ELAC Nautik

XSE Output Format Specification

for

SeaBeam 30xx MBES Systems

Interface Specification

SS 40 110 9003 E

Revision: D

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Changes and Supplements

Rev.	Contents	Pages	Created by	Approved by	Date
-	New	all	J. Brockhoff	D. Wendorff Ch. Zwanzig	22.07.2009
A	• Changes within Formula Set 2 • Editorial changes for clarification	24	Ch. Zwanzig	J. Brockhoff	16.02.2010
B	• Extension of the document concerning SB3030 / SB3050 MBES systems • Minor corrections	all	Ch. Zwanzig	B. Schulze D. Wendorff	24.01.2011
C	• The name “Pitch Group” (Id = 13) replaced by the name “Forward Beam Angle Group” (Id = 13) • Restructuring of the document • Renaming of chapter 4 • Inclusion of chapter 5 “Online XSE Data Exchange with Third Party Acquisition Software” • Minor corrections	all	Ch. Zwanzig	M. Rahn	11.04.2011
D	• On pages 15 and 38: Deletion of the incorrect text “(apply gyro correction, if known)” which was related to the azimuth. • On page 36: Replacement of the incorrect text “(augmented by azimuth and heading offset)” by the text “(augmented by the azimuth)”; this text is related to the bearing.	15, 36, 38	Ch. Zwanzig	J. Brockhoff	13.05.2011

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1 Applicable Documents

No.	Doc. Nr.	Title	Date	Revision / Version
/1/	TH 44 301 9001	Data Exchange Format (XSE): Technical Description	26.01.2011	m / 1.8.28

2 Abbreviations

Abbreviation	Description
AD	Along Distance from MB Frame (Frame Id: 6, Group Id: 8)
AZ	Azimuth from MB Frame (Frame Id: 6, Group Id: 19). The azimuth is the angle between Geographic North and the forward pointing perpendicular of the Swath Reference Line.
BA	Beam Axis, imaginary line between Transducer and centre of footprint. The beam axis describes the beam leaving the transducer, it does not necessarily include sound velocity profile induced beam deflection.
CL	Centre Line of the ship
CUBE	Combined Uncertainty and Bathymetry Estimator
DGPS	Differential GPS
GGA	The GGA message of a GPS receiver contains detailed GPS position information and is the most frequently used data message.
GLL	The GLL message of a GPS receiver contains the geographic position as latitude and longitude.
GPS	Global Position System, here the unit that receives satellite data and calculates a 3D position.
HDG	Heading from Navigation Frame (Frame Id: 1, Group Id: 11)
HSO	HydroStar Online
LAN	Local Area Network
LD	Lateral Distance from MB Frame (Frame Id: 6, Group Id: 7)
LSB	Least Significant Bit
MB	Multi Beam
MBES	Multi Beam Echo Sounder
N	Geographic North
NMEA	National Marine Electronics Association
PX	Component of position off-set parallel to ship's Centre Line (CL). Please be aware that the sign convention shown here does not indicate the position off-set from XSE ship frame (Frame Id: 4, Group Id: 9) but rather a combination of Navigation and Transducer off-sets (Frame Id: 4, Group Id: 10).
PY	Component of position off-set perpendicular to ship's Centre Line (CL). (see above).
SB	SeaBeam
SB30xx	L-3 ELAC Nautik SeaBeam product family, consisting of SB3012, SB3020, SB3030 and SB3050
SB3012	L-3 ELAC Nautik SeaBeam deep-sea multi beam echo sounder with an operating frequency of 12 kHz
SB3020	L-3 ELAC Nautik SeaBeam deep-sea multi beam echo sounder with an operating frequency of 20 kHz

Abbreviation	Description
SB3030	L-3 ELAC Nautik SeaBeam medium-depth multi beam echo sounder with operating frequencies in the 25 kHz band
SB3050	L-3 ELAC Nautik SeaBeam medium-depth multi beam echo sounder with operating frequencies in the 50 kHz band
Slant/Range Data	MBES data that is defined by two angles and the two way travel time. The direction of the beam axis is described by the projection on two orthogonal geo-vertical planes. The slant/range co-ordinate system differs from a classical spherical co-ordinate system.
SRL	Swath Reference Line. Imaginary line passing through the projector or transducer. For Cartesian Multi Beam Data the SRL (not the ship axis) defines the horizontal co-ordinate system for the lateral distance and the along distance. For Slant/Range Multi Beam Data, the SRL defines the geo-vertical planes onto which the beam axis is projected to measure the across-ship and along ship angle.
SRV	Swath Reference Vector. Geo-horizontal Vector perpendicular to SRL, pointing “more forward then backward”.
SSV	Surface Sound Velocity. Value online to derive observables as beam angles.
SVP	Sound Velocity Profile. SVP data is used to calculate the ray path through the water column.
TH	Technical Handbook
VRU	Vertical Reference Unit
WGS	World Geodetic System
XSE	Data Format from L-3 Communications ELAC Nautik

3 General

3.1 Applicability of the Document

This document is applicable for all L-3 ELAC Nautik SeaBeam 30xx MBES systems; these systems include the following different types:

- SeaBeam 3012 deep-sea MBES systems
- SeaBeam 3020 deep-sea MBES systems
- SeaBeam 3030 medium-depth MBES systems
- SeaBeam 3050 medium-depth MBES systems

3.2 Main Characteristics of the Different SeaBeam 30xx Systems

The main characteristics of the different SeaBeam 30xx MBES systems are indicated in the subsequent table:

Table 1: Main Characteristics of the Different SeaBeam 30xx MBES Systems

Characteristic	SeaBeam 3012	SeaBeam 3020	SeaBeam 3030	SeaBeam 3050
Operating Frequencies	12 kHz	20 kHz	25 kHz Band	50 kHz Band
Depth Range	> 12,000 m	Approx. 7,000 m	Approx. 7,000 m	Approx. 3,000 m
Variable Operating Frequency Bands	No	No	Yes, Depending upon Pulse Length and Swath Width	Yes, Depending upon Pulse Length and Swath Width
Number of Operating Frequency Bands per Swath	1 Frequency Band	1 Frequency Band	1 or 2 Frequency Bands (Depending upon Swath Width)	1 or 2 Frequency Bands (Depending upon Swath Width)
Motion Stabilization During Pulse Transmission	Patented Swept Beam™ Technique	Patented Swept Beam™ Technique	Sector Scan Technique with 3 Sectors (Port, Center, Starboard)	Sector Scan Technique with 3 Sectors (Port, Center, Starboard)
Operating Modes	Single-Ping Mode	Single-Ping Mode	Single-Ping Mode or Multi-Ping Mode (2 Pings)	Single-Ping Mode or Multi-Ping Mode (2 Pings)
Maximum Ping Rate	Approx. 4 Swaths per Second	Approx. 4 Swaths per Second	Approx. 30 – 50 Swaths per Second	Approx. 30 – 50 Swaths per Second
Maximum Number of Reception Beams per Swath	< 500 Beams	< 500 Beams	< 500 Beams	< 500 Beams

Characteristic	SeaBeam 3012	SeaBeam 3020	SeaBeam 3030	SeaBeam 3050
Side Scan Data	Amplitude in dB over Lateral Distance Amplitude in dB over Travel Time (Future Extension)	Amplitude in dB over Lateral Distance Amplitude in dB over Travel Time (Future Extension)	Amplitude in dB over Lateral Distance Amplitude in dB over Travel Time (Future Extension)	Amplitude in dB over Lateral Distance Amplitude in dB over Travel Time (Future Extension)
Transceiver Electronics	Transmitter Control Unit (TCU) and Receiver Control Unit (RCU)	Transmitter Control Unit (TCU) and Receiver Control Unit (RCU)	Combined Transceiver Unit SEE37	Combined Transceiver Unit SEE37

For the SeaBeam 3030/3050 MBES systems, the following additional remarks are important:

- The operating mode (single-ping mode or multi-ping mode) is selectable by the operator.
- The two associated pings (= swaths) of the of the multi-ping mode are sent by the Transceiver Unit SEE37 with different ping numbers, i.e. they are treated by the system as two individual independent pings. However, it has to be mentioned that the timestamps of two associated pings have only very short time differences.

3.3 Communication Channels for Providing XSE Data

The SeaBeam 30xx MBES systems include different communication channels to provide data formatted in XSE groups and frames:

- Data provided in real time (online) via LAN for display purposes (see chapter 4)
- Data exchanged in real time (online) via LAN with third party acquisition software (see chapter 5)
- Data stored (offline) in XSE data files for further use (see chapter 6).

All communication channels use the same rules to format data in frames and groups. However, the data content varies between the different channels.

4 XSE Data Provided Online for Display Purposes

4.1 General

HydroStar Online is capable of transmitting beam data for display purposes (e. g. Helmsman displays) via LAN connection. The data is encoded as XSE. Any client can request a connection to HydroStar Online, as long as the LAN connection allows this. The mechanism of initiating and ending the client server connection is described in TH 44 301 9001. The data available online from HydroStar Online are formatted the same way as the data written by HydroStar Online to XSE files. However, different groups are available via online communication; the client can tailor the selection of groups.

Described in this chapter is the selection of frames and groups that are transmitted for display purposes (e. g. Helmsman displays). The transmitted data consist of navigation data (position, speed, course, heading and accuracy) and Cartesian Multi Beam Data.

Cartesian Multi Beam Data represents pre-processed data. A number of processing steps with variable parameters are required to transform the originally observed data of the multi beam echo sounder into Cartesian co-ordinates. The parameters of these processing steps have significant impact on the result. Since the parameters are not completely logged, Cartesian Multi Beam Data is only suitable for online display, not for data storage.

4.2 Interfaced External Software Packages

The online data provision for display purposes has been realized up to now for EIVA NaviPac software.

4.3 Minimum Frame and Group Requirements

In order to process Cartesian Multi Beam Data, the following frames and groups are required as a minimum.

Table 2: Minimum Requirements for Cartesian Multi Beam Data Processing

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Navigation	1	Point	2	Position from navigation system. The values are from the NMEA GGA sentence, if available. Otherwise, the values from the NMEA GLL sentence are provided. No correction applied. Use time from Frame Header as time stamp. The geodetic description is WGS84. X is the longitude and Y is the latitude. The time is the time stamp out of the NMEA GGA sentence, if available. Otherwise, the time of arrival is used.
Navigation	1	Heading	11	Heading from heading sensor or motion sensor (e.g. iXsea OCTANS or POS/MV). NMEA HDT No corrections applied. The frame time reflects the time of arrival in HydroStar only if there are no further groups available in the specific frame.

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Multi Beam	6	Quality	4	The quality refers to the detected bottom value for each beam; the following quality values are possible: • 1 – 4: High quality • 5 – 7: Low quality • 8: No detected bottom (= Invalid beam) • 9: Beam is set invalid by HydroStar Online, based upon plausibility check.
Multi Beam	6	Lateral	7	See Figure 1.
Multi Beam	6	Along	8	See Figure 1.
Multi Beam	6	Depth	9	Depth corrected for: • Mounting offsets (if active). • SSV (if available online). • SVP (if active). • Tide (if active). Since the meta data, which correction is applied is not coded in XSE, the Cartesian Multi Beam Data is only suitable for online display.
Multi Beam	6	Azimuth	19	See Figure 1.

4.4 Available Frames and Groups

4.4.1 Available Frames

The only frames available are Navigation Frames (Frame Id: 1) and Multi Beam Frames (Frame Id: 6).

4.4.2 Available Groups

Table 3: All Available Groups for Cartesian Multi Beam Data

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Navigation	1	Point	2	Position from navigation system. The values are from the NMEA GGA sentence, if available. Otherwise, the values from the NMEA GLL sentence are provided. No correction applied. Use time from Frame Header as time stamp. The geodetic description is WGS84. X is the longitude and Y is the latitude. The time is the time stamp out of the NMEA GGA sentence, if available. Otherwise, the time of arrival is used..
Navigation	1	Accuracy	3	Additional GPS data to judge the accuracy and reliability of the position data.

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Navigation	1	Motion Ground Truth	4	Course and speed made good from the GPS system. In case the position requires extrapolation this data can be used.
Navigation	1	Heading	11	Heading from heading sensor or motion sensor (e.g. iXsea OCTANS or POS/MV). NMEA HDT No corrections applied. The frame time reflects the time of arrival in HydroStar only if there are no further groups available in the specific frame.
Navigation	1	GPS Altitude	13	Altitude data from GPS.
Multi Beam	6	General	1	Not required for processing of Cartesian Multi Beam Data.
Multi Beam	6	Quality	4	Required to decide whether beam is valid or not. Quality 1-4 describe valid beams. Quality 5-8 describe invalid beams. Quality 9 are filtered beams by HydroStar Online.
Multi Beam	6	Lateral	7	See Figure 1.
Multi Beam	6	Along	8	See Figure 1.
Multi Beam	6	Depth	9	Depth corrected for: • Mounting offsets (if active) • SSV (if available online) • SVP (if active) • Tide (if active) Since the meta data, describing which correction is applied, is not coded in XSE, the Cartesian Multi Beam Data is only suitable for online display, not for data storage.
Multi Beam	6	Azimuth	19	See Figure 1.
Multi Beam	6	Properties	20	See ref. /1/
Multi Beam	6	Normalized Amplitude	21	See ref. /1/

4.5 Definition of Parameters

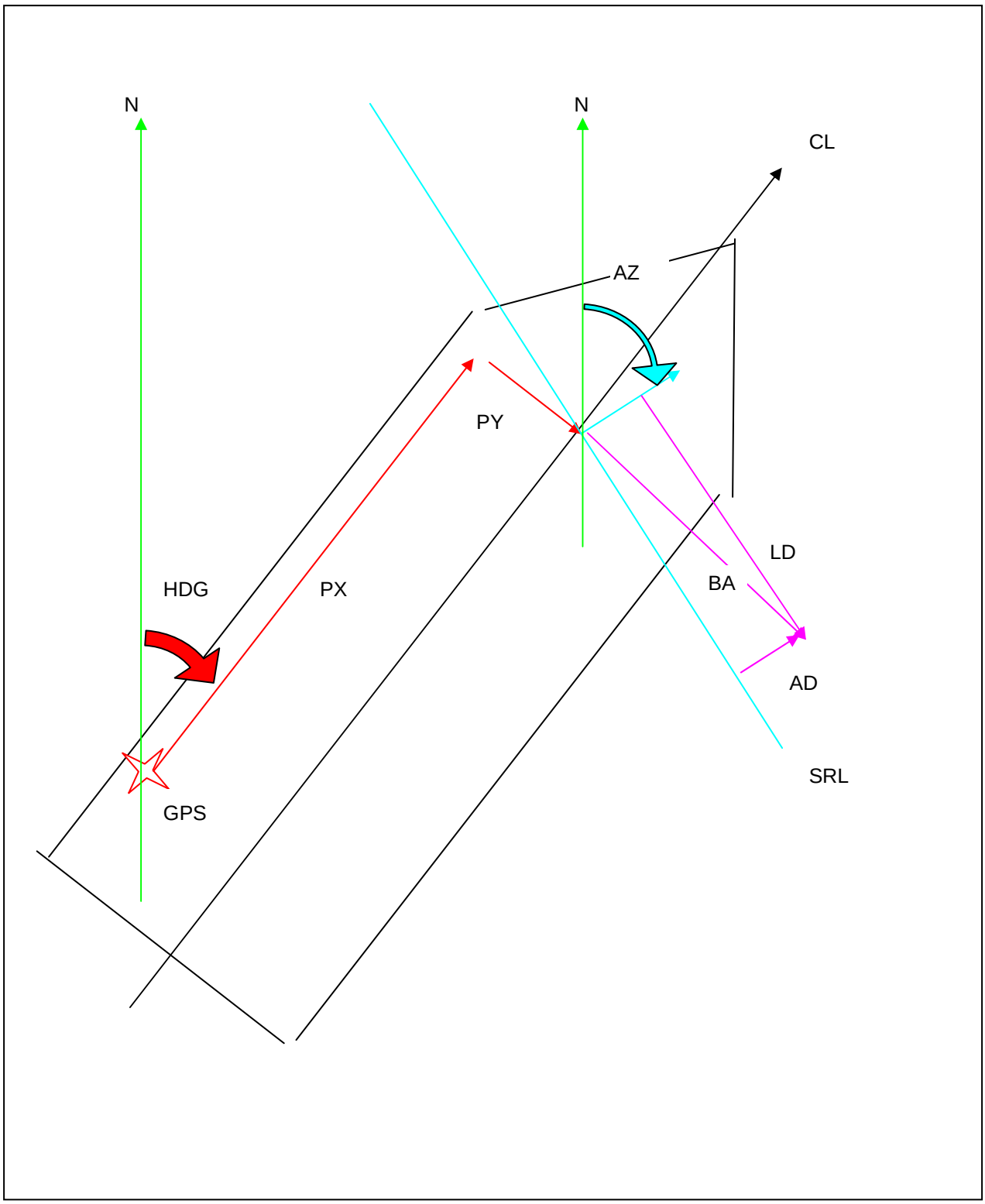

Figure 1: Description of Cartesian Multi Beam Data

AD: Along Distance from MB Frame (Frame Id: 6, Group Id: 8)

AZ: Azimuth from MB Frame (Frame Id: 6, Group Id: 19). The azimuth is the angle between Geographic North and the forward pointing perpendicular of the Swath Reference Line.

BA: Beam Axis, imaginary line between Transducer and centre of footprint. The beam axis describes the beam leaving the transducer, it does not necessarily include sound velocity profile induced beam deflection.

GPS: Position from Navigation Frame (Frame Id: 1, Group Id: 2) relative to reference point (normally GPS antenna).

CL: Ships Centre Line.

HDG: Heading from Navigation Frame (Frame Id: 1, Group Id: 11)

LD: Lateral Distance from MB Frame (Frame Id: 6, Group Id: 7)

N: Geographic North

PX: Component of position off-set parallel to ship's Centre Line (CL). Please be aware that the sign convention shown here does not indicate the position off-set from XSE ship frame (Frame Id: 4, Group Id: 9) but rather a combination of Navigation and Transducer off-sets (Frame Id: 4, Group Id: 10).

PY: Component of position off-set perpendicular to ship's Centre Line (CL). (see above)

SRL: Swath Reference Line. Imaginary straight line through Multi Beam Reference Point. This line is the reference for all beams. This line is not necessarily perpendicular to the ship's Centre Line. The variation can change from swath to swath.

4.6 Required Calculation Steps

Since the depth (Frame Id: 6, Group Id: 9) is already calculated for Cartesian Multi Beam Data, the only data left to be calculated is the position of each beam. The following steps need to be performed in series for each beam:

- Use the time of validity of the whole swath from the Multi Beam Frame Header (Frame Id: 6)
- Interpolate a position and a heading for this point of time from:
  - Point Groups of Navigation Frames (Frame Id: 1, Group Id: 2).
  - Heading Groups of Navigation Frames (Frame Id: 1, Group Id: 11).
  - Navigation Latency (if known).
- Calculate the Transducer Position from:
  - The interpolated position and heading.
  - Navigation offset are described in the ship frame.
  - Gyro correction (if known).
  - Navigation offsets (PX und PY in Figure 1, PZ not shown).
- Calculate the Beam Position from:
  - The previously calculated transducer position.
  - The Azimuth (Frame Id 6, Group Id: 19).
  - Lateral (Frame Id 6, Group Id: 7).
  - Along (Frame Id 6, Group Id: 8).

4.7 Corrections Already Applied to Data

4.7.1 Position

No corrections applied. The point group in the Navigation Frames contains the raw unprocessed position value as it was received by HydroStar Online. The time stamp in the associated Navigation Frame is uncorrected as well. Even if the Navigation Delay was known at the time of observation, it is not applied.

4.7.2 Heading

No corrections applied. The heading group in the Navigation Frames contains the raw unprocessed value as it was received by HydroStar Online. The time of validity can be derived from the time stamp in the associated Navigations frame only if there is no point group in the same Navigation Frame. However if a point group and a heading group are encapsulated in one Navigation Frame, the time stamp of the frame header is the time of validity of the position and the heading value was the last available heading at that time.

4.7.3 Lateral, Along, Depth and Azimuth

Lateral, Along and Depth are no original observations of the MBES. They are derived from parameters originally measured such as beam angles and travel times. HydroStar Online calculates Lateral, Along and Depth and corrects them for the following parameters, if these parameters are active at the time of observation:

Table 4: Corrections Applied to Cartesian Multi Beam Data

Parameter	Source	Status	Condition
Dynamic Roll	Motion Sensor	Mandatory	Motion sensor is working.
Dynamic Pitch	Motion Sensor	Mandatory	Motion sensor is working.
Dynamic Heave	Motion Sensor	Mandatory	Motion sensor is working.
Dynamic Yaw	Gyro	Mandatory	Motion sensor is working.
Static Roll Offset	Ship File	Optional	Ship File is loaded.
Static Pitch Offset	Ship File	Optional	Ship File is loaded.
Static Yaw Offset	Ship File	Optional	Ship File is loaded.
Draft	Ship File	Optional	Ship File is loaded.
SSV	SSV Sensor	Optional	SSV sensor is working.
SVP	SVP File	Optional	SVP File is loaded.
Tide	Tide File	Optional	Tide File is loaded.

5 Online XSE Data Exchange with Third Party Acquisition Software

5.1 General

HydroStar Online is capable of transmitting beam data for data processing via a LAN connection. The data is encoded as XSE. Any client can request a connection to HydroStar Online, as long as the LAN connection allows this. The mechanism of initiating and ending the client server connection is described in TH 44 301 9001. The datagrams available online from HydroStar Online are formatted the same way as the data written by HydroStar Online to XSE files. However, different groups are available via online communication; the client can tailor the selection of groups

Described in this chapter is the selection of frames and groups that are transmitted to third party acquisition software for purpose of online processing, data storage and data visualization. The data transmitted on this connection consists of navigation data (position, speed, course, heading and accuracy) and beam data.

It is important to mention, that HydroStar Online provides Slant/Range Multi Beam Data as well as Cartesian Multi Beam Data. However, for further data processing it is recommended that the third party acquisition software applies the Slant/Range Multi Beam Data.

5.2 Interfaced External Software Packages

The data exchange with third-party acquisition software, described in chapter 5, has been realized up to now for HYPACK data acquisition software and for QPS Qinsy data acquisition software.

5.3 Block Diagrams

The following figures show block diagrams for the connection of third party acquisition software to SeaBeam 30xx systems. As can be seen within the two figures, the interfacing is somewhat different for SeaBeam 3012/3020 systems and SeaBeam 3030/3050 systems. However, from the point of view of the third party acquisition software, the differences are of minor importance.

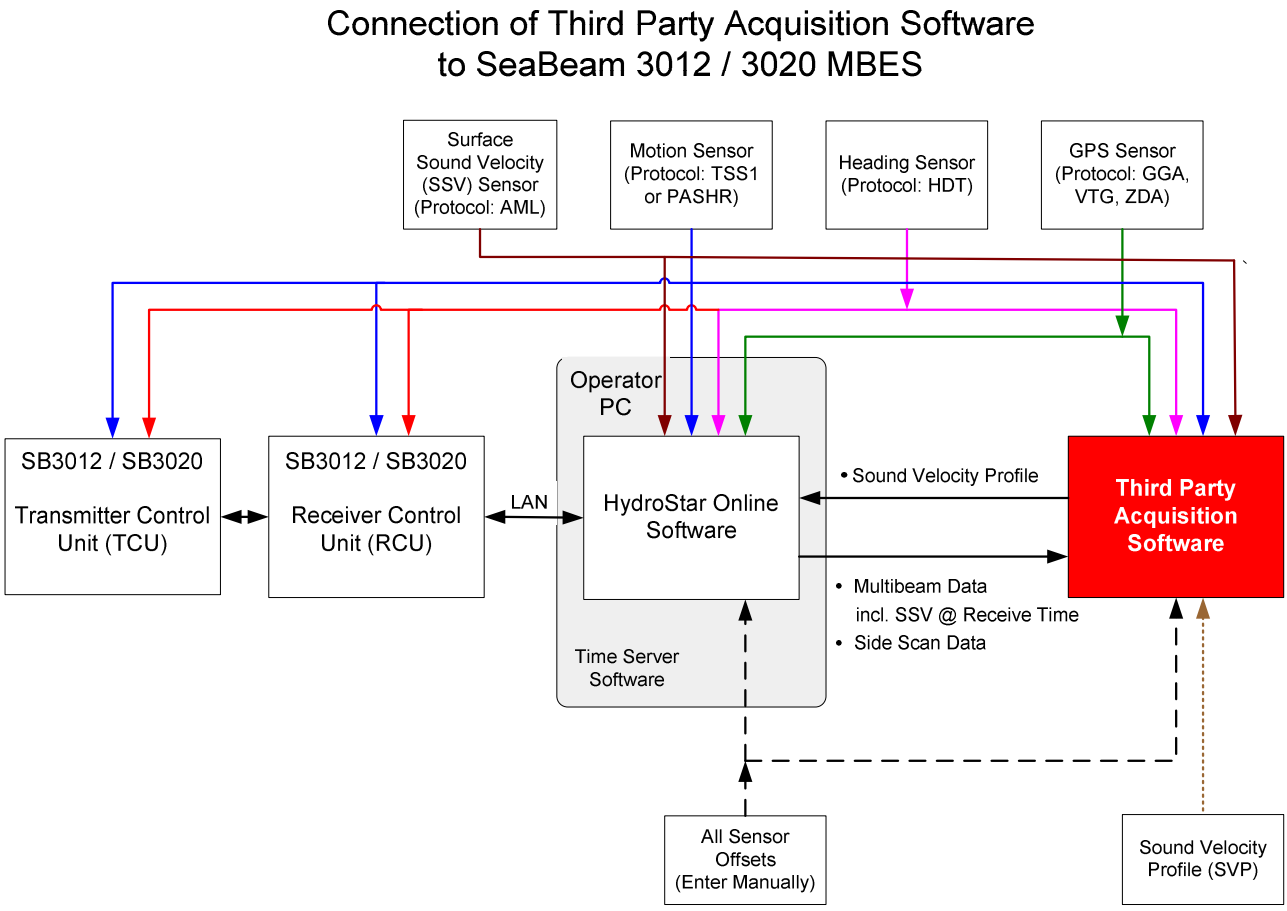

Figure 2: Connection of Third Party Software to SeaBeam 3012 / 3020 MBES

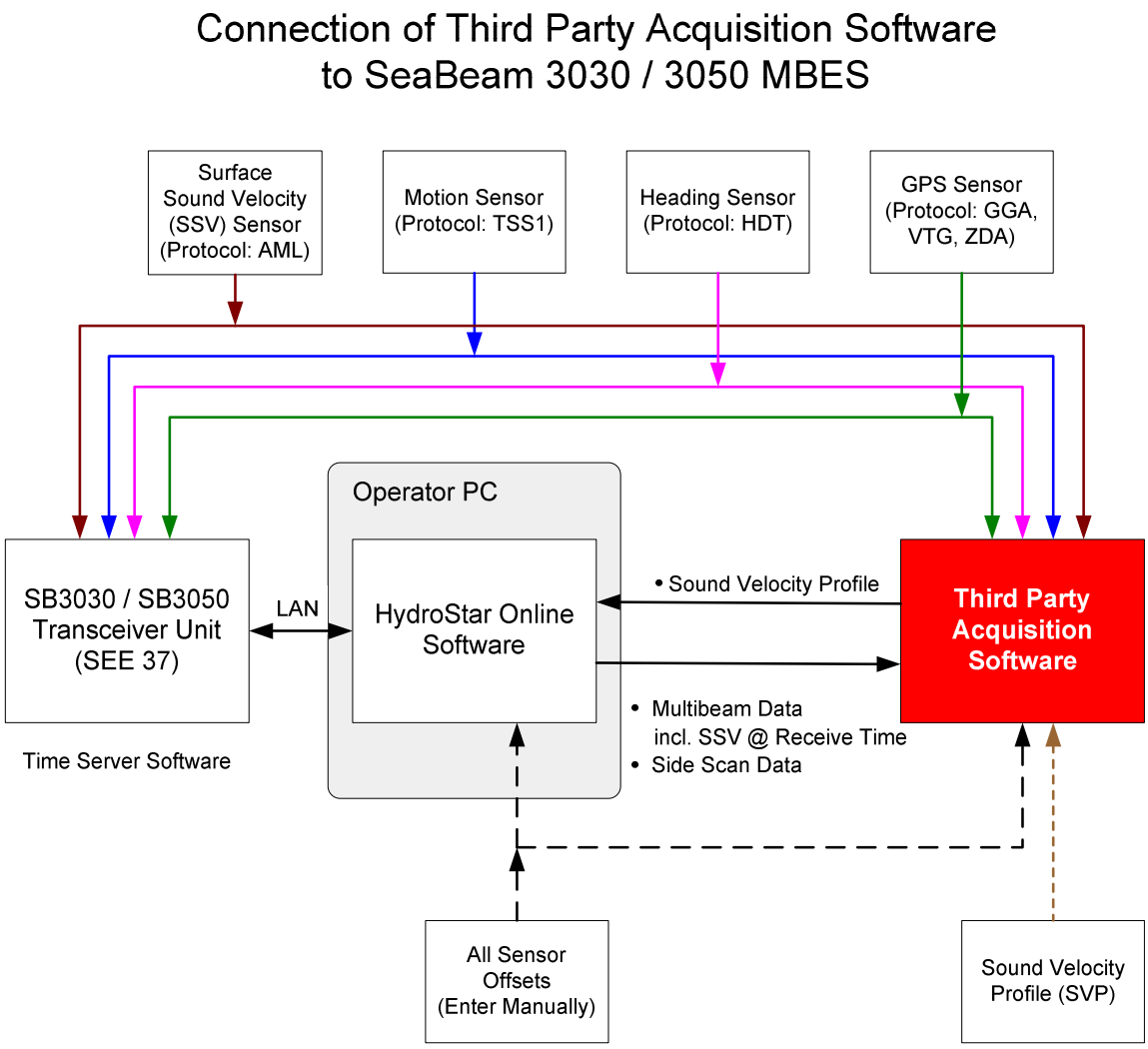

Figure 3: Connection of Third Party Software to SeaBeam 3030 / 3050 MBES

Important Note: The third-party acquisition software should provide to HydroStar Online exactly the information which is indicated in Figure 2, Figure 3 and section 5.5. The third-party acquisition software should not send any additional messages.

5.4 Minimum Frame and Group Requirements

In order to process Slant/Range Multi Beam Data, the following frames and groups are required as a minimum.

The indicated direction refers to HydroStar Online, i.e. “Out” means that HydroStar Online transmits the data to the third party acquisition software and “In” means that HydroStar Online receives the data from the third party acquisition software.

Table 5: Minimum Frame and Group Requirements

Frame		Group		Description / Explanation	Direc-tion
Name	ID	Name	ID		
Sound Velocity	2	Depth	2	Depth of sound velocity sample in meter.	In
Sound Velocity	2	Velocity	3	Sound velocity at given depth in meter per second.	In
Multi Beam	6	Travel Time	3	The two way travel time for each beam. Required to calculate the length of the beam path. The travel time is corrected for beam delays.	Out
Multi Beam	6	Quality	4	Required to decide whether beam is valid or not. Quality 1-4 describe valid beams. Quality 5-8 describe invalid beams. Quality 9 are filtered beams by HydroStar Online.	Out
Multi Beam	6	Angle	10	Across-ship angle between projected beam axis and geo-vertical. See Figure 5 for more details.	Out
Multi Beam	6	Heave	11	Heave at transmit for each beam.	Out
Multi Beam	6	Forward Beam Angle (formerly called “Pitch”)	13	Forward (= along-ship) angle between projected beam axis and geo-vertical. See Figure 5 for more details.	Out
Multi Beam	6	Heave at Receive	18	Heave at receive for each beam.	Out
Multi Beam	6	Azimuth	19	Angle between geographic North and the SRV. See Figure 4 for more details.	Out

5.5 Available Frames and Groups

5.5.1 *Available Frames*

The indicated direction refers to HydroStar Online, i.e. “Out” means that HydroStar Online transmits the data to the third party acquisition software and “In” means that HydroStar Online receives the data from the third party acquisition software.

Table 6: Available Frames

Frame		Description / Explanation	Direc-tion
Name	ID		
Sound Velocity	2	SVP data. This data is required to compute the ray path. It represents the current status at the time of data collection, not necessarily the best choice for post processing. This frame is created by HSO each time one of the following events takes place: • A new file is started (either by start recording or by next file). • A new SVP is loaded in HSO. • An existing SVP is manually modified. • The existing SVP is augmented by a new SSV value. The occurrence of this event depends on the settings of the SSV Sensor notebook.	In
Side Scan	5	Side scan sonar data from the SB 30xx system. This frame is created each time, the SB 30xx completes processing a swath. The correct geo-referencing can only be computed with information from the Multi Beam Frame	Out
Multi Beam	6	Beam data from the SB 30xx system. This frame contains the bathymetric information. This frame is created each time the SB 30xx completes processing a swath. Corrected for biases known at time of generation (roll bias, pitch bias, yaw bias).	Out

5.5.2 *Available Groups*

The indicated direction refers to HydroStar Online, i.e. “Out” means that HydroStar Online transmits the data to the third party acquisition software and “In” means that HydroStar Online receives the data from the third party acquisition software.

Table 7: Available Groups

Frame		Group		Description / Explanation	Direc-tion
Name	ID	Name	ID		
Sound Velocity	2	Depth	2	Field of N depth values to describe the current SVP at time of observation	In
Sound Velocity	2	Velocity	3	Field of N sound velocity values to describe the current SVP at time of observation.	In

Frame		Group		Description / Explanation	Direc-tion
Name	ID	Name	ID		
Sound Velocity	2	Conductivity	4	Field of N conductivity values to describe the current SVP at time of observation.	In
Sound Velocity	2	Salinity	5	Field of N salinity values to describe the current SVP at time of observation.	In
Sound Velocity	2	Temperature	6	Field of N temperature values to describe the current SVP at time of observation.	In
Side Scan	5	General	1	See ref. /1/	Out
Side Scan	5	Amplitude vs. Traveltime *(currently not implemented)*	2	The Amplitude vs. Traveltime Group provides side scan data over travel time of the transmitted pulse (future extension). The Amplitude vs. Traveltime Group will be provided in combination with a General Group (Group Id: 1) and a Weighting Group (Group Id: 9) in a separate Side Scan Frame.	Out
Side Scan	5	Amplitude vs. Lateral	4	The Amplitude vs. Lateral Group provides side scan data over lateral distance. The Amplitude vs. Lateral Group is provided in combination with a General Group (Group Id: 1) and a Weighting Group (Group Id: 9) in a separate Side Scan Frame.	Out
Side Scan	5	Signal	6	The Signal Group contains the amplitudes of the center beam. The Signal Group is provided in combination with a General Group (Group Id: 1) and a Weighting Group (Group Id: 9) in a separate Side Scan Frame.	Out
Side Scan	5	Weighting	9	The Weighting Group provides, separate for the port side and the starboard side, a scaling factor for the side scan amplitudes or the signals.	Out
Multi Beam	6	General	1	This group is not required for simple processing. The frequency includes the following information: • For SB3012 and SB3020: Operating frequency • For SB3030 and SB3050: Operating frequency of the swath center	Out
Multi Beam	6	Travel Time	3	See ref. /1/	Out
Multi Beam	6	Quality	4	Required to decide whether beam is valid or not. Quality 1-4 describe valid beams. Quality 5-8 describe invalid beams. Quality 9 are filtered beams by HydroStar Online.	Out

Frame		Group		Description / Explanation	Direc-tion
Name	ID	Name	ID		
Multi Beam	6	Amplitude	5	Amplitude of detected echo in 0.1 dB relative 1 LSB; the amplitude is an average amplitude over a calculated echo length. The maximum possible amplitude is 90 dB (i.e. 15 bit). This value can be used to map sea floor reflectivity. To this amplitude, not any corrections are applied.	Out
Multi Beam	6	Delay	6	For SB30xx systems, the delays are always zero and are NOT necessary for any post-processing.	Out
Multi Beam	6	Lateral	7	See Figure 1	Out
Multi Beam	6	Along	8	See Figure 1	Out
Multi Beam	6	Depth	9	Depth corrected for: • Mounting offsets (if active) • SSV (if available online) • SVP (if active) • Tide (if active) Since the meta data which correction is applied is not coded in XSE, the Cartesian Multi Beam Data is only suitable for online display, not for data storage.	Out
Multi Beam	6	Angle	10	It is the angle between the geo-vertical and the beam axis' projection onto the plane spanned between the geo-vertical and the swath reference line. See Figure 5 for more details Use the Angle, the Forward Beam Angle (Id: 13) and the Azimuth (Id: 19) to calculate beam steering angle in space.	Out
Multi Beam	6	Heave	11	Heave at time of transmit.	Out
Multi Beam	6	Roll	12	Roll of the ship at time of transmit for each beam. This value does not need to be applied for normal bathymetry computations, since all angles are vertically referenced. However, should post processing require a re-computation due to a changed SSV, the roll at time of receive is required to recalculate the beam angle (Group Id: 10).	Out
Multi Beam	6	Forward Beam Angle (formerly called "Pitch")	13	This is the angle between the geo-vertical and the beam axis' projection onto the plane spanned between the geo-vertical and the swath reference vector. See Figure 5 for more details. Important note: This XSE group does NOT include the pitch of the ship at the time of transmit.	Out

Frame		Group		Description / Explanation	Direc-tion
Name	ID	Name	ID		
Multi Beam	6	Gates	14	The gates group defines the upper and lower border for depth detector. The gates are not required for processing of the bathymetry data.	Out
Multi Beam	6	Noise	15	Signal to noise ratio of the detected echo in dB. The value indicates the quotient between the echo amplitude (Group Id: 5) and the noise level. This value can be used for advanced error processing as required for CUBE.	Out
Multi Beam	6	Heave Receive	18	Heave at time of receive. This value must be applied together with the heave at transmit (Group Id: 11) to correct for short term vertical displacement. Positive values indicate a position above the reference plane.	Out
Multi Beam	6	Azimuth	19	Angle between geographic north and the SRV measured North via East. See Figure 4 for details.	Out
Multi Beam	6	Properties	20	See ref. /1/; if the azimuth of the transmitted swath is contained in the Properties Group, then it is the same value as in the Azimuth Group (Group Id: 19). The Properties Group includes the Surface Sound Velocity (SSV) value which has been applied for reception beamforming.	Out
Multi Beam	6	Normalized Amplitude	21	Normalized amplitude of bottom echo per beam (see ref. /1/): All system characteristics like transmission source level in the beam direction, receive sensitivity in the beam direction and overall receiver gain have been removed within the normalized amplitude. System-independent losses like spherical transmission loss, absorption and bottom backscatter loss are NOT part of the normalization. • For SB3012 and SB3020: This group is provided and includes one overall frequency value (= operating frequency). • For SB3030 and SB3050: This group will be provided as a future extension; due to the multi-frequency capabilities of the SB3030 and the SB3050, the group will include one frequency value for each beam direction.	Out

5.6 Definition of Parameters

The definition of the different parameters is described in section 6.4.

5.7 Required Calculation Steps

The required calculation steps are described in section 6.5.

5.8 Corrections Already Applied to Data

The corrections already applied to data are described in section 6.6.

6 XSE Data Provided Offline via XSE Files

6.1 General

HydroStar Online is capable of storing MBES data in files. This data is encoded as XSE. The datagrams available from XSE files are formatted the same way as those available via online communication. However, different groups are available from XSE files.

6.2 Minimum Frame and Group Requirements

In order to process Slant/Range Multi Beam Data, the following frames and groups are required as a minimum.

Table 8: Minimum Frame and Group Requirements

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Navigation	1	Point	2	Position from navigation system. The values are from the NMEA GGA sentence, if available. Otherwise, the values from the NMEA GLL sentence are provided. No correction applied. Use time from Frame Header as time stamp. The geodetic description is WGS84. X is the longitude and Y is the latitude. The time is the time stamp out of the NMEA GGA sentence, if available. Otherwise, the time of arrival is used.
Navigation	1	Heading	11	Heading from heading sensor or motion sensor (e.g. iXsea OCTANS or POS/MV). NMEA HDT No corrections applied. The frame time reflects the time of arrival in HydroStar only if there are no further groups available in the specific frame.
Sound Velocity	2	Depth	2	Depth of sound velocity sample in meter.
Sound Velocity	2	Velocity	3	Sound velocity at given depth in meter per second.
Multi Beam	6	Travel Time	3	The two way travel time for each beam. Required to calculate the length of the beam path. The travel time is corrected for beam delays.
Multi Beam	6	Quality	4	Required to decide whether beam is valid or not. Quality 1-4 describe valid beams. Quality 5-8 describe invalid beams. Quality 9 are filtered beams by HydroStar Online.
Multi Beam	6	Angle	10	Across-ship angle between projected beam axis and geo-vertical. See Figure 5 for more details.
Multi Beam	6	Heave	11	Heave at transmit for each beam.

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Multi Beam	6	Forward Beam Angle (formerly called “Pitch”)	13	Forward (= along-ship) angle between projected beam axis and geo-vertical. See Figure 5 for more details.
Multi Beam	6	Heave at Receive	18	Heave at receive for each beam.
Multi Beam	6	Azimuth	19	Angle between geographic North and the SRV. See Figure 4 for more details.

6.3 Available Frames and Groups

6.3.1 Available Frames

Table 9: Available Frames

Frame		Description / Explanation
Name	ID	
Navigation	1	Navigation Frames can contain data from one or more of the following sensors: • Position Sensor (Position, Altitude Speed, and Course) • Motion Sensor (Heave, Roll and Pitch) • Heading Sensor (Geographic North) This type of frame is created by HSO each time one of the previously listed sensors transmits a valid datagram.
Sound Velocity	2	SVP data. This data is required to compute the ray path. It represents the current status at the time of data collection, not necessarily the best choice for post processing. This frame is created by HSO each time one of the following events takes place: • A new file is started (either by start recording or by next file). • A new SVP is loaded in HSO. • An existing SVP is manually modified. • The existing SVP is augmented by a new SSV value. The occurrence of this event depends on the settings of the SSV Sensor notebook.
Tide	3	Tide data. This data may be used to correct for changes in the water level with respect to the charting datum. It represents the current status at the time of data collection, not necessarily the best choice for post processing. This frame is created by HSO each time one of the following events takes place: • A new file is started (either by start recording or by next file). • A new tide table is loaded in HydroStar Online software. • An existing tide table is modified. This data is rarely used for oceanographic surveys.

Frame		Description / Explanation
Name	ID	
Ship	4	Data to describe the geometry of the sensors used for the current observation. It represents the current status at the time of data collection, not necessarily the best choice for post processing. This frame is created by HSO each time one of the following events takes place: • A new file is started (either by start recording or by next file). • A new Ship File is loaded. • The existing Ship File is modified.
Side Scan	5	Side scan sonar data from the SB 30xx system. This frame is created each time, the SB 30xx completes processing a swath. The correct geo-referencing can only be computed with information from the Multi Beam Frame
Multi Beam	6	Beam data from the SB 30xx system. This frame contains the bathymetric information. This frame is created each time the SB 30xx completes processing a swath. Corrected for biases known at time of generation (roll bias, pitch bias, yaw bias).
SeaBeam	13	Information from SB 30xx system. Formatted text, for debugging purposes only. This frame is created each time the SB 30xx is transmitting information deemed noteworthy for the benefit of future generations.

6.3.2 Available Groups

Table 10: Available Groups

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Navigation	1	Point	2	Position from navigation system (GPS or e.g. POS/MV). No correction applied. Use time from Frame Header as observation time. If the position data is derived from NMEA 0183 strings GGA or GLL, the Description field will always read WGS84. This indicates, that the following 3 fields are latitude, longitude and height above ellipsoid. Note, that frames with a point group will always contain a heading group as well. The heading from this frame was the last heading available at the time of the GPS observation. But the headings observation time is not retained.
Navigation	1	Accuracy	3	Additional GPS data to judge the accuracy and reliability of the position data like GPS quality indicator, Number of satellites, HDOP, correction age. This data can be used for position verification, editing and for CUBE processing.

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Navigation	1	Motion Ground Truth	4	Course and speed made good from the GPS system. In case the position requires extrapolation this data can be used. Since the data is the result of an independent measurement, it can be used as input into a Kalman Filter for improved position calculation.
Navigation	1	Heave Roll Pitch	7	Heave, Roll and Pitch from VRU. No correction applied in HydroStar Online software. Data is required for precise position calculation, especially if the antenna is mounted high up in the mast. The angles of the multi beam data are already geo-vertical referenced and do not require to be corrected with this data.
Navigation	1	Heading	11	Heading from heading sensor or motion sensor (e.g. iXsea OCTANS or POS/MV). No corrections applied. Required for precise position computation.
Navigation	1	GPS Altitude	13	Altitude data from GPS. With high quality GPS system the mean sea level (antenna height) and the geodial separation is available. This data can be used for tide calculation after appropriate processing. The mean sea level is not corrected for heave, but the unprocessed value from the GPS message.
Sound Velocity	2	Depth	2	Field of N depth values to describe the current SVP at time of observation
Sound Velocity	2	Velocity	3	Field of N sound velocity values to describe the current SVP at time of observation.
Sound Velocity	2	Conductivity	4	Field of N conductivity values to describe the current SVP at time of observation.
Sound Velocity	2	Salinity	5	Field of N salinity values to describe the current SVP at time of observation.
Sound Velocity	2	Temperature	6	Field of N temperature values to describe the current SVP at time of observation.
Tide	3	Point	2	Geographic point on which the time and tide values refer.
Tide	3	Time	3	UTC time values (in seconds since 00:00 01.01.1901) which correspond to the tide values.
Tide	3	Tide	4	Tide values in meters
Ship	4	General	1	This group includes the following ship parameters: • Ship name • Total length of the ship • Total width of the ship • Maximum possible draft of the ship • Maximum height of the ship.
Ship	4	Sensors	4	See ref. /1/

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Ship	4	Navigation and Motion	9	See ref. /1/
Ship	4	Transducers	10	See ref. /1/
Ship	4	Transducer Extended	11	See ref. /1/
Side Scan	5	General	1	See ref. /1/
Side Scan	5	Amplitude vs. Traveltime	2	The Amplitude vs. Traveltime Group provides side scan data over travel time of the transmitted pulse (future extension). The Amplitude vs. Traveltime Group will be provided in combination with a General Group (Group Id: 1) and a Weighting Group (Group Id: 9) in a separate Side Scan Frame.
Side Scan	5	Amplitude vs. Lateral	4	The Amplitude vs. Lateral Group provides side scan data over lateral distance. The Amplitude vs. Lateral Group is provided in combination with a General Group (Group Id: 1) and a Weighting Group (Group Id: 9) in a separate Side Scan Frame.
Side Scan	5	Signal	6	The Signal Group contains the amplitudes of the center beam. The Signal Group is provided in combination with a General Group (Group Id: 1) and a Weighting Group (Group Id: 9) in a separate Side Scan Frame.
Side Scan	5	Weighting	9	The Weighting Group provides, separate for the port side and the starboard side, a scaling factor for the side scan amplitudes or the signals.
Multi Beam	6	General	1	This group is not required for simple processing. The frequency includes the following information: • For SB3012 and SB3020: Operating frequency • For SB3030 and SB3050: Operating frequency of the swath center
Multi Beam	6	Travel Time	3	See ref. /1/
Multi Beam	6	Quality	4	Required to decide whether beam is valid or not. Quality 1-4 describe valid beams. Quality 5-8 describe invalid beams. Quality 9 are filtered beams by HydroStar Online.
Multi Beam	6	Amplitude	5	Amplitude of detected echo in 0.1 dB relative 1 LSB; the amplitude is an average amplitude over a calculated echo length. The maximum possible amplitude is 90 dB (i.e. 15 bit). This value can be used to map sea floor reflectivity. To this amplitude, not any corrections are applied.

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Multi Beam	6	Delay	6	For SB30xx systems, the delays are always zero and are NOT necessary for any post-processing.
Multi Beam	6	Lateral	7	See Figure 1
Multi Beam	6	Along	8	See Figure 1
Multi Beam	6	Depth	9	Depth corrected for: • Mounting offsets (if active) • SSV (if available online) • SVP (if active) • Tide (if active) Since the meta data which correction is applied is not coded in XSE, the Cartesian Multi Beam Data is only suitable for online display, not for data storage.
Multi Beam	6	Angle	10	It is the angle between the geo-vertical and the beam axis' projection onto the plane spanned between the geo-vertical and the swath reference line. See Figure 5 for more details Use the Angle, the Forward Beam Angle (Id: 13) and the Azimuth (Id: 19) to calculate beam steering angle in space.
Multi Beam	6	Heave	11	Heave at time of transmit.
Multi Beam	6	Roll	12	Roll of the ship at time of transmit for each beam. This value does not need to be applied for normal bathymetry computations, since all angles are vertically referenced. However, should post processing require a re-computation due to a changed SSV, the roll at time of receive is required to recalculate the beam angle (Group Id: 10).
Multi Beam	6	Forward Beam Angle (formerly called "Pitch")	13	This is the angle between the geo-vertical and the beam axis' projection onto the plane spanned between the geo-vertical and the swath reference vector. See Figure 5 for more details. Important note: This XSE group does NOT include the pitch of the ship at the time of transmit.
Multi Beam	6	Gates	14	The gates group defines the upper and lower border for depth detector. The gates are not required for processing of the bathymetry data.
Multi Beam	6	Noise	15	Signal to noise ration of the detected echo in dB. The value indicates the quotient between the echo amplitude (Group Id: 5) and the noise level. This value can be used for advanced error processing as required for CUBE.

Frame		Group		Description / Explanation
Name	ID	Name	ID	
Multi Beam	6	Heave Receive	18	Heave at time of receive. This value must be applied together with the heave at transmit (Group Id: 11) to correct for short term vertical displacement. Positive values indicate a position above the reference plane.
Multi Beam	6	Azimuth	19	Angle between geographic north and the SRV measured North via East. See Figure 4 for details.
Multi Beam	6	Properties	20	See ref. /1/; if the azimuth of the transmitted swath is contained in the Properties Group, then it is the same value as in the Azimuth Group (Group Id: 19). The Properties Group includes the Surface Sound Velocity (SSV) value which has been applied for reception beamforming.
Multi Beam	6	Normalized Amplitude	21	Normalized amplitude of bottom echo per beam (see ref. /1/): All system characteristics like transmission source level in the beam direction, receive sensitivity in the beam direction and overall receiver gain have been removed within the normalized amplitude. System-independent losses like spherical transmission loss, absorption and bottom backscatter loss are NOT part of the normalization. • For SB3012 and SB3020: This group is provided and includes one overall frequency value (= operating frequency). • For SB3030 and SB3050: This group will be provided as a future extension; due to the multi-frequency capabilities of the SB3030 and the SB3050, the group will include one frequency value for each beam direction.
SeaBeam	13	*<Several groups>*	*<IDs>*	The groups within the SeaBeam frame are only used for debugging purposes.

6.4 Definition of Parameters

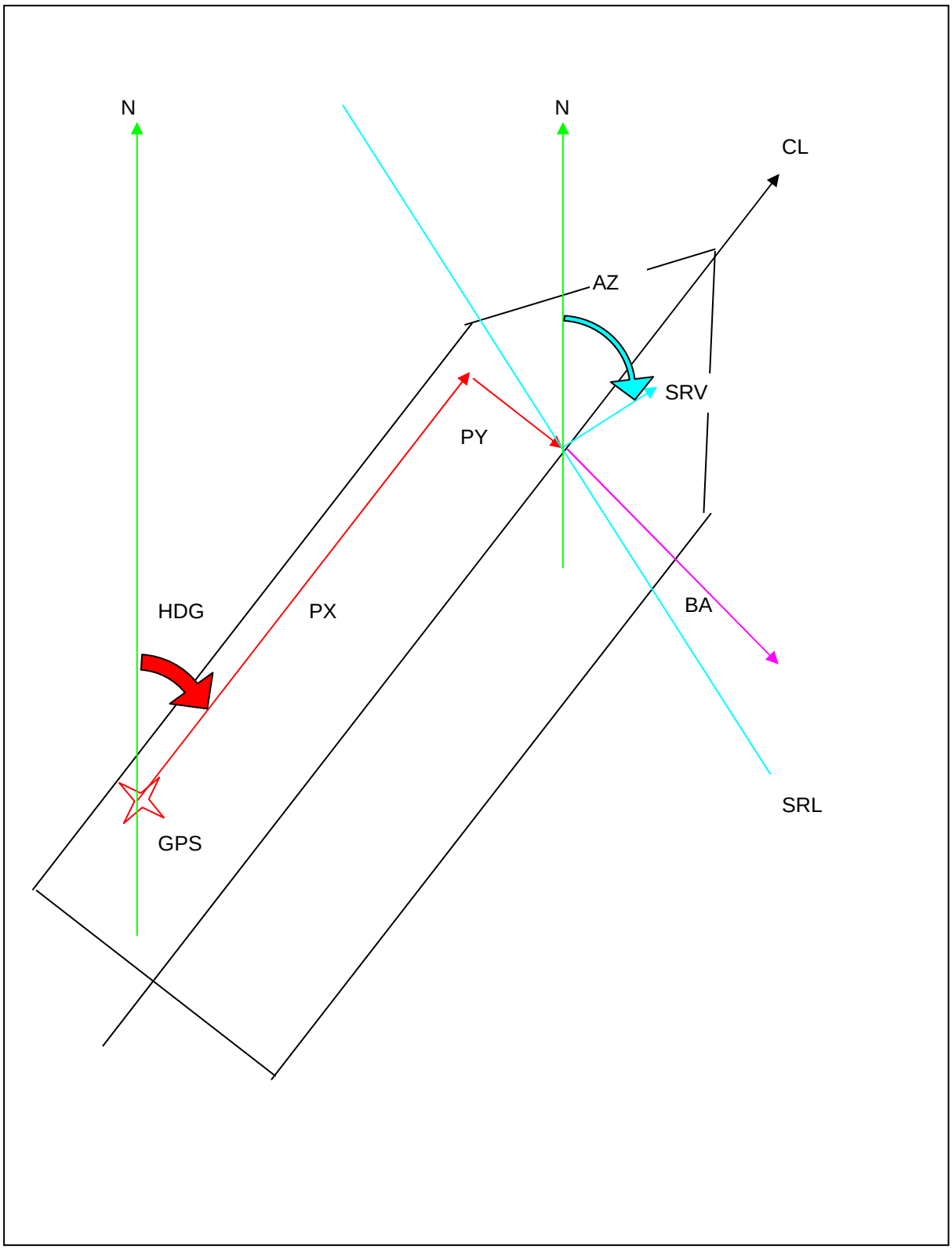

Figure 4: Description of Slant/Range Multi Beam Data

A:	Across-ship beam angle (Frame Id: 6, Group Id: 10)
AZ:	Azimuth from MB Frame (Frame Id: 6, Group Id: 19). The azimuth is the angle between geographic North and the Swath Reference Vector (SRV).
BA:	Beam Axis, imaginary line between Transducer and centre of footprint. The beam axis describes the beam leaving the transducer, it does not necessarily include sound velocity profile induced beam deflection.
CL:	Ships Centre Line.
GPS:	Position from Navigation Frame (Frame Id: 1, Group Id: 2). Reference point is the C-Nav GPS antenna.
HDG:	Heading from Navigation Frame (Frame Id: 1, Group Id: 11)
N:	Geographic North
P:	Forward Beam Angle (formerly called “Pitch”) of beam axis as defined in Figure 5 (Frame Id: 6, Group Id: 13)
PX:	Component of position off-set parallel to ship’s Centre Line (CL). Please be aware that the sign convention shown here does not indicate the position off-set from XSE ship frame (Frame Id: 4, Group Id: 9) but rather a combination of Navigation and Transducer off-sets (Frame Id: 4, Group Id: 10).
PY:	Component of position off-set perpendicular to ship’s Centre Line (CL). (see above)
SRL:	Swath Reference Line. Imaginary straight line through Multi Beam Reference Point (acoustic centre of the projector). This Geo-horizontal line is the reference for all beams. This line is not necessarily perpendicular to the ship’s Centre Line. The variation can change from swath to swath.
SRV	Swath Reference Vector. Geo-horizontal vector vertical to SRL pointing “more forward then backward”.

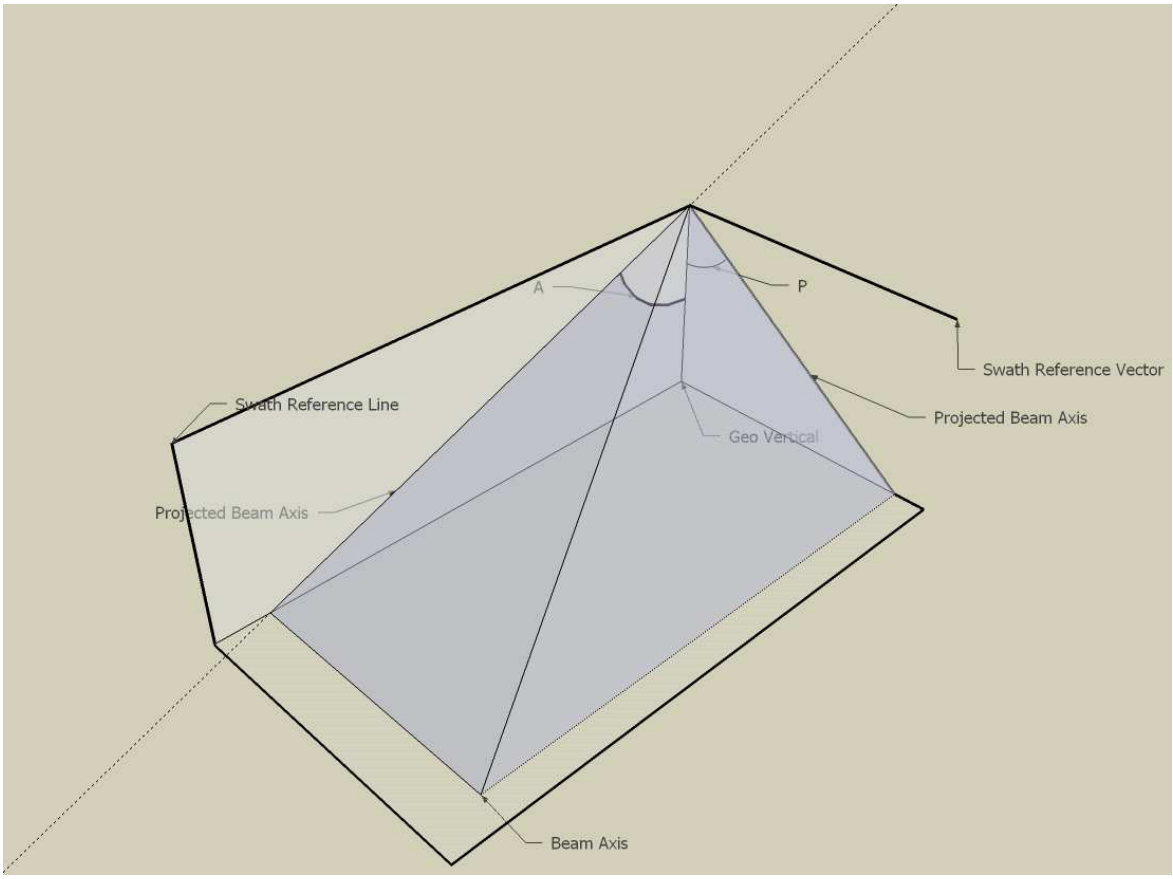

Figure 5: Definition of Across-Ship Angle A and Forward Beam Angle P of Selected Beam

The basic groups relevant for Slant/Range Multi Beam Data belong to the Multi Beam Frame (Id: 6). The items depicted in Figure 5 are:

- **Angle Group** (Frame Id: 6, Group Id: 10) is denoted as A. It is the angle between the geo-vertical and the beam axis' projection onto the plane spanned between the geo-vertical and the swath reference line.
- **Forward Beam Angle Group** (formerly called "Pitch Group") (Frame Id: 6, Group Id: 13). is denoted as P. It is the angle between the geo-vertical and the beam axis' projection onto the plane spanned between the geo-vertical and the swath reference vector.
- **Travel Time** Group (Frame Id: 6, Group Id: 3) is only shown indirectly as the length of the beam axis. The travel time is always given as two way travel time.

The number of beams for the current frame is given in each individual group, that contains beam data (Ids: 3, 4, 5, 6, 10, 11, 12, 13, 15, 16, 17, 18, 19) and is identical within one frame. From these three values (per beam) and the sound velocity profile the depth and a ship referenced position can be calculated. But be aware, that the angle you need for refraction correction is not the beam angle.

More commonly slant/range is given as travel time, take-off angle and bearing. The take-off angle is the angle between the (geo-) vertical and the beam axis. The bearing is the angle between the SRV and the projection of the beam axis onto the (geo-) horizontal plane. The take-off angle can directly be used to "feed" the refraction algorithm (ray tracing). The bearing can be used (augmented by the azimuth) to geo-reference the beam's position. This co-ordinate system is commonly referred to as spherical co-ordinates.

To transform between the two co-ordinate systems, the following abbreviations are applied:

i: beam index:

A_i : Beam Angle as in XSE Angle group (frame Id: 6, Group Id: 10)

P_i : Forward Beam Angle as in XSE Forward Beam Angle group (frame Id: 6, Group Id: 13)

B_i : Bearing (angle between SRV and beam axis' projection onto horizontal plane)

T_i : Take-off angle (angle between vertical down and beam axis)

Formula Set 1

The conversion from spherical co-ordinates to beam angle and forward beam angle co-ordinates is:

$$A_i = \tan^{-1}\{\tan(T_i) * \sin(-B_i)\} \qquad \forall T_i \neq 90°$$

$$P_i = \tan^{-1}\{\tan(T_i) * \cos(-B_i)\} \qquad \forall T_i \neq 90°$$

Formula Set 2

The conversion from beam angle and forward beam angle as given in the XSE file to bearing angle and take-off angle is:

$$B_i = -\tan^{-1}\left\{\frac{\tan(A_i)}{|\tan(P_i)|}\right\} \qquad \forall P_i \neq 0°$$

$$B_i = 90° * sign(A_i) \qquad \forall P_i = 0°$$

$$T_i = \tan^{-1}\sqrt{\tan^2(A_i) + \tan^2(P_i)} \qquad \forall P_i \neq 90° \wedge A_i \neq 90°$$

6.5 Required Calculation Steps

Since neither depth nor distance from the Reference Point are known, they need to be calculated to geo-reference each beam. The following steps need to be performed in series for each beam:

- The "foot print" of a beam is determined by the transmitted ping. Hence, use the time of validity for the whole swath from the Multi Beam Frame Header (Frame Id: 6).
- Interpolate position, heading, roll and pitch for this point of time from:
  - Point groups of Navigation Frames (Frame Id: 1, Group Id: 2).
  - Heading Groups of Navigation Frames (Frame Id: 1, Group Id: 11).
  - Heave Roll Pitch Groups of Navigation Frames (Frame Id: 1, Group Id: 7).
  - Navigation Latency (if known)
- Calculate the transducer's position at time of ping from:
  - The interpolated position, heading, roll and pitch
  - Navigation offsets (PX und PY in Figure 4, PZ not shown)
  - Gyro correction (if known)
  - Roll offset of VRU (if known)
  - Pitch offset VRU (if known)
- Using Formula Set 2 calculate the take-off angle and bearing angle for each beam from:
  - Angle group (Frame Id: 6, Group Id: 10).
  - Forward Beam Angle group (Frame Id: 6, Group Id: 13)

- Use a suitable ray tracing algorithm to calculate the depth and the horizontal distance of the beam's footprint from:
    - Take-off angle
    - Travel time (Frame Id: 6, Group Id: 3)
- Calculate the beam's position:
    - The previously calculated transducer position
    - The azimuth (Frame Id 6, Group Id: 19).
    - The bearing angle from Formula Set 2
    - The horizontal distance from the ray tracing
    - The depth from the ray tracing

6.6 Corrections Already Applied to Data

The data in the Angle Group (Id: 10) and the Forward Beam Angle Group (Id: 13) is corrected for surface sound velocity, if one of the following conditions is true:

- A Surface Sound Velocity Sensor was connected to HydroStar Online during data acquisition, and it was transmitting data.
- A Sound Velocity Profile was loaded during data acquisition.

The data in the Angle Group (Id: 10) is corrected for static roll offset, if both following conditions are true:

- In HydroStar Online, a ship parameter was loaded during acquisition of the data.
- A static roll off-set for the respective transducer was entered in this file.

The data in the Forward Beam Angle Group (Id: 13) is corrected for static pitch offset, if both following conditions are true:

- In HydroStar Online, a ship parameter was loaded during acquisition of the data.
- A static pitch off-set for the respective transducer was entered in this file.

6.7 Example of Frame Sequences within an XSE File

To give an example of how the frames may be packed within an XSE file, the following exemplary sequence was extracted from the middle of an existing XSE file.

The most important point, that can be seen in this example is that the frames are not sorted by their timestamp. This is due to the fact, that the Multi Beam Frame for example needs a lot of processing before the data is ready, but the Navigation Frame just has to be written. So the Multi Beam Frame and the Navigation Frames in the example below differ by about 10 seconds.

It might even happen, that the Navigation Data that corresponds to a Multi Beam Frame is not part of the file, that the Multi Beam Frame is in. This happens if the XSE file, in which the navigation Frame is written, reached the maximum allowed file size before the Multi Beam Frame was ready, this Multi Beam Frame is written into a new file.

This has to be taken into account, when writing a post-processing software.

……

11:47:30.351	Navigation-Frame
11:47:30.390	Navigation Frame
11:47:30.400	Navigation Frame
11:47:30.427	Sound Velocity Frame
11:47:30.441	Navigation Frame
11:47:20.440	Multi Beam Frame
11:47:30.451	Navigation Frame
11:47:20.440	Side Scan Frame
11:47:20.440	Side Scan Frame

11:47:20.440	SeaBeam Frame
11:47:30.501	Navigation Frame
11:47:30.510	Navigation Frame
11:47:30.550	Navigation Frame
11:47:30.560	Navigation Frame
11:47:30.351	SeaBeam Frame
11:47:30.600	Navigation Frame

…….

The Ship Frame, Sound Velocity Frame, Tide Frame and a Product Frame are written once at the beginning of each file. This is done because else these frames are only written, if a value included in them changes and it is likely, that the values don't change for the duration of the write process of an XSE file.