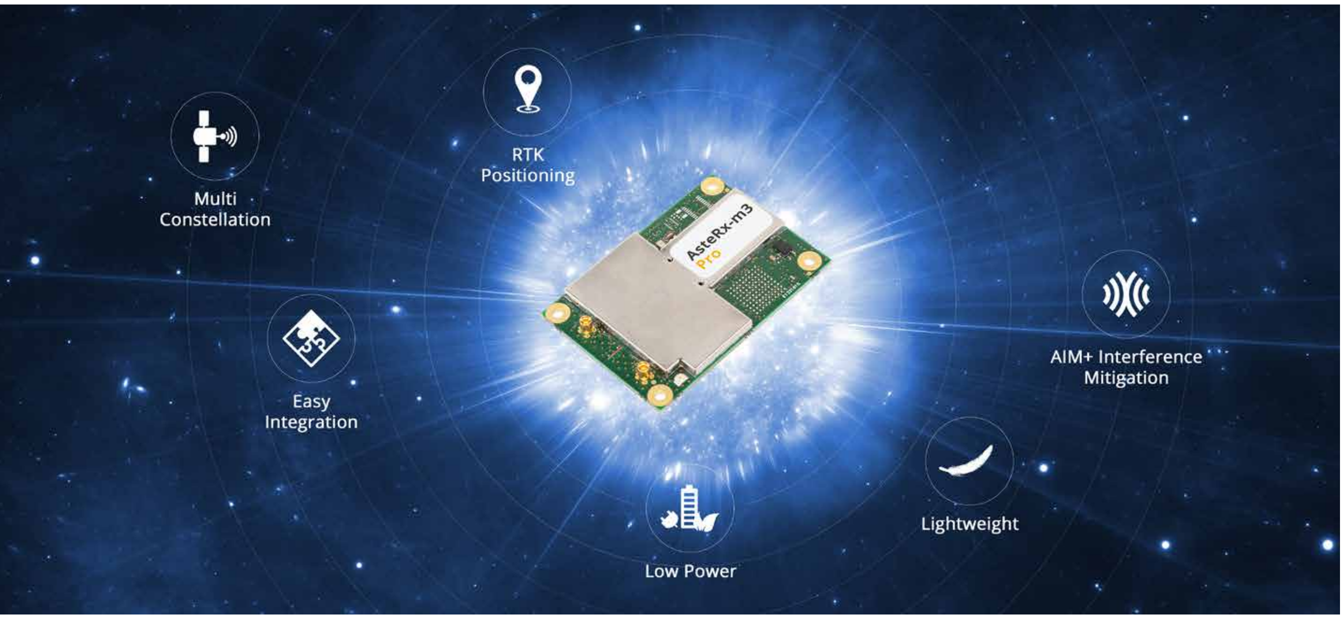
The Phins 6000 INS is the main tool for the AUV sub-surface navigation. To further improve the positioning, the INS can be aided by GPS (at surface) and USBL and DVL during submerged oprations. Here the specification sheets for the system is given in the following order:

- GPS: Septentrio GNSS
- INS: Phins 6000
- DVL: Tasman DVL
- DEPTH: from pressure, Valeport uxSVP

AsteRx-m3 Pro

Compact ultra low-power multi-frequency GNSS rover receiver

septentrio



The AsteRx-m3 Pro is a compact, high performance, ultra-low power GNSS receiver ideal for integration into robotics and other demanding industrial applications where power and space are at a premium. It incorporates the latest anti-jamming technology and offers unbeatable robustness and reliability.

KEY FEATURES

- **Reliable and robust centimeter-level (RTK)**
- **AIM+ industry-leading anti-jamming, anti-spoofing technology**
- **OSNMA Support**
- **Industry-leading ultra-low power consumption**
- **Multi-constellation, multi-frequency satellite tracking**
- **Easy-to-integrate**

Rover applications

The AsteRx-m3 Pro is a rover GNSS receiver with best-in-class positioning performance, with Septentrio's latest multi-frequency multi-constellation RTK technology. It delivers robust and reliable positions in challenging environment in both single and dual antenna modes. Its specialized design makes it easy to use and cost efficient as a rover receiver.

BENEFITS

State of the art

The AsteRx-m3 Pro is a state-of-the-art GNSS rover receiver designed to deliver reliable and robust position in challenging environments.

The GNSS+ toolset is the technology that allows AsteRx-m3 Pro to deliver reliable positions even GNSS signals are disturbed or when the receiver is subject to shocks and vibrations:

- **LOCK+** enables robust tracking during high vibrations and shocks
- **APME+** disentangles direct signal and those reflected from nearby structure
- **IONO+** provides advanced protection against ionospheric disturbance
- **AIM+** is the most advanced anti-jamming, anti-spoofing on-board interference mitigation technology on the market (narrow and wide band, chirp jammers).

Ultra-low power design

The AsteRx-m3 Pro provides RTK positioning at the lowest power consumption of any comparable device on the market. This means longer operation on a single battery charge, smaller batteries and improved efficiency.

Easy-to-integrate

The AsteRx-m3 Pro comes with fully documented interfaces, commands and data messages. The included RxTools software allows receiver configuration and monitoring as well as data logging and analysis. An SDK is provided, which allows integrators to create professional custom post-processing applications. AsteRx-m3 Pro is compatible with its SDK library for PPK (Post-processed kinematic) offline processing.

AsteRx-m3 Pro

FEATURES

GNSS signals

544 Hardware channels for simultaneous tracking of most visible signals:

- GPS: L1 C/A, L1C, L2C, L2 P(Y), L5
- GLONASS: L1 C/A, L2C/A, L3, L2P
- BeiDou: B1I, B1C, B2a, B2b, B2I, B3I
- Galileo: E1, E5a, E5b
- QZSS: L1 C/A, L1 C/B, L2C, L5
- NavIC: L5
- SBAS: EGNOS, WAAS, GAGAN, MSAS, SDCM

Septentrio's patented GNSS+ technologies

- **AIM+** industry leading anti-jamming, anti-spoofing interference monitoring & mitigation technology
- **IONO+** advanced scintillation mitigation
- **APME+** a posteriori multipath estimator for code and phase multipath mitigation
- **LOCK+** superior tracking robustness under heavy mechanical shocks or vibrations
- **RAIM+** (Receiver Autonomous Integrity Monitoring)

OSNMA Support

Formats

Septentrio Binary Format (SBF), fully documented with sample parsing tools

NMEA 0183, v3.01, v4.0

RTCM v2.x, v3.x (MSM messages included)

CMR v2.0 and CMR+ (CMR+ input only)

Connectivity

4 Hi-speed serial ports (LVTTL)

1 USB device port (TCP/IP communication and with 2 extra serial ports)

xPPS output (max 100Hz)

Ethernet port (TCP/IP, UDP, LAN 10/100 Mbps)

2 Event markers

Outputs to drive external LEDs

General purpose output

NTRIP (client)

SUPPORTING COMPONENTS

Web UI with full control and monitoring functionality.

RxTools, a complete and intuitive GUI tool set for receiver control, monitoring, data analysis and conversion.

GNSS receiver communication SDK. Available for both Windows and Linux.

PERFORMANCE

RTK performance [2,3,4]

Horizontal accuracy	0.6 cm + 0.5 ppm
Vertical accuracy	1 cm + 1 ppm
Initialisation	7 s

GNSS attitude accuracy [1,2,3]

Antenna separation	Heading	Pitch/Roll
1 m	0.15°	0.25°
5 m	0.03°	0.05°

Position accuracy [2,3]

	Horizontal	Vertical
Standalone	1.2 m	1.9 m
SBAS	0.6 m	0.8 m
DGNSS	0.4 m	0.7 m

Velocity accuracy [2,3]

0.03m/s

Maximum update rate

Position	10 Hz
Measurements	10 Hz

Latency [5]

<10 ms

Time precision

xPPS out[6]	5 ns
Event accuracy	< 20 ns

Time to first fix

Cold start[7]	< 45 s
Warm start[8]	< 20 s
Re-acquisition	avg. 1 s

Tracking performance (C/N0 threshold)

Tracking	20 dB-Hz
Acquisition	33 dB-Hz

OPTIONAL ACCESSORIES

- Antennas
- SDK library for UAS applications
- Robotics interface board

PHYSICAL AND ENVIRONMENTAL

Size	47.5 x 70 x 9.32 mm
	1.87 x 2.75 x 0.36 in
Weight	27 g / 0.952 oz
Input voltage	3.3 VDC ± 5%

Power consumption

GPS L1/L2	750 mW
GPS/GLO L1/L2	800 mW
All signals, all GNSS constellations	1000 mW

Antenna

Connectors[9]	2 x MMCX
Antenna supply voltage	3-5.5 VDC
Maximum antenna current	150 mA
Antenna gain range	15-45 dB

I/O connectors [10]

30 Pins Hirose DF40 socket

60 Pins Hirose DF40 socket for expanded connectivity

Environment

Operating temperature	-40° C to +85° C
	-40° F to +185° F
Storage temperature	-55° C to +85° C
	-67° F to +185° F
Humidity	5% to 95% (non-condensing)
Vibration	MIL-STD-810G

Certification

RoHS, WEEE, CE, FCC, UKCA, ISO 9001-2015

1 Optional feature
2 Open sky conditions
3 RMS level
4 Baseline < 40 Km
5 99.9%
6 Including software compensation of sawtooth effect
7 No information available (no almanac, no approximate position)
8 Ephemeris and approximate position known
9 Second connector for heading configuration
10 Backwards compatible with AsteRx-m2 and AsteRx-m2a for easy replacement

BBR-05/2023

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Asia-Pacific
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Yokohama, **Japan**
Seoul, **Korea**

septentrio.com

Phins Subsea

FOG-based high-performance subsea inertial navigation system for deep water

Phins Subsea is a subsea inertial navigation system providing position, true heading, attitude, speed, depth and heave. Its high-accuracy inertial measurement unit is coupled with an embedded digital signal processor that runs an advanced Kalman filter.
Phins Subsea can be pre-assembled and pre-calibrated with a doppler velocity log version, making the system easy to install and ready to use for more precise navigation.

FEATURES

- All-in-one high-accuracy 3D positioning with heading, roll and pitch
- FOG, unique strap-down technology
- Multiple aiding sensors available: (DVL, USBL, LBL, RAMSES, GPS, depth sensor)
- Options: DVL or RAMSES easy coupling
- Ethernet, web server (GUI)

APPLICATIONS

- AUV navigation
- Towfish navigation
- Metrology
- Precise positioning
- Out-of-straightness survey

BENEFITS

- High grade INS performance
- High reliability and maintenance free
- Rugged design for water depths up to 6,000 m
- Ultimate sub-metric performance using sparse array transponders and on-the-fly calibration
- Ease of use and quick installation

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iXblue

TECHNICAL SPECIFICATIONS

Performance / Characteristics

Position accuracy[1]	
With GNSS/USBL/LBL	Three times better than GNSS / USBL / LBL
DVL-Aided straight line performance	0.05 %TD (CEP 50)
DVL-aided optimal performances in typical conditions	0.01 %TD (CEP 50)
No aiding for 60s / 120s	0.06m / 0.3m (CEP50)
Heading accuracy [2][3]	
With GNSS (or USBL/LBL) & DVL	0.010 deg secant latitude RMS
With GNSS or DVL or USBL/LBL	0.025 deg secant latitude RMS
Roll and pitch dynamic accuracy (no aiding)	0.01 deg RMS

Operating range / Environment

Operating / storage temperature	-20 to 55°C/-40 to 80°C
Rotation rate dynamic range	Up to 750° /Sec
Acceleration dynamic range	+/-30g
Heading /roll/ pitch ranges	0 to +360 deg / ±180 deg / ±90 deg
MTBF	150,000 hours (System observed) 500,000 hours (FOG + Accelerometers)
Robust to harsh environment, shock and vibration proof	Robust to harsh environment, shock and vibration proof
Depth rating	6,000 m

Physical Characteristics

Material	Titanium
Weight in air /water	23 / 13 kg
Mounting (Ø in mm)	6 Ø 6.5 holes
Dimensions (Ø x H in mm)	Ø 255 x 288 mm
Connector	3 x 12 pins, 1 x 19 pins,1 x 26 pins SEACON

Interfaces

Sensors	GNSS / USBL / LBL / DVL / EMLOG / DEPTH / CTD / SVP
Serial	5 ports : RS422 or RS232
Ethernet	10/100 Mbits, UDP/TCP (client / server) / web server (GUI)
Pulse	3 inputs / 2 outputs
Input/ output	Configurable 7i / 5o Industry standards: NMEA, ASCII, IXBLUE STD BIN etc... more than 130 output protocols
Baud Rate	Up to 460 kbaud
Data output rate	0.1 Hz to 200 Hz
Power supply / consumption [5]	24 VDC (20 - 32 V) / < 20 W

(1) Secant latitude = 1/cosine latitude
(2) Input GPS PPS pulse for accurate time synchronization of PHINS 6000

PRODUCT DATASHEET

TELEDYNE MARINE

Tasman DVL

600 kHz / 300 kHz Phased-Array DVLs

Teledyne RDI's new **Tasman DVL** represents the next generation of DVL technology, promising to take your navigation to the next level. Teledyne RDI's long-standing Workhorse Navigator was the first DVL to enter the market, and remains the gold-standard for precision subsea navigation around the globe. The new Tasman DVL, with its wide array of advanced features, reduced size, and increased range, has been designed to supercede this industry icon with enhanced broadband signal processing and innovative field-replaceable phased-array transducer design.

With bottom tracking ranges from 0.15 m to 420 m, in up to 6,000 m water depths, the Tasman delivers a solid, value-priced solution for vehicles ranging from small ROVs to large diameter AUVs.

PRODUCT FEATURES

- Innovative field-replaceable phased-array transducer design delivers enhanced position accuracy at a reduced size, eliminates the need for speed of sound correction, and reduces drag on your vehicle
- Ethernet compatibility allows for plug-and-play with vehicle network interfaces
- Time of validity output for highly accurate coupling with an Inertial Navigation System (INS) further improves your resulting DVL aided INS position accuracy
- Upgradeable to include Acoustic Doppler Current Profiling (ADCP) capability
- Designed as a drop-in replacement for Workhorse Navigator for ease of installation
- Measurements include:
  - Estimate of single-ping bottom-track velocity variance for improved Kalman filter integration and data quality estimation
  - Bottom track velocity
  - Altitude: 4 individual measurements
  - Error velocity (data quality indicator)
  - Acoustic echo intensity
  - Water track velocity
  - Temperature
  - Current profiling (optional)

The 600 kHz and 300 kHz DVLs combine Teledyne RDI's proven bottom detection algorithms and single ping bottom location accuracy with its broadband velocity processing technology, providing users with highly reliable precision data for navigation and position processing, even over indeterminate terrain.

Raising the bar

Increased Bottom Tracking Range: Our new patent pending technology allows you to bottom track up to 160 m altitude with the 600 kHz DVL, and 420 m with the 300 kHz DVL while delivering the same low power consumption and high accuracy you've come to expect from Teledyne RDI.

Improved Accuracy: The new Tasman DVL offers customers industry-leading velocity accuracies throughout the entire altitude range and with no pre-calibration required.

Cutting-edge internal sensors

Transducer Health Monitor: The innovative transducer health monitor provides insight, in near real-time, about the status of the transducer, and alerts the user of potential problems. The health monitor sensor also tracks pressure cycles, maximum pressure, and operating time for quality tracking purposes.

Leak Sensor: Real-time leak detection monitoring provides peace of mind and strategic decision-making for critical missions.

TELEDYNE MARINE
RD INSTRUMENTS
Everywhereyoulook™

PRODUCT DATASHEET

TELEDYNE MARINE

Tasman DVL 600 kHz / 300 kHz Phased-Array DVLs

TECHNICAL SPECIFICATIONS

		600 kHz	300 kHz
Bottom Tracking	Maximum Altitude[1]	100 m (160 m optional)	275 m (420 m optional)
	Minimum Altitude	0.15 m	0.3 m
	Velocity Range	±9 m/s or +16 m/s upon request	±9 m/s or +16 m/s upon request
	Long Term Accuracy[2, 3]	±0.06% ±0.1 cm/s (<4 m altitude) ±0.2% ±0.1 cm/s (>4 m altitude)	±0.08% ±0.1 cm/s (<8 m altitude) ±0.3% ±0.1 cm/s (>8 m altitude)
	Long Term Accuracy[4]	±1.15% ±0.1 cm/s	±1.15% ±0.1 cm/s
	Precision @ 1 m/s	±0.5 cm/s @ ½ alt.	±0.6 cm/s @ ½ alt.
	Resolution	0.01 mm/s	0.01 mm/s
	Maximum Ping Rate[5]	12 Hz	7 Hz
Water Profiling	Maximum Range[1]	60 m	150 m
	Minimum Range	1.9 m	4.5 m
	Velocity Range	±12 m/s	±17 m/s
	Long-Term Accuracy	±0.3% ±0.1 cm/s	±0.6% ±0.1 cm/s
Acoustic	Center Frequency	614.4 kHz	307.2 kHz
	Source Level (re 1 μPa)	217 dB@1 m	220 dB@1 m
	1-Way Beam Width	2.2°	2.7°
	Number of Beams	4-phased array	4-phased array
	Beam Angle (nominal)	30°	30°
	Bandwidth (nominal)	6.25% of center freq.	6.25% of center freq.
Environmental	Maximum Operating Depth	4,000 and 6,000 m	4,000 and 6,000 m
	Operating Temperature	-5°C to 45°C	-5°C to 45°C
	Storage Temperature	-30°C to 60°C	-30°C to 60°C
Internal Sensors	Health Monitor	Transducer health, leak detection, pressure cycles, maximum pressure, over pressure, operating time	
	Leak Detection	Electronic housing	Electronic housing
	Pressure Sensor	600 Bar (6000 m)	600 Bar (6000 m)
	Dual-Axis Digital Inclinometer		
	AHRS (optional)	SBG Ellipse2-A (200 deg/s)	SBG Ellipse2-A (200 deg/s)
Dimensions	(cm)	17.78 diameter x 17.4 high	17.78 diameter x 17.4 high
Weight	(kg)	7.26 in air, 4.35 in water	7.26 in air, 4.35 in water
Power	Average Power[6] (typical)	5.4 W	11.8 W
	Quiescent Power Input	1.4 W	1.4 W
	Quiescent Power with Ethernet	2.3 W	2.3 W
	Voltage[6]	10.7-36 VDC	12-36 VDC
	Peak Current[6] (typical)	1.8 A	5.4 A
Communications	Ethernet and RS232 (optional RS422 only installed at factory)		

1. @5°C and 35ppt, salinity, @ max V.
2. No pre-calibration necessary.
3. ECCN: 6A001
4. ECCN: 6A991
5. @5% of maximum altitude.
6. @24 VDC Input

TELEDYNE MARINE
RD INSTRUMENTS
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www.teledynemarine.com

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Tel. +1-858-842-2600 • Email: rdisales@teledyne.com

Les Nertieres 5 Avenue Hector Pintus 06610 La Gaude France
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uvSVX

Sound Velocity, Temperature, Pressure with calculated Salinity & Density for an Underwater Vehicle

Aimed primarily at the underwater vehicle market, the uvSVX is a compact direct reading instrument that outputs a selectable, fixed data string at up to 60Hz of Sound Velocity, Temperature, Depth and optionally, Salinity and Density calculated with Valeport's proprietary DASH formula.

High accuracy data is assured with the added bonus of Valeport's unique interchangeable pressure module that allows customers to maximise operationally specific depth requirements. This innovative pressure module, with integral calibration, can be changed in a couple of minutes without opening the instrument and is available in 0.01% accuracy 10, 20, 30, 50, 100, 200, 300, 400 and 600 Bar.

Vibration and Shock tested to the standard ISO 13628-6:2006 (Q2 Levels).

DATA SHEET

Product Details

MULTI-PARAMETER

SOUND SPEED

BATHYMETRY

VALEPORT CONFIGURE & DATALOG X2 SOFTWARE

Valeport Limited
St. Peter's Quay, Totnes,
Devon TQ9 5EW United Kingdom

Telephone: +44 (0) 1803 869292
Email: sales@valeport.co.uk
www.valeport.co.uk

Sensors

Each sound velocity measurement is made using a single pulse of sound traveling over a known distance, so is independent of the inherent calculation errors present in all CTDs. Our unique digital signal processing technique virtually eliminates signal noise, and gives an almost instantaneous response; the digital measurement is also entirely linear, giving predictable performance under all conditions.

Sound Velocity

Range	1375 - 1900m/s
Resolution	0.001m/s
Accuracy	±0.02m/s

Temperature

Range	-5°C to +35°C
Resolution	0.001°C
Accuracy	±0.01°C

Interchangeable Pressure Sensor Module

Range	10, 20, 30, 50,100, 200, 300, 400 & 600 Bar
Resolution	0.001% range
Accuracy	±0.01% range
Units	dBar (default option) | Meters | Feet

Calculated Parameters and Accuracies
Calculations based on Valeport's proprietary DASH formula

Salinity	Salinity ±0.05 PSU
Density	Density ±0.05 kg/m³

Data Output

RS232 & RS485 or Ethernet output. RS232 data may be taken directly into a PC over cables up to 200m long, whereas RS485 is suitable for longer cables (up to 1000m) and allows for multiple addressed units on a single cable

Baud rate	2400-230400
Protocol	8 data bits, 1 stop bit. No parity. No flow control
Modbus	8N1 or 8E1 framing
Format	RS232 & RS485

ASCII text data format compatible with Valeport DataLog X2 and BathyLog software, allowing real-time depth correction using Density Profiles

Physical

Housing	Titanium
Size	78mmØ x 218mm (excluding connector)
Connector	SubConn MCBH6F
Vibration & Shock	Tested to standard ISO 13628-6:2006 (Q2 Levels)
Depth Rating	6000m
Weight	1.9kg (in air)
Shipping	42 x 32 x 30cm, 5kg

Electrical Voltage

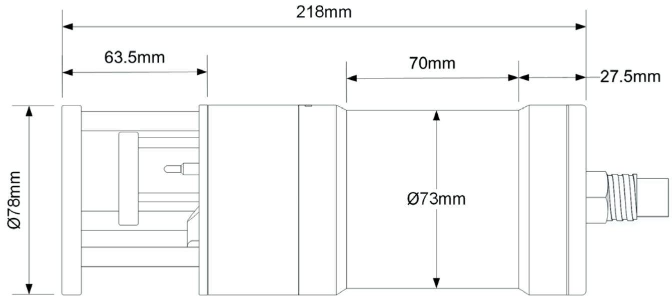
Input	9-28V DC (isolated)
Power	RS232 & RS485 - 30mA @ 12V DC Ethernet - 130mA @ 12V DC

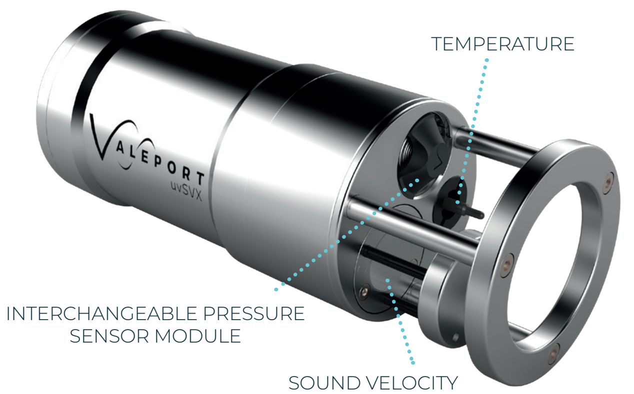
Software

Valeport Configure has been introduced to simplify the configuration of instruments prior to deployment. It can be used instead of DataLog X2.

Ordering

0650030-XXX	for RS232/RS485 version Supplied with: · 0.5m interface cable · Operation manual and transit case
0650031-XXX	for Ethernet version Supplied with: · 0.5m interface cable · Operation manual and transit case
Note	XX denotes pressure transducer range. Select from 10, 20, 30, 50, 100, 200, 300, 400 or 600 Bar Two communication options of the uvSVX will be offered, RS232 / RS485 and Ethernet
PTSA-XXX	Additional interchangeable pressure modules
Note	XX denotes pressure transducer range. Select from 10, 20, 30, 50, 100, 200, 300, 400 or 600 Bar





Datasheet Reference: uvSVX | May 2021

VALEPORT

6.3.3 MBES: Reson T50-S specifications

SeaBat® T50-S

Subsea Multibeam Echosounder

Unprecedented image quality engineered for the demanding marine environment

The T50-S is a new addition to the leading SeaBat product range engineered from the ground up to evolve with your business.

Combined with a Subsea Sonar Processor (SSP), the T50-S produces unprecedented clean data, providing faster operational surveys and reduced processing time in a fully integrated sonar processing and data storage unit housed in a subsea pressure vessel.

The SSP provides internal data storage for self-contained survey solution and interfacing via standard Ethernet to reduce integration time.

FEATURES

Product features

- Tracker – powerful tool for automated control
- Selectable Beam Density – you define what you need to get the job done. Minimize data storage rates to only what you require.
- Multi-Detect - Multiple detections for enhanced detail over complex features and water column targets.

For detailed description see relevant Feature Description document

Optional extra features

- FlexMode – increase data density where you need it most
- X-Range – improve range and reduce the impact of external noise
- Pipe Detection & Tracking – unique to SeaBat, optimize detection of pipes and automated steering of FlexMode sector.

T50-S sonar head assembly

- 200/400kHz
- Robust titanium housing
- High resolution, maximum performance

T50-S Standard configuration

- EM7218-1 Receiver array
- TC2160 (400kHz) Projector
- TC2163 (200kHz) Projector
- Subsea Sonar Processor
- 6000m titanium pressure housing
- 22- 60V DC input
- Wet cable set
- Survey data storage 0.5TByte for approx. 150hours, optional 2.0TByte for approx. 600hours.

Options:

- Wet-end brackets (customized)
- Motion and positioning sensors
- Teledyne RESON Sound Velocity Probes
- Teledyne PDS Survey Package
- Teledyne RESON Service Level Agreements
- Available without pressure housing

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RESON
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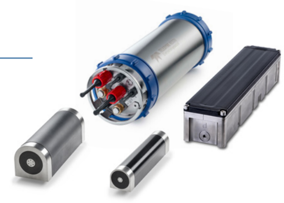
SeaBat® T50-S Subsea Multibeam Echosounder



T50 ACOUSTIC PERFORMANCE

Sonar operating frequency	400kHz	200kHz
Across-track receiver beam width (nominal values[1])	0.5° (center)	1° (center)
Along -track trasmit beam width (nominal values[1])	1°	2°
Number of beams	Min 10, Max 1024	
Swath coverage (up to)	150° Equi -Distant (170° Equi-Angle)	
Typical depth (CW)[2]	0.5-150m	300m
Max depth (CW)[3]	225m	400m
Typical depth (FM)[2]	0.5-180m	450m
Max depth (FM)[3]	300m	575m
Ping rate (depth dependent)	Up to 50 pings/s	Up to 50 pings/s
Pulse length	15-300µs (CW) 300µs – 20ms (FM)	
Depth resolution	6mm	6mm
Depth rating	6000m	6000m

For relevant tolerances for dimensions above and detailed outlined drawings see Product Description

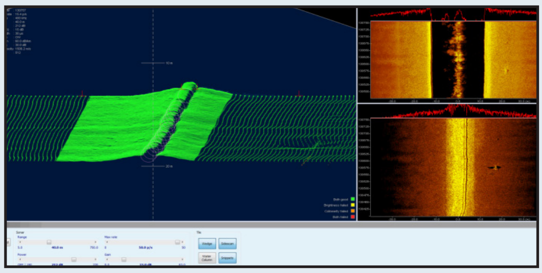
[1] All beam widths measured at -3dB, unsteered with a sound velocity of 1480m/s.

[2] This is the range within which the system is normally operated. It consists of the minimum range below the sensor to a range value corresponding to max swath -50%

[3] This is a single value corresponding to the range at which the swath has reduced to 10% of its maximum value.

POWERFUL FEATURE SET

The systems provides un-compromised data quality combined with a range of powerful software features at an attractive price, with options for future feature expansions to grow with your needs.



T50-S SYSTEM SPECIFICATIONS

Input voltage	22- 60V DC
Power (approx)	Average 130W. Peak 390W
TRANSDUCER CABLE LENGTH	3m standard (1m, 10m optional)
Temperature (operational / storage)	Subsea Sonar Processor: -2°C to +36°C / -30°C to +70°C Sonar wet-end: -2°C to +36°C / -30°C to +70°C

	height [mm]	width [mm]	depth [mm]	weight [kg/air]	weight [kg/water]
T50 Rx (EM7218-1)	102.0	460.0	90.7	8.2	3.9
T50 Tx 400kHz (TC2160)	77.0	62.0	285	2.75	1.7
T50 Tx 200kHz (TC2163)	115	100	280	7.5	5.0
Subsea Sonar Processor (with pressure housing)	538	174	n/a	24.4	12.0

For relevant tolerances for dimensions above and detailed outlined drawings see Product Description or contact Teledyne RESON Engineering Services for more information.

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6.3.4 SBP: Benthos Chirp 3 LF specifications

Teledyne Benthos

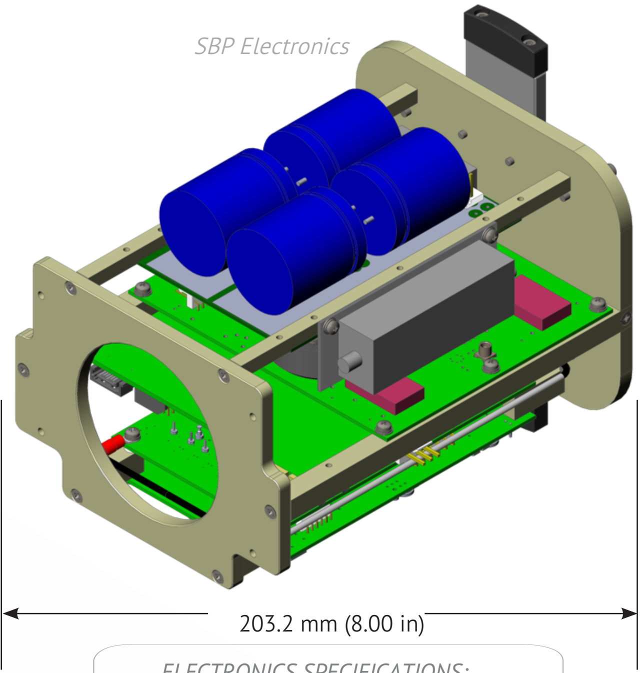
LF Sub-Bottom Profiler

Sub-Bottom Profiling That's Ready to Integrate

The sub-bottom profiling module is derived from field proven Chirp III technology. Teledyne Benthos are pioneers in Chirp Technology, which uses digitally produced acoustic transmission and matched-filter processing to achieve both high resolution and good penetration.

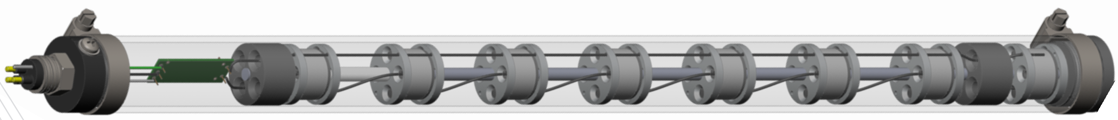
The SBP module gives users the ability to quickly integrate sub-bottom profiling into their survey capabilities. The SBP provides a true 3-dimensional look at the ocean floor and sub-bottom layers from a cost effective, self-contained survey solution.

SBP Electronics



ELECTRONICS SPECIFICATIONS:

WEIGHT IN AIR: 4.8 LBS (2.2 KG)
DIMENSIONS: (L x W x H, inches): 8.00 x 7.13 x 5.63
(L x W x H, mm): 203.2 x 181.1 x 143.0



Hydrophone Array

PRODUCT FEATURES

Advantages of Chirp Sonar:

- Greater dynamic range
- Enhanced resolution
- Repeatable transmitted waveforms
- Constant temporal resolution

Applications

- Rig debris clearance
- Buried pipeline surveys
- Environmental surveys
- Mining and dredging
- Pre-trenching surveys
- UXO/MCM surveys

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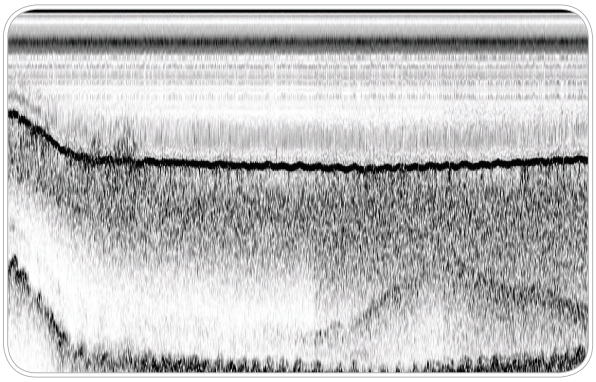
A Teledyne Marine Systems Company

FAL-21-008

LF Sub-Bottom Profiler

TECHNICAL SPECIFICATIONS

Signal Resolution:	16 bit
Data Storage:	Stores data in internal logger in SEG-Y format
Ping Rate	2 pps to 15 pps
Pulse Length:	5 ms to 60 ms
Transmit Power:	0 to -21 dB
Sample Rate	62K Samples per second FFT and Match Filter Operation
Transducer:	Chirp bands 1 - 10 kHz
Operating Depth:	6000 m
Controls:	HW gain 0 - 42dB
Power Consumption, average:	25 watts
Frequency:	LF Chirping 1.5 - 8kHz
Data Storage:	32GB
Timing	NTP with ZDA 1PPS Inputs



Data image generated by SBP module

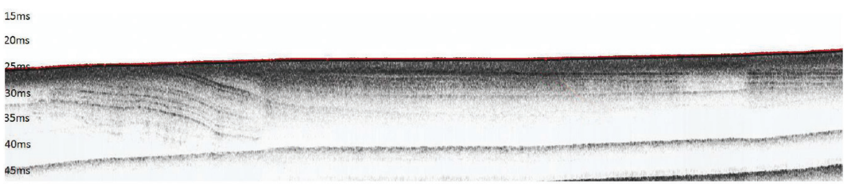
Transducer

TRANSDUCER SPECIFICATIONS:

WEIGHT IN AIR: 7.5 LBS (34.3 KG)
WEIGHT IN WATER (FRESH): 49.9 LBS (22.7 KG)
DIMENSIONS: (L x W x H, inches): 8.3 x 10.5 OD x 15.1
(L x W x H, mm): 210.8 x 266.7 OD x 383.5

HYDROPHONE ARRAY SPECIFICATIONS:

WEIGHT IN AIR: (PAIR) 4.2LBS (1.9KG) – (EA) 2.1LBS (0.95KG)
WEIGHT IN WATER (FRESH): (PAIR) 1.8LBS (0.8KG) – (EA) .9LBS (0.4KG)
DIMENSIONS: (L x W x H, inches): 26.2 x 2.1 x 1.7 (1.5OD)
(L x W x H, mm): 665.5 x 53.3 x 43.2 (38.1OD)



Horizontal layering (H) and dipping reflectors (R) resolved in a 350-meter SBP line collected in the channel between Greenwich Bay and Patience Island, Rhode Island.

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www.benthos.com

6.3.5 Magnetometer: Applied Physics 1540 specifications

Applied Physics Systems

Model 1540

Digital 3-Axis Fluxgate Magnetometer

Features

- Complete 3-axis system
- Low noise level <5 microGauss
- Measures up to ±0.65 G
- Compact size, rugged construction
- Cylindrical or rectangular design
- Single power input, +4.95V to 12V

Applications

- Fluxgate compass systems
- Magnetic fuses
- Measurement of magnetic signatures
- Measurement of magnetic fields generated by power lines

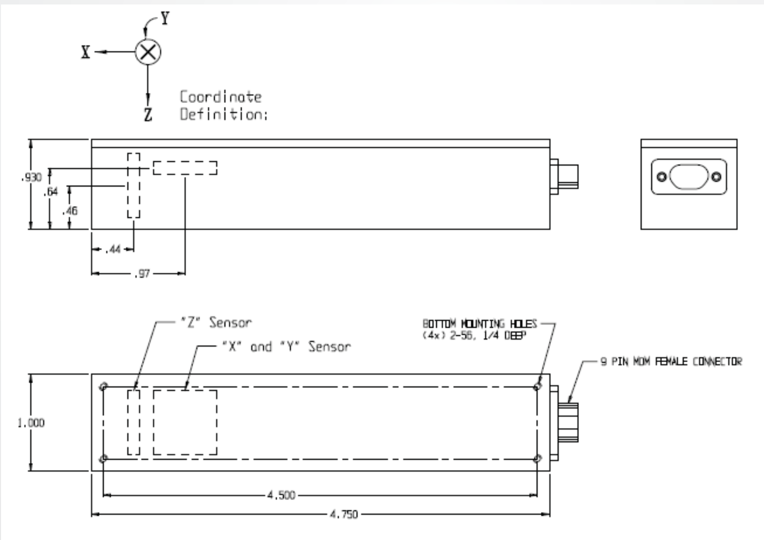
The Model 1540 is a high-speed 3-axis fluxgate magnetometer employing 24-bit analog-to-digital converters. Magnetic field data transmitted by the 1540 is expressed in the units of Gauss (G). The use of 24-bit converters enables the 1540 system to measure magnetic field magnitudes from ±0.65G down to the system noise level (5 μG peak-to-peak) using a single range.

The 1540 is packaged as either a cylinder (1" diameter and 4.725" length) or, optionally, as a rectangular package (1540S).

Power is provided from a single input voltage that ranges from +4.95V to +12V. Input current is 40mA.

The 1540 system communicates over a bi-directional serial interface using TTL logic levels and RS232 levels. The system can be optionally configured to communicate with the RS422 protocol.

An autosend data mode is included in the 1540 software. When this mode is active, data is repeatedly sent out the serial port automatically after power is applied to the system.



www.appliedphysics.com
281 East Java Drive, Sunnyvale, CA 94089 USA • 650.965.0500 • Fax: 650.965.0404 • email: service@appliedphysics.com

Model 1540

Digital 3-Axis Fluxgate Magnetometer

Applied Physics Systems

PHYSICAL	
Cylinder size	4.725″ (120 mm) L x 1″ (25.4 mm) dia.
Rectangle size (1540S)	4.75″ (120.65 mm) x 1.15″ (29.2 mm) x .95″ (24.1 mm)
Input/Output Connections	Flying leads (Teflon insulated) #28 gauge >6″ length or 9-pin nonmagnetic MDM connector

ELECTRICAL	
Power Input	+4.95 VDC to +9 VDC @ 55 mA
Data Rate in Autosend Mode	ASCII mode: 10 transmissions/sec Binary mode: 20 transmissions/sec
A to D Communications	24-bit Sigma Delta TTL and RS232 (RS422 optional)
Baud Rate	300, 1200, 4800, 9600, 19200, 38400, 72800

ENVIRONMENTAL	
Noise Level	±0.5 nT (±5 μGauss) peak-to-peak
Dynamic Range	±65 μT (±0.65 Gauss)
Resolution	0.0001 mG
Accuracy	±0.5% FS
Operating Temperature Range	-25 to 70°C
Scale Stability	±0.05% FS/°C
Initial Offset	<0.005 mG
Offset vs. Temperature	<0.01 mG/°C
Orthogonality of Axes	Better than ±0.2°
Alignment of Axes with Package	Better than ±0.2°
Linearity	±0.05%FS
Analog Scale	3V/G

Specifications within this document are subject to change without notice.

250-0183-02-0715

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6.3.6 ENV: RBR maestro, Tasman DVL, uvSVX

Argeo Environmental Sensors

SeaRaptor 6000

AUV Navigation and Environmental sensors	
INS	iXblue Phins 6000 (0.01% DT racetrack, 0.05% DT straight line)
DVL	RDI Tasman DVL (300 kHz w/ADCP)
CTD	Valeport uxSVP
Environmental sensor pack	o CTD o Dissolved Oxygen o Methane o pH o Turbidity o ORP

- 240M readings
- Up to 16Hz sampling
- USB-C download
- Twist activation
- Wi-Fi communication option
- Supports 5 to 10 channel combinations
- Realtime communication with USB, RS-232, or RS-485

Sensor	Manufacturer	Maximum depth, m	Calibrated Range*	Accuracy*
Temperature	RBR	6,000	-5°C to 35°C	±0.002°C
Conductivity	RBR	6,000	0 to 85mS/cm	±0.003 mS/cm
Pressure	Valeport	6,000	0 to 6000 dbar	±0.01% full scale
Sound Velocity	Valeport	6,000	1375 – 1900 m/s	±0.02 m/s
Dissolved Oxygen	RBR	6,000	0 to 120% saturation 0 to 500 µM concentration	±8 µM ±5%
ORP (RedOx)	Idronaut	6,000	-1 ro +1 V	±0.01
pH	Idronaut	6,000	1 to 13 pH	±0.1
Turbidity	Seapoint	6,000	0 to 2,500 FTU (NTU)	±2% up to 1250 FTU
Methane	Franatech	6,000	50 nM to 10 µM	Response Time within few sec
ADCP (DVL 300kHz)	Teledyne Marine	6,000	4.5 m to 150 m; ±17 m/s (Vel)	±0.6% ±0.1 cm/s

* the listed values represent measurement range and accuracy for ideal standard conditions, and assume that sensors are calibrated

RBR

MEASURE THE BLUE PLANET

rbr-global.com

RBR*maestro*³

MEASURE MORE, DEPLOY LONGER, DOWNLOAD FASTER

MULTI-CHANNEL LOGGER (3-10)

The RBR*maestro*³ multi-channel logger supports 3-10 sensors, offers flexible measurement schedules, sampling up to 16 Hz, large memory, ample power for extended deployments, twist activation, and fast USB download for large data sets. Optional features include fast sampling, thresholding, and Wi-Fi. The RBR*maestro*³ has the flexibility for 10 channels that can be configured to meet your measurement needs.

FEATURES

- Wi-Fi ready
- Twist activation
- 240M readings
- Up to 16Hz sampling
- USB-C download
- Realtime communications

The RBR*maestro*³ can be equipped with any 10 channel combinations. Examples:

▶ RBR*maestro*³ C.T.D+	moored instrument; measures conductivity, temperature, depth and up to 7 additional parameters
▶ RBR*maestro*³ C.T.D+|fast8	8Hz profiling instrument; as above with fast sensor response
▶ RBR*maestro*³ C.T.D+|fast16	16Hz profiling instrument; as above with fast sensor response

Custom configurations can include up to 10 of the following options:

- Temperature
- Depth
- Conductivity
- pCO_2
- Tide
- Wave
- Dissolved O_2
- pCH_4
- Turbidity
- Fluorescence
- Transmission
- pH
- ORP (RedOx)
- PAR
- Irradiance

MULTI-CHANNEL LOGGER

MEASURE MORE, DEPLOY LONGER, DOWNLOAD FASTER

RBR*maestro³* loggers make it easy to configure the optimum sampling regime for your measurements. The large data storage capacity, and fast download ability facilitate long deployments with higher sampling rates. The RBR*maestro³* has more battery power for extended deployments and supports additional sensor configurations. Almost any sensor from RBR can be interfaced to the RBR*maestro³*. Dataset export to Matlab, Excel, OceanDataView®, or text files makes post processing with your own algorithms effortless.

Specifications

Physical

Storage:	240M readings
Power:	8 AA cells
Communication:	USB-C or RS-232/485
Clock drift:	±60 seconds/year
Depth rating:	Up to 10,000m - sensor dependent
Housing:	Plastic or titanium
Size:	Configuration dependent
Weight:	Configuration dependent
Sampling period:	1s to 24h (moored)
Fast option:	|fast8 — 1, 2, 4, 8Hz |fast16 — 1, 2, 4, 8, 16Hz

Conductivity (up to 6000m)

Range:	0-85mS/cm
Initial accuracy:	±0.003 mS/cm
Resolution:	0.001 mS/cm
Typical stability:	0.010 mS/cm per year

Temperature

Range:	-5°C to 35°C
Initial accuracy:	±0.002°
Resolution:	0.00005°C
Time constant:	~1s (standard), ~0.1s (option)
Typical stability:	0.002°C per year

Depth

Range:	20 / 50 / 100 / 200 / 500 / 750 1000 / 2000 / 4000 / 6000 / 10,000m (dbar)
Initial accuracy:	±0.05% FS (full scale)
Resolution:	0.001% FS
Time constant:	<0.01s
Typical stability:	0.1% FS per year

Options

- Wi-Fi communication
- |fast8 or |fast16 sampling for profiling
- External data and power connector with USB, RS-232, or RS-485

RBR Ltd

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info@rbr-global.com
rbr-global.com

PRODUCT DATASHEET

TELEDYNE MARINE

Tasman DVL

600 kHz / 300 kHz Phased-Array DVLs

Teledyne RDI's new **Tasman DVL** represents the next generation of DVL technology, promising to take your navigation to the next level. Teledyne RDI's long-standing Workhorse Navigator was the first DVL to enter the market, and remains the gold-standard for precision subsea navigation around the globe. The new Tasman DVL, with its wide array of advanced features, reduced size, and increased range, has been designed to supercede this industry icon with enhanced broadband signal processing and innovative field-replaceable phased-array transducer design.

With bottom tracking ranges from 0.15 m to 420 m, in up to 6,000 m water depths, the Tasman delivers a solid, value-priced solution for vehicles ranging from small ROVs to large diameter AUVs.

PRODUCT FEATURES

- Innovative field-replaceable phased-array transducer design delivers enhanced position accuracy at a reduced size, eliminates the need for speed of sound correction, and reduces drag on your vehicle
- Ethernet compatibility allows for plug-and-play with vehicle network interfaces
- Time of validity output for highly accurate coupling with an Inertial Navigation System (INS) further improves your resulting DVL aided INS position accuracy
- Upgradeable to include Acoustic Doppler Current Profiling (ADCP) capability
- Designed as a drop-in replacement for Workhorse Navigator for ease of installation
- Measurements include:
  - Estimate of single-ping bottom-track velocity variance for improved Kalman filter integration and data quality estimation
  - Bottom track velocity
  - Altitude: 4 individual measurements
  - Error velocity (data quality indicator)
  - Acoustic echo intensity
  - Water track velocity
  - Temperature
  - Current profiling (optional)

The 600 kHz and 300 kHz DVLs combine Teledyne RDI's proven bottom detection algorithms and single ping bottom location accuracy with its broadband velocity processing technology, providing users with highly reliable precision data for navigation and position processing, even over indeterminate terrain.

Raising the bar

Increased Bottom Tracking Range: Our new patent pending technology allows you to bottom track up to 160 m altitude with the 600 kHz DVL, and 420 m with the 300 kHz DVL while delivering the same low power consumption and high accuracy you've come to expect from Teledyne RDI.

Improved Accuracy: The new Tasman DVL offers customers industry-leading velocity accuracies throughout the entire altitude range and with no pre-calibration required.

Cutting-edge internal sensors

Transducer Health Monitor: The innovative transducer health monitor provides insight, in near real-time, about the status of the transducer, and alerts the user of potential problems. The health monitor sensor also tracks pressure cycles, maximum pressure, and operating time for quality tracking purposes.

Leak Sensor: Real-time leak detection monitoring provides peace of mind and strategic decision-making for critical missions.

TELEDYNE MARINE
RD INSTRUMENTS
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PRODUCT DATASHEET

TELEDYNE MARINE

Tasman DVL 600 kHz / 300 kHz Phased-Array DVLs

TECHNICAL SPECIFICATIONS

		600 kHz	300 kHz
Bottom Tracking	Maximum Altitude[1]	100 m (160 m optional)	275 m (420 m optional)
	Minimum Altitude	0.15 m	0.3 m
	Velocity Range	±9 m/s or +16 m/s upon request	±9 m/s or +16 m/s upon request
	Long Term Accuracy[2, 3]	±0.06% ±0.1 cm/s (<4 m altitude) ±0.2% ±0.1 cm/s (>4 m altitude)	±0.08% ±0.1 cm/s (<8 m altitude) ±0.3% ±0.1 cm/s (>8 m altitude)
	Long Term Accuracy[4]	±1.15% ±0.1 cm/s	±1.15% ±0.1 cm/s
	Precision @ 1 m/s	±0.5 cm/s @ ½ alt.	±0.6 cm/s @ ½ alt.
	Resolution	0.01 mm/s	0.01 mm/s
	Maximum Ping Rate[5]	12 Hz	7 Hz
Water Profiling	Maximum Range[1]	60 m	150 m
	Minimum Range	1.9 m	4.5 m
	Velocity Range	±12 m/s	±17 m/s
	Long-Term Accuracy	±0.3% ±0.1 cm/s	±0.6% ±0.1 cm/s
Acoustic	Center Frequency	614.4 kHz	307.2 kHz
	Source Level (re 1 µPa)	217 dB@1 m	220 dB@1 m
	1-Way Beam Width	2.2°	2.7°
	Number of Beams	4-phased array	4-phased array
	Beam Angle (nominal)	30°	30°
	Bandwidth (nominal)	6.25% of center freq.	6.25% of center freq.
Environmental	Maximum Operating Depth	4,000 and 6,000 m	4,000 and 6,000 m
	Operating Temperature	-5°C to 45°C	-5°C to 45°C
	Storage Temperature	-30°C to 60°C	-30°C to 60°C
Internal Sensors	Health Monitor	Transducer health, leak detection, pressure cycles, maximum pressure, over pressure, operating time	
	Leak Detection	Electronic housing	Electronic housing
	Pressure Sensor	600 Bar (6000 m)	600 Bar (6000 m)
	Dual-Axis Digital Inclinometer		
	AHRS (optional)	SBG Ellipse2-A (200 deg/s)	SBG Ellipse2-A (200 deg/s)
Dimensions	(cm)	17.78 diameter x 17.4 high	17.78 diameter x 17.4 high
Weight	(kg)	7.26 in air, 4.35 in water	7.26 in air, 4.35 in water
Power	Average Power[6] (typical)	5.4 W	11.8 W
	Quiescent Power Input	1.4 W	1.4 W
	Quiescent Power with Ethernet	2.3 W	2.3 W
	Voltage[6]	10.7-36 VDC	12-36 VDC
	Peak Current[6] (typical)	1.8 A	5.4 A
Communications	Ethernet and RS232 (optional RS422 only installed at factory)		

1. @5°C and 35ppt, salinity, @ max V.
2. No pre-calibration necessary.
3. ECCN: 6A001
4. ECCN: 6A991
5. @5% of maximum altitude.
6. @24 VDC Input

TELEDYNE MARINE
RD INSTRUMENTS
Everywhereyoulook™

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uvSVX

Sound Velocity, Temperature, Pressure with calculated Salinity & Density for an Underwater Vehicle

Aimed primarily at the underwater vehicle market, the uvSVX is a compact direct reading instrument that outputs a selectable, fixed data string at up to 60Hz of Sound Velocity, Temperature, Depth and optionally, Salinity and Density calculated with Valeport's proprietary DASH formula.

High accuracy data is assured with the added bonus of Valeport's unique interchangeable pressure module that allows customers to maximise operationally specific depth requirements. This innovative pressure module, with integral calibration, can be changed in a couple of minutes without opening the instrument and is available in 0.01% accuracy 10, 20, 30, 50, 100, 200, 300, 400 and 600 Bar.

Vibration and Shock tested to the standard ISO 13628-6:2006 (Q2 Levels).

DATA SHEET

Product Details

MULTI-PARAMETER

SOUND SPEED

BATHYMETRY

VALEPORT CONFIGURE & DATALOG X2 SOFTWARE

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VALEPORT

Sensors

Each sound velocity measurement is made using a single pulse of sound traveling over a known distance, so is independent of the inherent calculation errors present in all CTDs. Our unique digital signal processing technique virtually eliminates signal noise, and gives an almost instantaneous response; the digital measurement is also entirely linear, giving predictable performance under all conditions.

Sound Velocity

Range	1375 - 1900m/s
Resolution	0.001m/s
Accuracy	±0.02m/s

Temperature

Range	-5°C to +35°C
Resolution	0.001°C
Accuracy	±0.01°C

Interchangeable Pressure Sensor Module

Range	10, 20, 30, 50,100, 200, 300, 400 & 600 Bar
Resolution	0.001% range
Accuracy	±0.01% range
Units	dBar (default option) | Meters | Feet

Calculated Parameters and Accuracies
Calculations based on Valeport's proprietary DASH formula

Salinity	Salinity ±0.05 PSU
Density	Density ±0.05 kg/m³

Data Output

RS232 & RS485 or Ethernet output. RS232 data may be taken directly into a PC over cables up to 200m long, whereas RS485 is suitable for longer cables (up to 1000m) and allows for multiple addressed units on a single cable

Baud rate	2400-230400
Protocol	8 data bits, 1 stop bit. No parity. No flow control
Modbus	8N1 or 8E1 framing
Format	RS232 & RS485

ASCII text data format compatible with Valeport DataLog X2 and BathyLog software, allowing real-time depth correction using Density Profiles

Physical

Housing	Titanium
Size	78mmØ x 218mm (excluding connector)
Connector	SubConn MCBH6F
Vibration & Shock	Tested to standard ISO 13628-6:2006 (Q2 Levels)
Depth Rating	6000m
Weight	1.9kg (in air)
Shipping	42 x 32 x 30cm, 5kg

Electrical Voltage

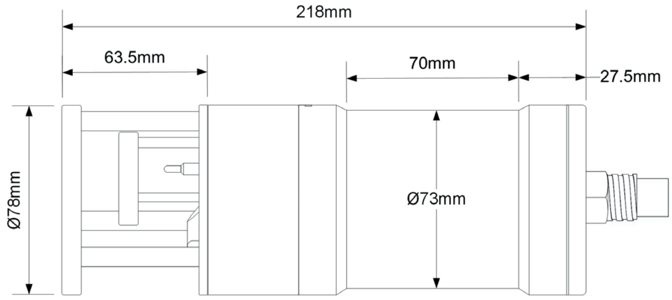
Input	9-28V DC (isolated)
Power	RS232 & RS485 - 30mA @ 12V DC Ethernet - 130mA @ 12V DC

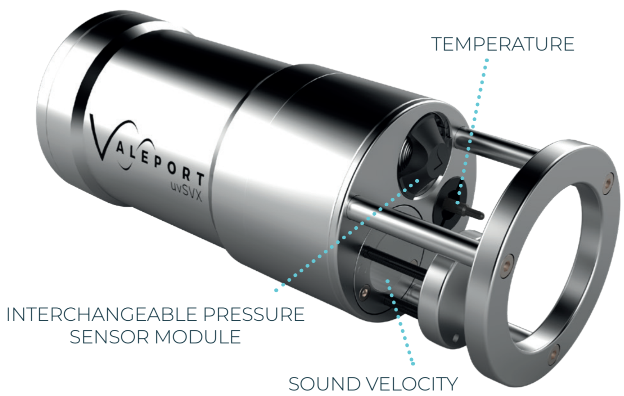
Software

Valeport Configure has been introduced to simplify the configuration of instruments prior to deployment. It can be used instead of DataLog X2.

Ordering

0650030-XXX	for RS232/RS485 version Supplied with: · 0.5m interface cable · Operation manual and transit case
0650031-XXX	for Ethernet version Supplied with: · 0.5m interface cable · Operation manual and transit case
Note	XX denotes pressure transducer range. Select from 10, 20, 30, 50, 100, 200, 300, 400 or 600 Bar Two communication options of the uvSVX will be offered, RS232 / RS485 and Ethernet
PTSA-XXX	Additional interchangeable pressure modules
Note	XX denotes pressure transducer range. Select from 10, 20, 30, 50, 100, 200, 300, 400 or 600 Bar





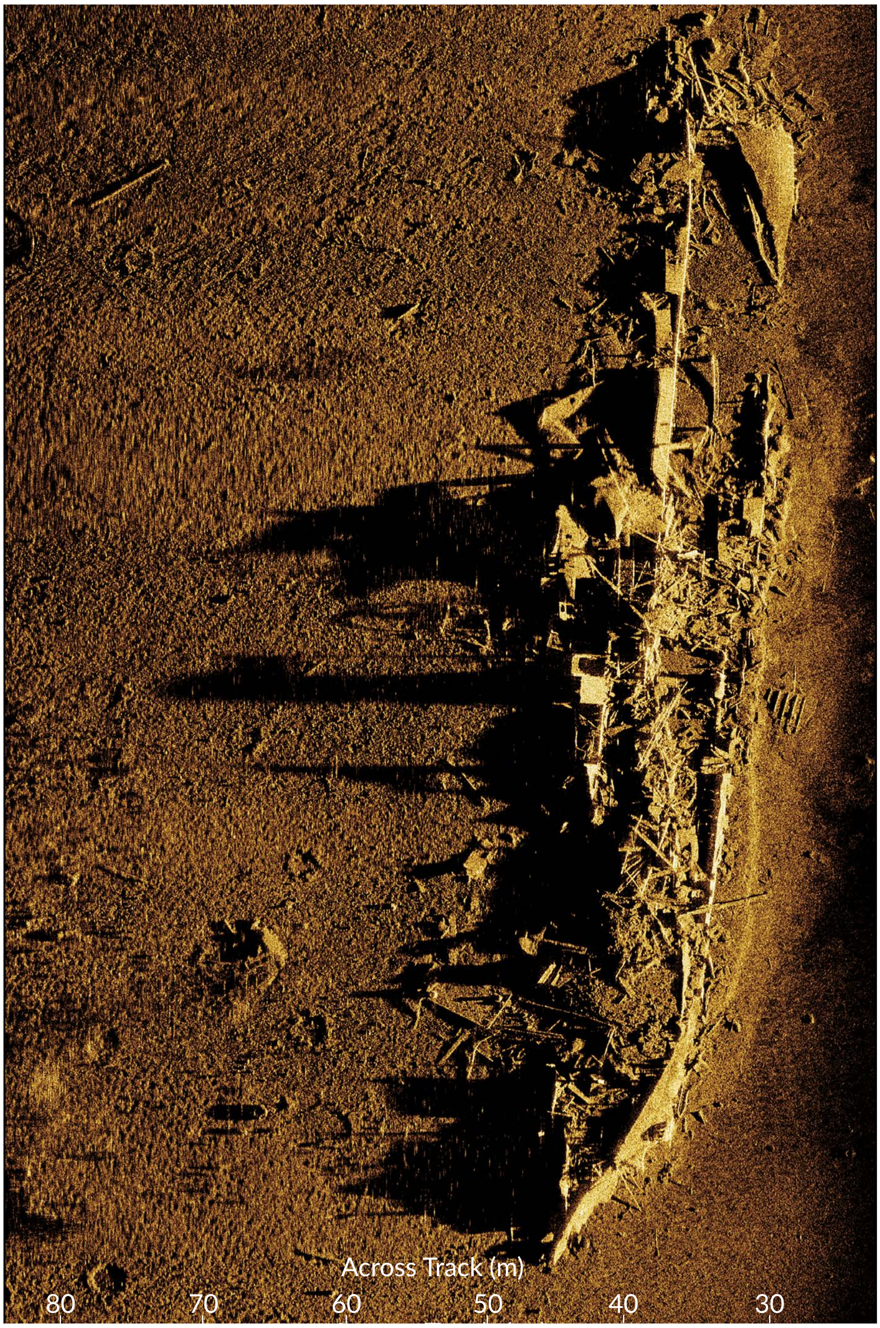
Datasheet Reference: uvSVX | May 2021

6.3.7 SAS: Kraken minSAS

AquaPix® MINSAS

KRAKEN

SEEING WITH SOUND



AquaPix MINSAS image of the SS Ferrando shipwreck provided courtesy of ECA Robotics

AquaPix® MINSAS is an off the shelf configurable Interferometric Synthetic Aperture Sonar (SAS) which replaces high end sidescan systems at an affordable price, while delivering significantly higher resolution, range, and area coverage rates (ACR).

MINSAS provides 3 cm x 3 cm constant resolution out to ranges of 220 meters per side, along with simultaneous 6 cm x 6 cm bathymetry.

Innovative and unique features of the MINSAS make it the ideal sonar for a wide range of underwater platforms and UUVs. MINSAS is based around a modular array system which allows for array lengths of 60 cm to 180 cm depending upon platform size and requirements. This modularity along with the industry smallest SAS processing module allow the MINSAS to be integrated to vehicles ranging from Man Portable to Large Diameter.

Another unique feature of Kraken's AquaPix® sonars is our Real Time SAS (RTSAS) processing module. This industry first capability processes raw sonar data into SAS tiles, in real time during the mission, to the internal storage hard drive or optional removable data pod. RTSAS allows for ATR and Data Exfiltration capabilities of processed SAS data, along with greatly reduced PMA.

With SAS once relegated to only expensive military platforms, Kraken's AquaPix® now makes it available to commercial and research customers looking to increase their capability while reducing survey costs.

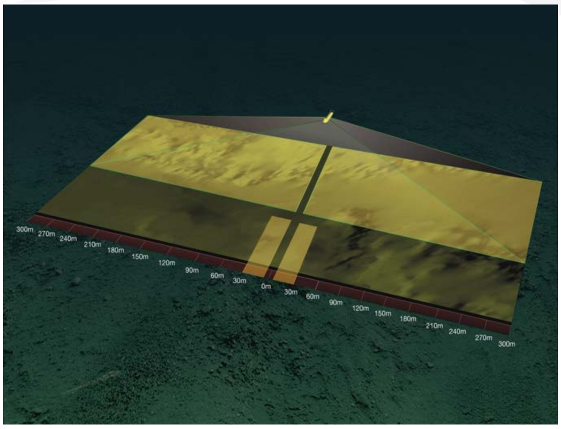
Aquapix® MINSAS

AquaPix MINSAS 120 system components shown with RTSAS Processing and deep water oil compensators

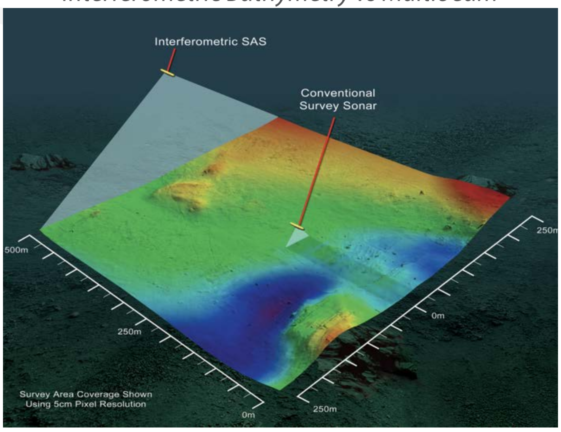
System Specifications	MINSAS 60	MINSAS 120
Platform speed	2-5 kts	2-6 kts
Receiver array dimensions - L/W/H	53.0 / 3.0 / 7.0 cm	109.0 / 3.0 / 7.0 cm
Receive array weight - air / water	6.4 kg / 3.2 kg	12.8 kg / 6.4 kg
Transmit array weight - air / water	0.5 kg / 0.19 kg	
Electronics module dimensions	47 cm x 17 cm dia.	
Electronics module weight - air / water	12.4 kg / 1.4 kg (1000 m)	
Total system weight - air / water	26.2 kg / 8.18 kg	39.0 kg / 14.58 kg
Depth rating	1000, 3000, 6000 m	
System power, no SAS processing	58 W	70 W
RTSAS processing power	75 W	
Power supply	24 VDC / 48 VDC, 250 W peak power	
Along track SAS image resolution	2.5 cm unshaded, 3 cm shaded	
Across track SAS image resolution	1.5 cm (downsampled to 3 cm)	
SAS bathymetry resolution - Real Time	25 cm x 25 cm	
SAS bathymetry resolution - Post Proc.	6 cm x 6 cm	
SAS bathymetry vert. accuracy @ 100m	10 cm	
Source level	210 dB re 1µPa @ 1 m	
PRF	8 Hz	4 Hz
Center frequency	337 kHz	
Pulse length	10 ms (configurable 1 ms -> 1-10 ms)	
Pulse bandwidth	40 kHz	
Pulse type	Linear FM	
SAS robustness against yaw	±4° over 20 m track length	
SAS robustness against sway	±10 m	
Max crab angle	20°	

Physical Specifications and Performance Characteristics of the MINSAS 60 and 120

SAS swath vs SSS swath



Interferometric Bathymetry vs Multibeam



Kraken Aquapix SAS swath width at 3 cm constant resolution compared to typical Side Scan Sonar swath width at 5 cm resolution - Left

Kraken Interferometric SAS Bathymetry coverage area compared to Multibeam coverage area - Right

MINSAS swath width is 20X altitude

Speed		MINSAS 60		MINSAS 120	
Knots	m/s	Range meters	ACR km^2 / hr	Range meters	ACR km^2 / hr
3.00	1.54	118	0.92	220	1.71
3.50	1.80	100	0.91	208	1.88
4.00	2.06	87	0.91	181	1.88
4.50	2.32	77	0.90	160	1.87
5.00	2.57	69	0.90	143	1.86
8.00	4.12	-	-	87	1.80
10.00	5.14	-	-	68	1.76

Typical Area Coverage Rates (ACR) of AquaPix MINSAS at 3 cm resolution based on speed and array length

References

1 *Resolutions adopted by the UN conference on Environment and Development | Rio Convention*

2 *The United Nations Convention on the Law of the Sea | UNCLOS*

3 *ISA Regulations on prospecting and exploration for polymetallic sulphides in the Area | ISBA/16/A/12/Rev.1*