Afdeling Waterwegen Kust
Hydrografie
OOSTENDE

HET GEBRUIK VAN DE SIMRAD EM950

AAN BOORD VAN MS. TER STREEP

53550

Hydrographic Society

Multibeam Echosounder Technology

Oostende, 13 oktober 1995

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Rapport nr.42 van de Hydrografische Dienst der Kust

Afdeling Waterwegen Kust - Hydrografie
OOSTENDE

HSBB-workshop "MULTIBEAM ECHOSOUNDER TECHNOLOGY"
op 13/10/1995 te OOSTENDE (Clubhuis NSYC).
by Ing.C.Van Cauwenberghe.

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SWATH-SOUNDING SYSTEMS

Introduction

For hydrographic purposes swath-sounding systems become more and more important,because these systems enhance the efficiency of bathymetric surveys, when compared to the conventional methods (single track measurements).
Already *in 1976* a paper revealed that, in bathymetric surveys, residual depth errors occur as a function of the line spacing, i.e. the distance between 2 sounding lines *(R.Cloet)*.
These depth errors could be in excess of 1 metre, where the line spacing was 60 metres or more (formula E = 0,4 + 0,1L with E: error and L:line spacing).
After 1976, a lot of experiments were done in the Netherlands and the United Kingdom (UK) and also these findings supported the contents of the paper, mentionned above.
A recent paper of 1993 (International Hydrographic Review of March 1993) confirmed the findings of R.Cloet as well.
On the basis of this experience, it was felt imperative that, in a sandwave area, line-spacing needed to be reduced to at least 50 metres, which was a considerable increase in the workload of the hydrographic service.

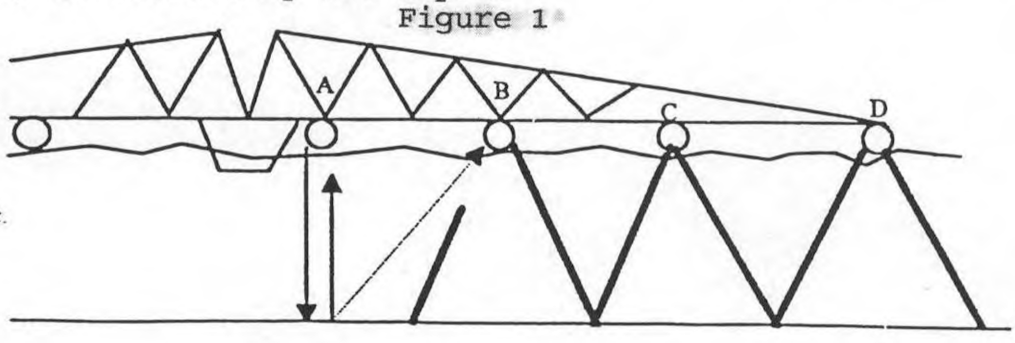
Methods - Principles of operation

Three methods can be identified:
- **multiple echosounders**;
- **interferometers with a sidescan sonar**: *phase* and distance measurement
- **fan shaped multi-beam swath echo sounder** - principle of *amplitude* measurement

1. Multiple Echo Sounders

The multiple echo sounder require a very stable platform and is only really suitable for sheltered waters, such as rivers and confines harbours.
Lack of manoeuvrability and low operating speeds are disadvantages in busy waterways.
The swath width is limited in current equipments to a maximum of 50 metres.
The number of echo sounders, that can be used at the same time, is limited by the depth.

Figure 1



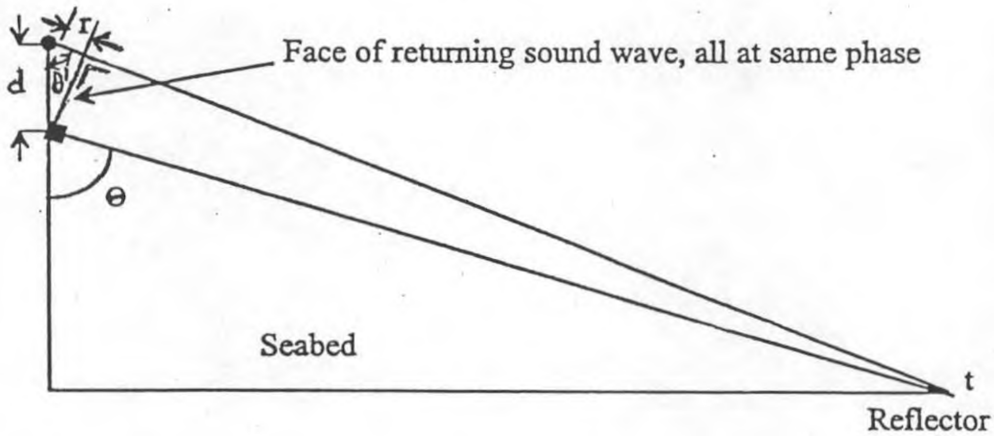
2. **Interferometers - Principle of phase measurement**

Here *two* different systems are to distinguish:

(a) **The Bathyscan System.**

This system, used till now as a towfish configuration, combines time or distance (with a sidescan sonar) and angle measurements (with different interferometers)
We can clarify this solution by focussing first on the principle of *1 single interferometer*:
The interferometric sounder transmits a beam, similar to a sidescan sonar, but as well as recording signal amplitude, measures the phase difference between 2 signals from the same reflector on the sea bottom, using a pair of vertically-displaced transducers. See also Figure 2 below.

Figure 2



Knowing *d*, or the transducer separation, and *Φ*, the phase difference, measured by the interferometer, then *r* may be deduced.
From this, the angle, subtended by a reflector t on the seabed, can be calculated:
$\theta' \approx \theta = bg \cos r/d$
This calculation is independent of range and depth and the number of individual sample comparisons made is limited by the ability to resolve phase-difference. In practice, very many samples are obtainable, every transmission cycle. Furthermore, since the sampling is not affected by range, resolution is maintained across the full swath. Systems, employing single interferometres, are limited in their swath by ambiguities, generated when the phase difference exceeds 360°.
Additional transducers enables these ambiguities to be removed and are incorporated in Bathyscan; on this manner several interferometers are used. See also the Annex 1.
Accuracy of Bathyscan
Arithmetically it is easy to indicate that the footprint of a Bathyscan sounding is much smaller than that of a multi-beam sounder; this leads to a higher resolution so that the sounding accuracy is higher.

(b) **The EM-950 or EM-1000 System of SIMRAD**
Here 60 beams are sent to the seabed in a honey-combe structure.
Primarily for the outer beams the interferometric principle is used, because here beamforming is smaller and also the maximum swath width is bigger (7.4 * depth).
The determination of time for one of the outer bundles can be illustrated on on a phase difference versus time diagram, shown in Annex 2.
The phase difference of 2 adjacent tranducers are represented in the diagram and the zero phase difference (crossing with the x-axis) is to take into account, because this signal from the reflector on the bottom is coming from precisely the direction in which the transducer is pointing to the seabed.
The time, the transmit pulse is underway, is therefore determined at this moment as well, which, depending on the sound velocity, is a gauge of the measured depth.
The accuracy for determining the beam's angle is considered to be something around 0.02°.

3. Multi-beam Echo Sounders - Principle of amplitude measurement

Here the necessary time and direction measurements of the different transducer-elements are carried out by the so called "amplitude measurements".
The time of one measurement corresponds with the peak of the amplitude of the bottom echo and the direction corresponds with the position of the transducer-element, where this echo is measured, as illustrated in Annex 2.
The use of multiple beams enables wider swaths to be covered, but, as interferometres in the centre beams are unsuccessfull, it is the only mean to measure under the survey vessel (angles of phase differences are there to small to be measured).
Because the outer receive beams spread more than the inner ones, they have a lower resolution.
The last statement is the reason why the EM-950 or the EM-1000 of SIMRAD uses primarily multi-beam for the inner beams and the principle of phase-measurements for the outer beams.
The Bathyscan does NOT uses multibeam at all; the drawback is that no measurements are available under the survey vessel...
A comparison between BATHYSCAN and EM 950 is given in Table 1.

The EM 950 ON BOARD THE MS " TER STREEP"

As a result of a tender, the EM 950 has been chosen for the hydrographic survey vessel "Ter Streep" (Annex 3) with a *hull-mounted* solution (Annex 4).
The *main system specifications* are given in the Annex 5.
The Annex 6 shows the System Configuration with the **System Units**
(1) The **main system units** of the EM 950 are:
-Transducer array
-Transceiver
-Bottom Detector Unit
-Operator Unit with colour display

The last 3 Units are hold in a *Electronics Cabinet*.
The *Transducer array* is formed as a 160° segment of a cylinder, with a radius of 45 cm and a length of 47 cm.
The *Transceiver* contains power amplifiers, preamplifiers, digital signal processors, interfaces and control processor.
The signals processors are used for:
-beamforming
-frequency filtering
-roll compensation
-determination of amplitude and phase in each beam
-transmission of data to the Bottom Detector Unit.
The *Bottom Detection Unit* controls the tranceiver circuitry in the Electronics Cabinet and sets all the system parameters.
The *Operator Unit with colour display* runs the operator interface via a 14" colour graphic monitor with integrated joystick and connects the EM 950 to all external units.

(2) The so called **system options** of the EM 950 are:
(a) Real time processing:
Data are transferred by Ethernet to a SUN workstation, running a Unix operating system.
Two systems are running on this workstation:
-*MERMAID* or data recording software: loggs all echo sounder data in a digital form for archiving and postprocessing
-*MERLIN*: visualisation software, ,available from the end of 1993, provides 2-dimensional and 3-dimensional real time presentations of both bathymetric data and sonar image data.
(b) Postprocessing:
Normally bathymetric data processing is handled by the NEPTUNE II software system of SIMRAD, but, as our office already used CARIS for the electronic charting, it looked for us more handy to use *CARIS HIPS* (Hydrographic Information Processing System):
Some Product Information about HIPS is provided in Annex 7.
HIPS is a powerful software system, which has been designed specially to process very large quantities of sounding data, especially swath systems. This system is generic - that is, it can be supplied to any swath sounding system.
HIPS is comprised of 2 major components:
(i) The Hydrographic Data Cleaning Software (HDTC): retrieves previously logged survey data and processes further the data globally: that means its corrects for blunders, tides, draught, sound velocity, heave, roll, pitch, etc., so that the corrected data are clean;
(ii) The cleaned soundings are then processed and displayed via the Data Visualisation software.

(3) The **external units** are:
-*Sound velocity profiling probe*
-*Positioning system DGPS* of Aquanav
-Ship's course *Gyro*
-*Vertical Reference Unit Hippy 150 with an analog B-filter*, providing the heave, roll and pitch measurements.
As the last Unit is installed in the middle of the survey vessel, the horizontal offset (15,11 m) and pitch's angle is needed for a further compensation of the heave measurements.

Ship's roll is compensated by the outer 4 transducers by switching on or off transducers, as a function of the roll angle; full compensation for roll is thus possible to a maximum roll of +/- 5 degrees.

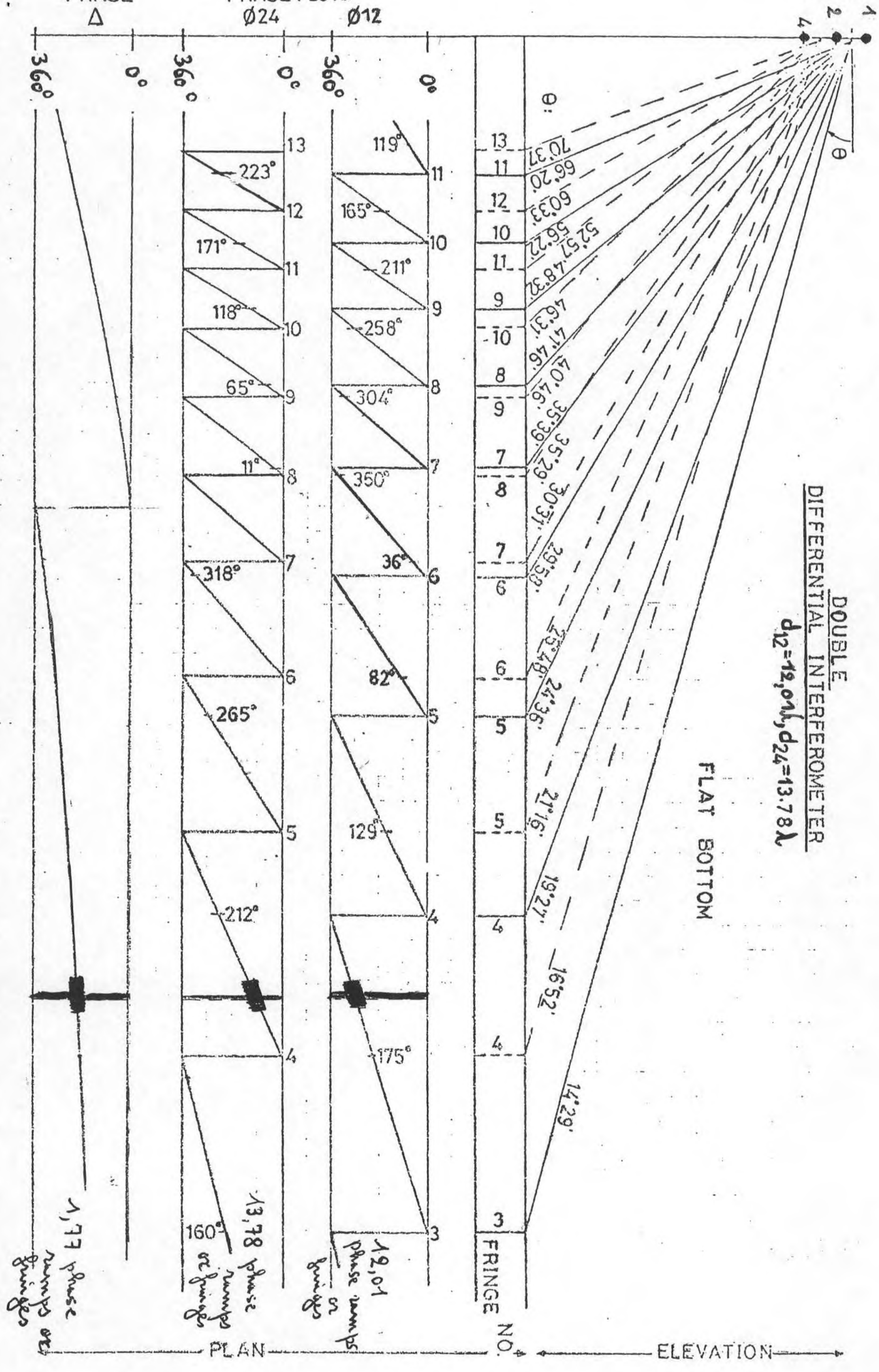
Performances of the EM 950 so far

After the elimination of the classical "child diseases", the system is now subject to a thorough quality control. Meanwhile the system also has been used in areas with complicated features, such as sandwaves on the Flemish sand banks.

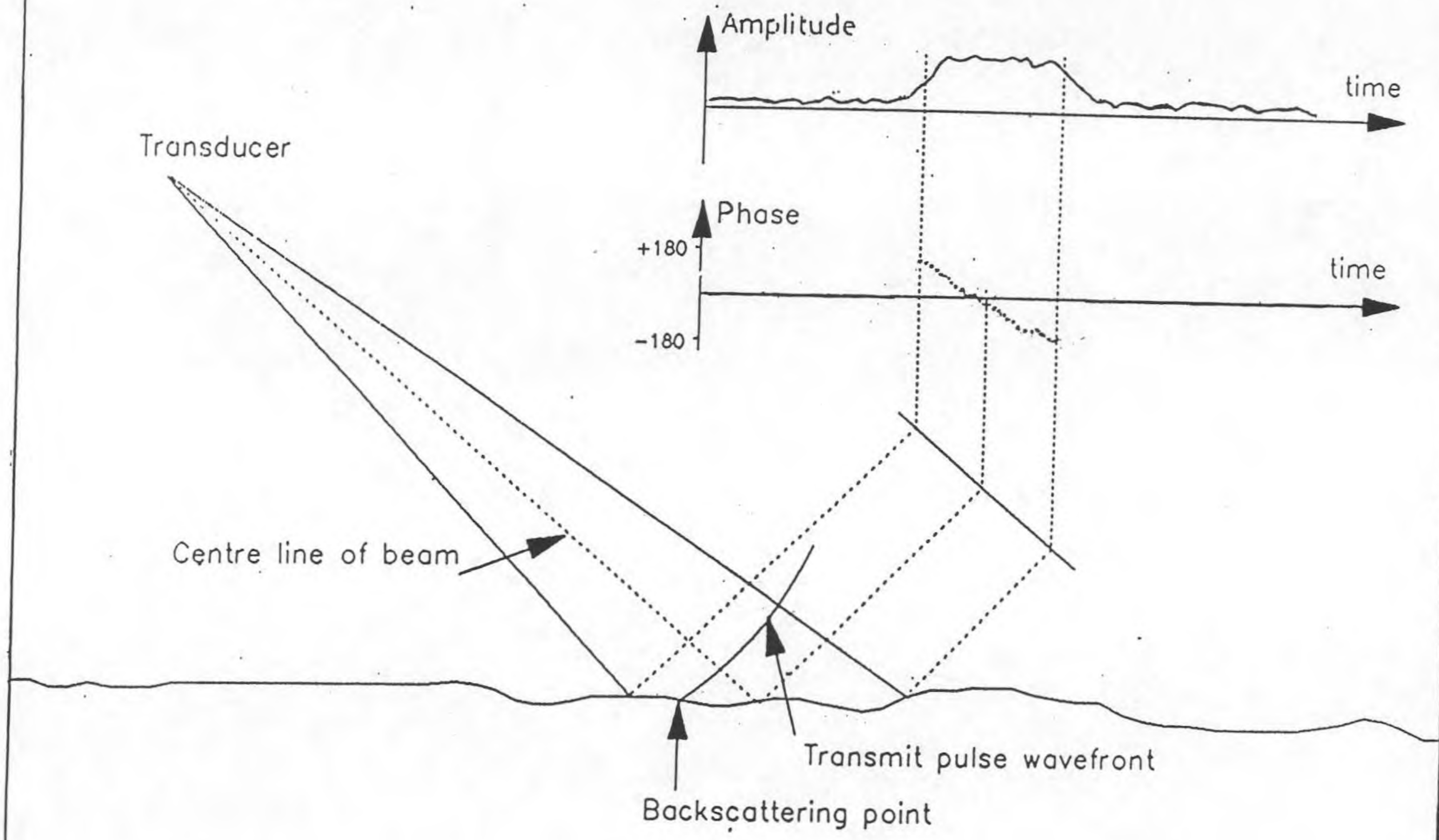
Ostend, 13 October 1995

Ing.C.Van Cauwenberghe.

Annex 1



PHASE
Δ
PHASE PLOTS
Ø24
Ø12
360°
0°
FRINGE NO.
PLAN
ELEVATION
θ
DOUBLE
DIFFERENTIAL INTERFEROMETER
d12=12,01λ, d24=13.78λ
FLAT BOTTOM
1,77 phase ramps or fringes
13,78 phase ramps or fringes
12,01 phase ramps or fringes



Interferometric Signal Processing

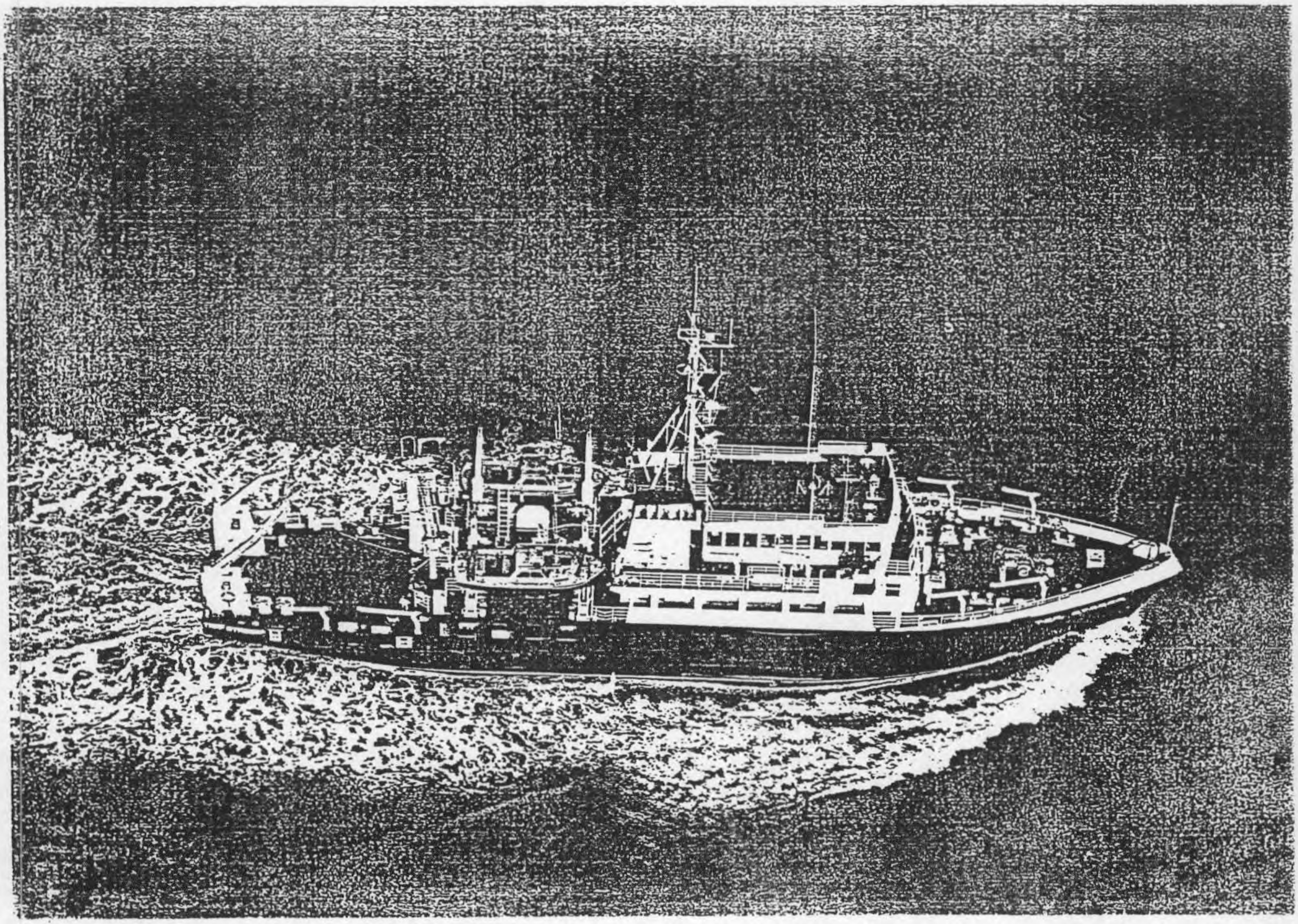
Same accuracy across the swath

Ministerie van de Vlaamse Gemeenschap
Departement Leefmilieu en Infrastructuur
Administratie Waterinfrastructuur en Zeewezen
Dienst de Kusthavens - Hydrografie
8400 - OOSTENDE

Annex 3

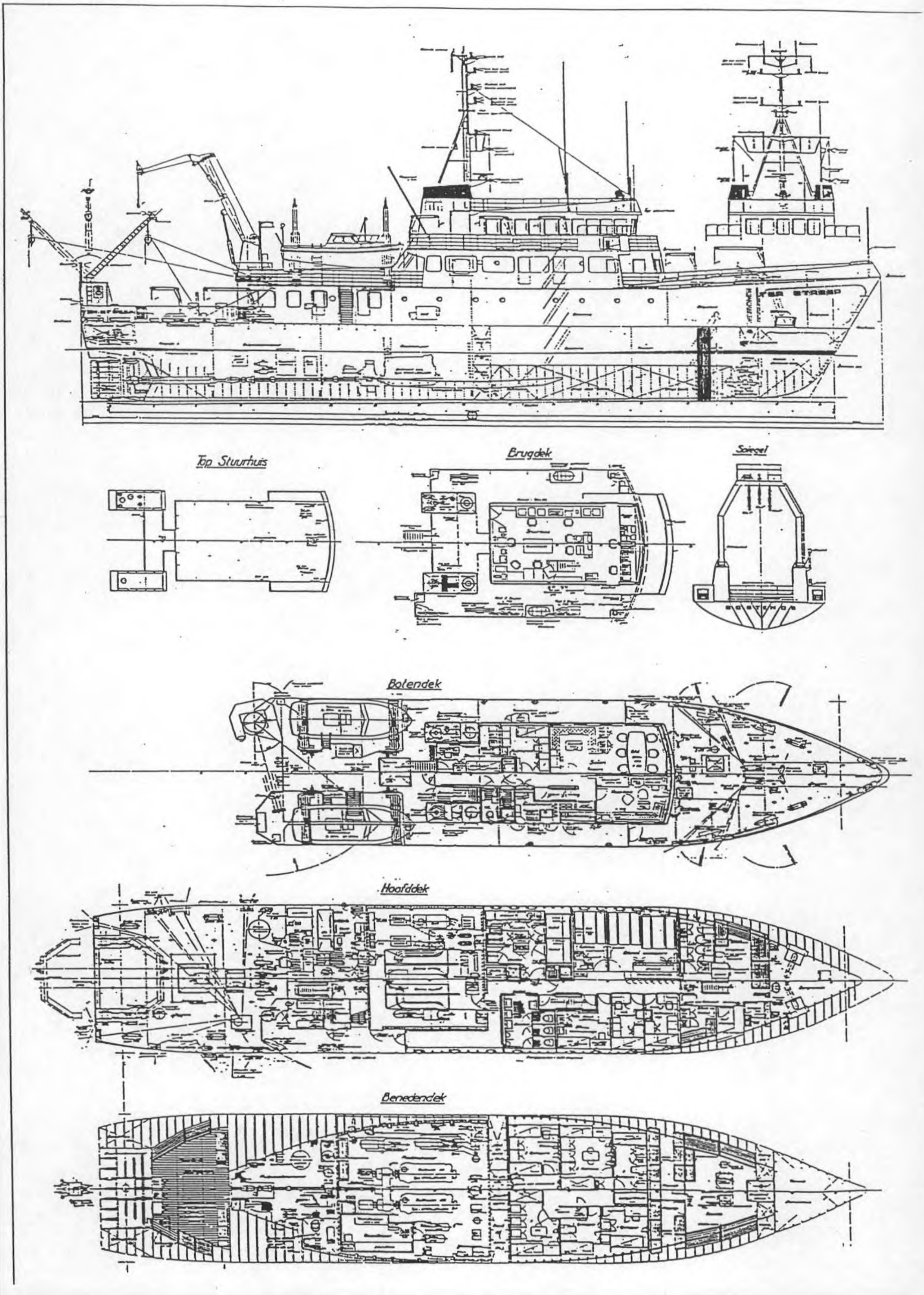
MS TER STREEP

Hydrographic survey vessel for the Belgian conshelf



Main dimensions and characteristics

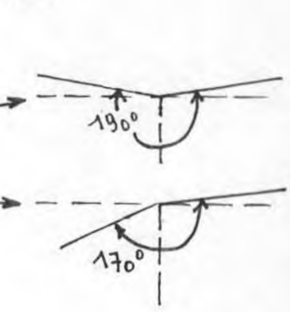
Length overall	49.550 m
Length P.P.	44.900 m
Moulded breadth	9.600 m
Moulded depth	4.800 m
Draught at underside keel	3.250 m
Displacement	647 m³
Gross tonnage	643 GRT
Net register tonnage	193 NRT


Top Stuurhuis
Brugdek
Spiegel
Botendek
Hoofddek
Benedendek

Simrad EM 950 Multibeam Echo Sounder System

Main system specifications:

Transducer:	Size:	400 x 900 mm
	Weight:	130/95 kg (in air/water)
	Shape:	Cylinder segment
	Number of staves:	128
Transmission:	Number of transmitters:	128
	Total peak power:	4.5 kW
	Frequency:	95 kHz
	Pulse length:	0.2 msec
	Source level:	225 dB
	Max. ping rate:	4 pulses/second
Reception:	Number of amplifiers:	128
	TVG:	Digitally controlled
	A/D conversion:	12-bit quadrature sampling
	Range resolution:	15 cm
	Depth resolution:	2 cm
Beamforming:	Equidistant and equiangle spacing of soundings	
	Number of soundings:	120 over 2 pings
	Angular displacement: 1°,25	
	Normal operation:	EDBS-mode (Equal Distance Beam Spacing) / Shallow mode
Horizontal	Sounding spacing:	6.3%*, 4.6%, 3.4% or 1.3% of depth or 1.25°
	Sector covered:	150°, 140°, 128° or 75° (e.g. 120 * 1°,25 = 150°)
	Max. swath width:	7.4 x depth d; 5,5 x d; 4,1 x d
	Water depth:	3 - 300 m, 100-250m., 150-300m (from transducer)
	Embankment modes:	
	Channel	±95° (total coverage:190°)
	Port bank	-75° to +95° (idem:170°)
	Starboard bank	-95° to +75° (idem: 170°)
	Water depth	0 - 100 m



* e.g. for d= 10m is the horizontal sounding spacing:

$$\frac{7{,}4 \times 10 \text{ (max.swath width)}}{120 \text{ (number of beams)}} = 0{,}62\text{m or } \pm 6{,}3\ \%\text{ of d}$$

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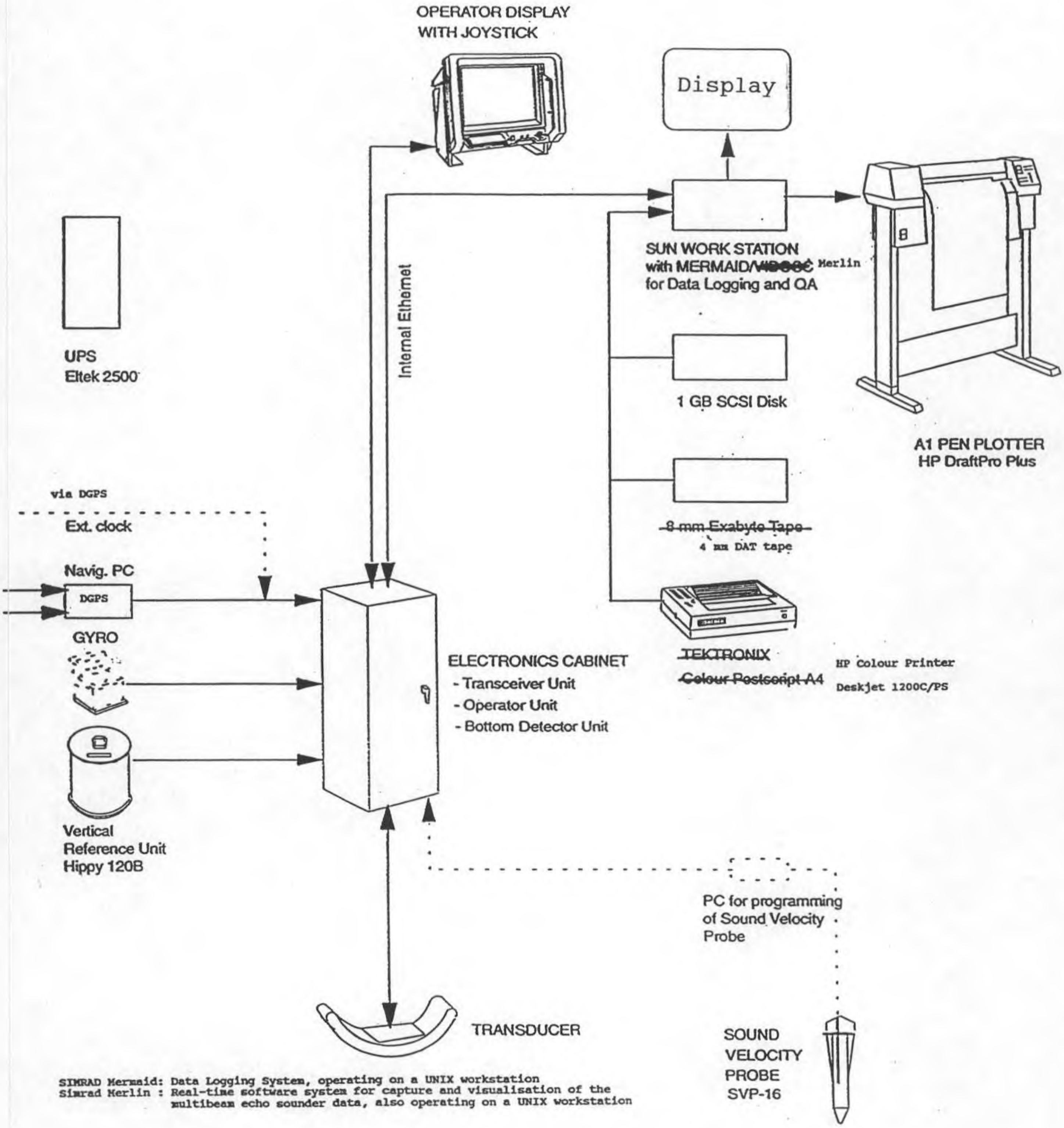
Annex 6

EM 950 MULTIBEAM ECHOSOUNDER

System Configuration

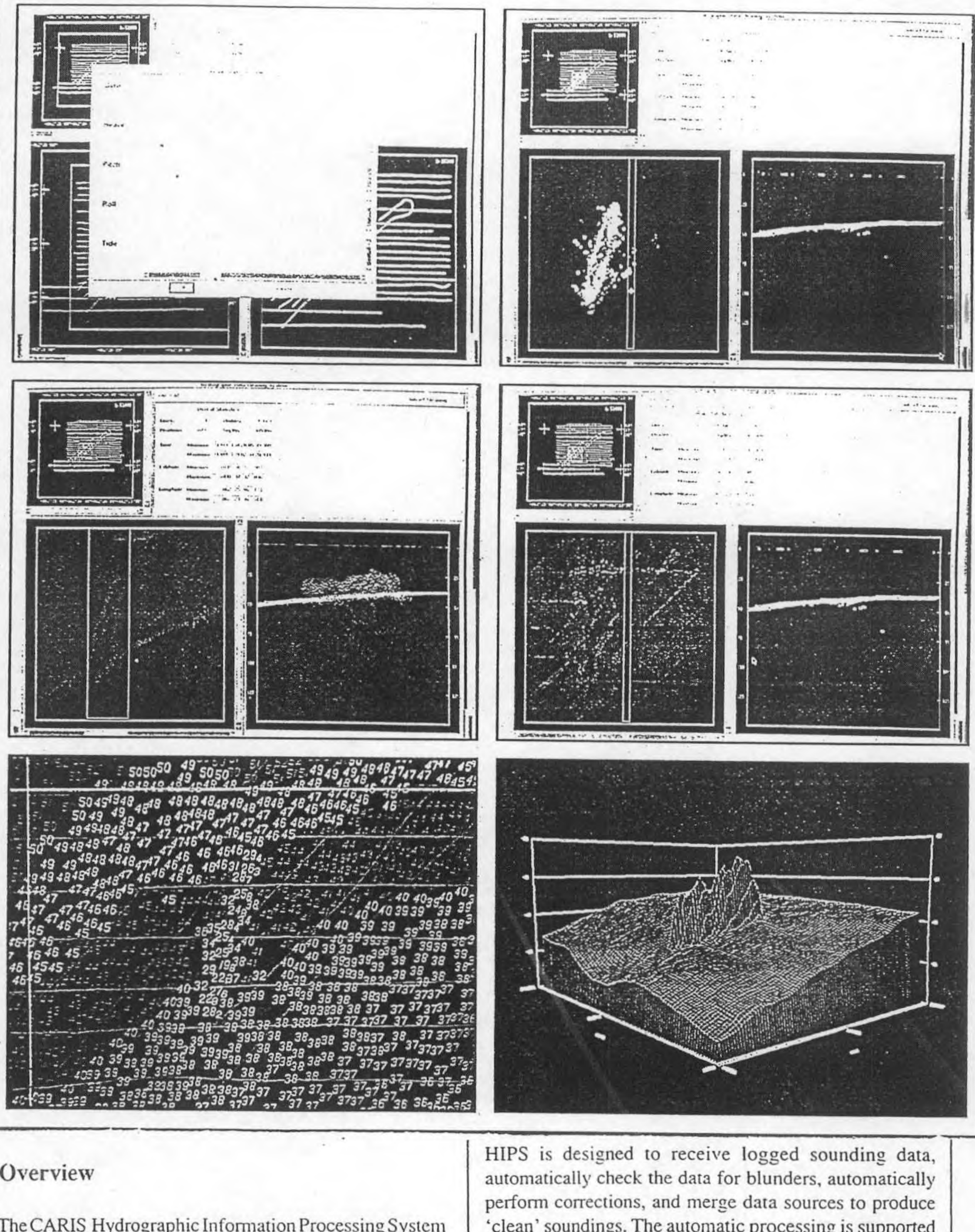


SIMRAD Mermaid: Data Logging System, operating on a UNIX workstation
Simrad Merlin : Real-time software system for capture and visualisation of the multibeam echo sounder data, also operating on a UNIX workstation

CARIS™ HIPS

Hydrographic Information Processing System

Product Information



Overview

The CARIS Hydrographic Information Processing System (HIPS) is a powerful software system which has been designed specifically to process the very large quantities of sounding data now being collected by echosounders, especially swath systems. The system is generic - that is, it can be applied to any swath sounding system.

HIPS is designed to receive logged sounding data, automatically check the data for blunders, automatically perform corrections, and merge data sources to produce 'clean' soundings. The automatic processing is supported by powerful, user-friendly interactive editors, developed specifically for swath data editing. Upon cleaning, field sheets can be prepared and plotted using a wide range of hydrographic processing software. The cleaned data is available for further input into, for example, hydrographic databases.

HIPS is comprised of 2 major components:
(1)The Hydrographic Data Cleaning Software(HDCS):retrieves previously logged survey data and processes further the data globally (i.e.corrects for blunders, tides, draught, sound velocity, heave, roll, etc.) so that the collected data are "clean".
(2)The cleaned soundings are then processed and displayed via the Data Visualisation software.

COMPARISON OF 2 SWATH SOUNDING SYSTEMS

	BATHYSCAN	**EM 950**
Frequency in kHz	300 (100 also possible)	95
Wavelength in metres	0,005 m	0,0167 m
Number of transducers	1 transmitter & 4 receivers in one	128 elements (120 used) in one
Pulse duration	0,2 msec	0,2 msec
Sampling rate	1024 data per 0",2048(=1024 X 0,2 msec); filtering with moving averages to 256 data	Honeycombe structure: 4 X 60 = 240 data per 1"
Distance measurement	Principle of SSS; increments of 15 cm; for, 1500 x 0,2 / 1000 = 0,30 M = 2 x 0,15 m	Triggering of 60 transducers simultaneously
Angle measurement	Interferometric principle of R.Cloet with 3 or 4 receivers (see Annex 1 with 3 receivers)	SIMRAD Interferometric principle for the outer beams. Multibeam principle/amplitude measurement for the inner beams
Vertical angular displacement	0°,2	1°,25 X 2=2°50
Vertical angular coverage	2 x 60° = 120°	Normally EDBS: 2°,5*60=150° Other modes are also possible: Shallow and Embankment
Horizontal beam angle	1°,0	3°,0
Mean swathe depth	8 x depth	7,4 X depth
Water depth	5-70 m	3-300 m for 150°
Advantage	High resolution	Data available everywhere

Table 1

Het gebruik van de SIMRAD EM950 aan boord van ms. Ter Streep

Hydrographic Society
Multibeam Echosounder Technology
13 oktober 1995

ing Carlos Van Cauwenberghe
Hydrografische Dienst
Afdeling Waterwegen Kust

Dr. Jean Lanckneus
Marine Geological Assistance

AWK

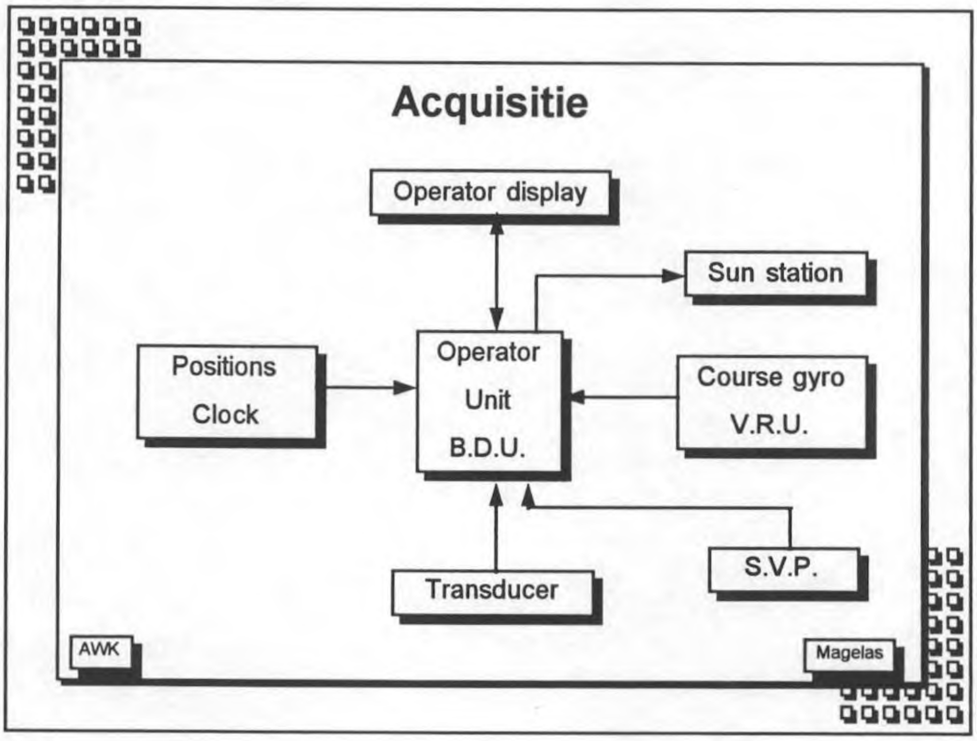
Magelas

Schema presentatie

- Acquisitie (problemen)
- Verwerking
  - Nodige hardware
  - Keuze software
  - Praktische verwerking van data
  - Duur van verwerking

AWK

Magelas

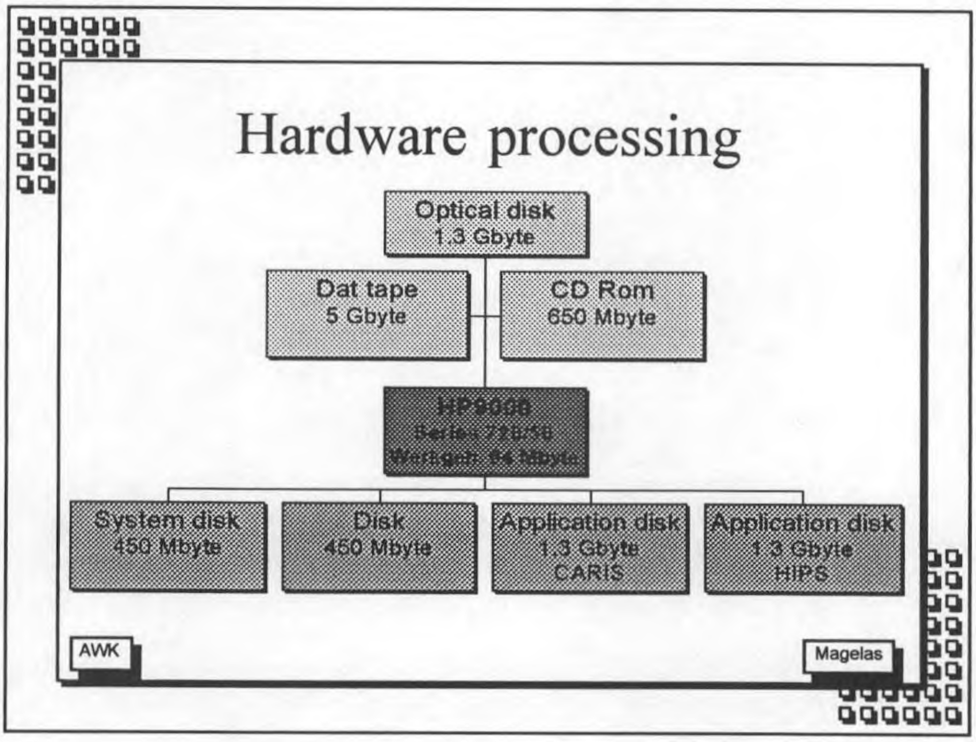

Acquisitie
Operator display
Sun station
Positions
Clock
Operator
Unit
B.D.U.
Course gyro
V.R.U.
S.V.P.
Transducer
AWK
Magelas

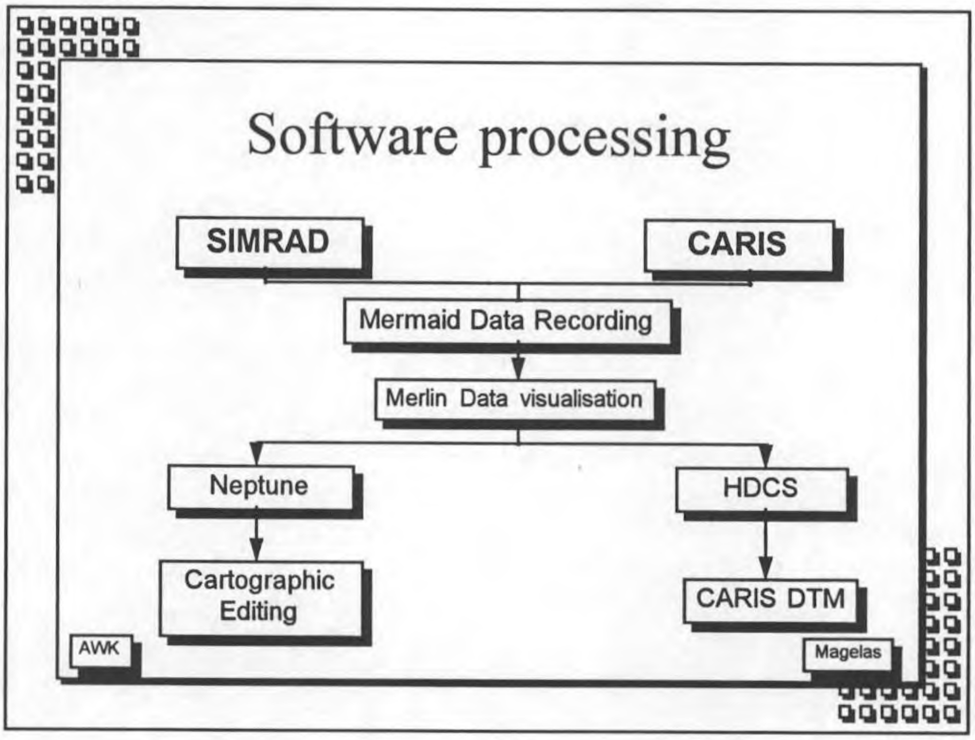
Problemen bij acquisitie

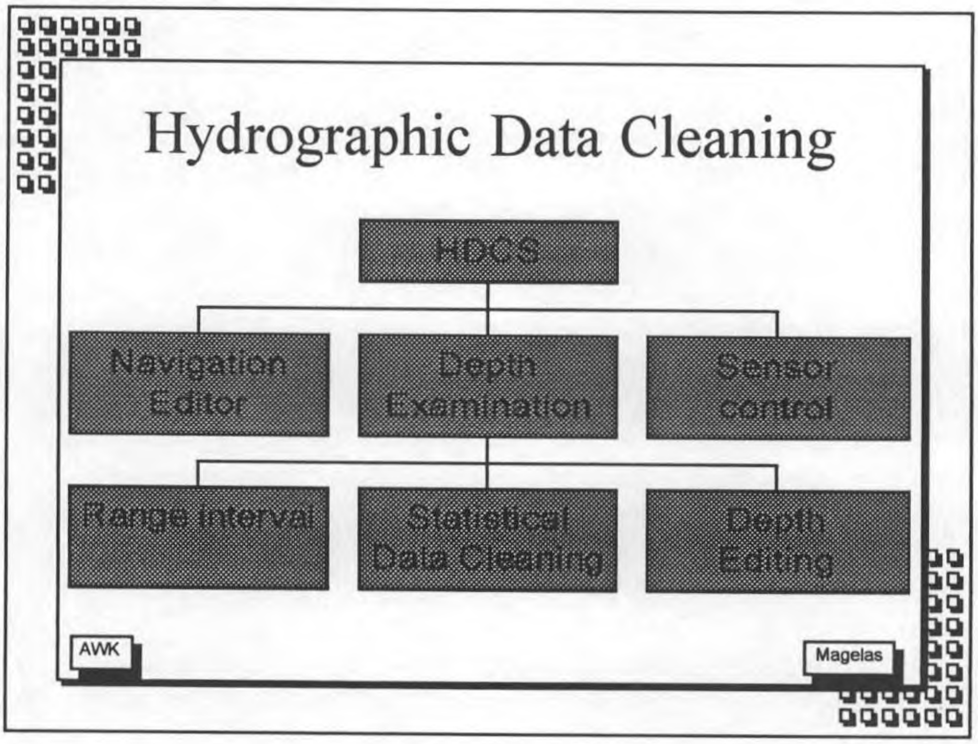
- External time tag
  - » Software aanpassing
- Sensoren (gyro kompas)
  - » Kalibratie
- Roll offset
  - » Software aanpassing

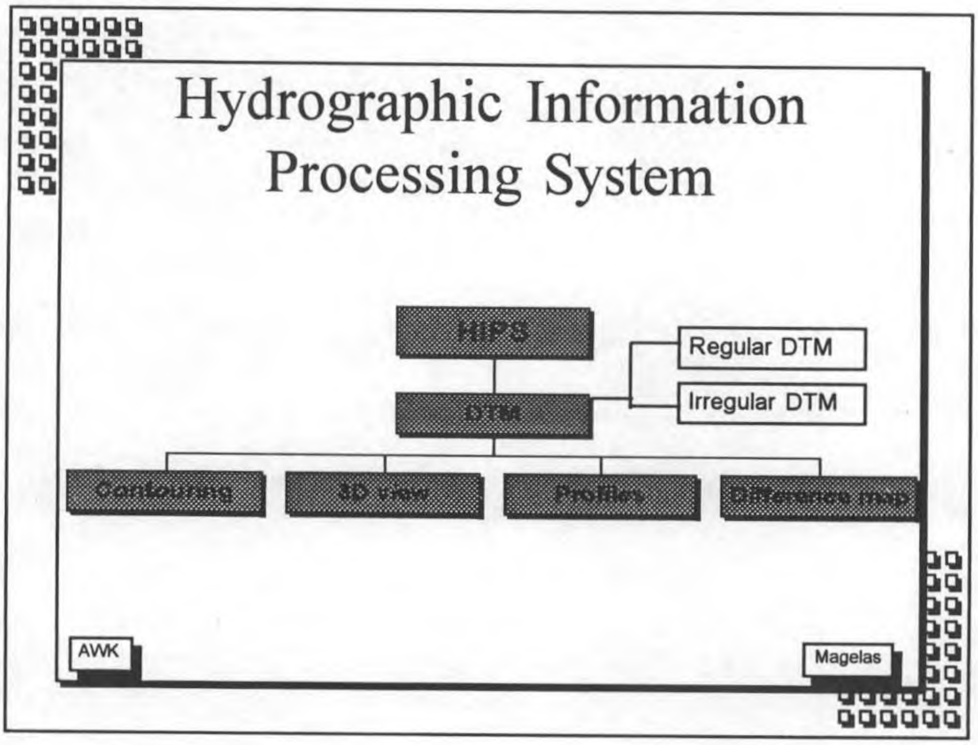
AWK

Magelas


Hardware processing
Optical disk
1.3 Gbyte
Dat tape
5 Gbyte
CD Rom
650 Mbyte
HP9000
System disk
450 Mbyte
Disk
450 Mbyte
Application disk
1.3 Gbyte
CARIS
Application disk
1.3 Gbyte
HIPS
AWK
Magelas

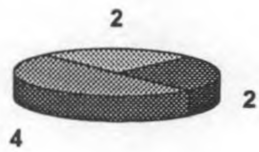

Software processing
SIMRAD
CARIS
Mermaid Data Recording
Merlin Data visualisation
Neptune
HDCS
Cartographic Editing
CARIS DTM
AWK
Magelas


Hydrographic Data Cleaning
HDCS
Navigation Editor
Depth Examination
Sensor control
Range interval
Statistical Data Cleaning
Depth Editing
AWK
Magelas


Hydrographic Information
Processing System
HIPS
DTM
Regular DTM
Irregular DTM
Contouring
3D view
Profiles
Difference map
AWK
Magelas

Duur van processing

- Voorbereiding: 2u
- HDCS: 4u
- HIPS: 2u



AWK

Magelas