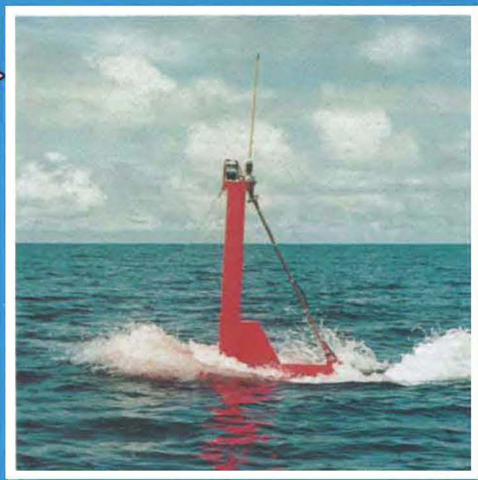
PRAKLA-SEISMOS INFORMATION No. 46

Streamer Positioning and Coverage Control



Introduction

Advanced 3-D marine surveys nowadays require a much higher degree of accuracy in streamer positioning than was possible until recently. Dense grids in conjunction with multi-line and strike line shooting make the tolerances allowable for the determination of streamer positions even more stringent.

In order to obtain all angles and distances with the required accuracy PRAKLA-SEISMOS has added new features to the existing measuring systems and the associated computer software. These efforts aim to **pinpoint each common reflection point to within ± 10 m.** The new techniques to resolve the difficulties involved were adopted after careful research into the problems of sensing angles and tensions, pertaining to the seismic streamer, as primary input parameters in deriving the streamer position.

The Precision Direction Finding System, developed by PRAKLA-SEISMOS, controls and adjusts the streamer compasses. Reference North is provided by a specially assembled multiple gyro system. An automated control system monitors all onboard events in realtime.

In the **post-processing stage,** a highly reliable motion model is established by cross-correlating multiple sequences of angle measurements, thereby taking **full advantage of the redundancy** in the data. This procedure improves the realtime data significantly.

Streamer Tracking System

General

The following hardware/software components are utilized in deriving streamer locations under the new scheme:

- **Gyro Compass System:** to reduce the error against true North to within ± 0.12 degree.
- **Two Independent Streamer Tracking Systems**

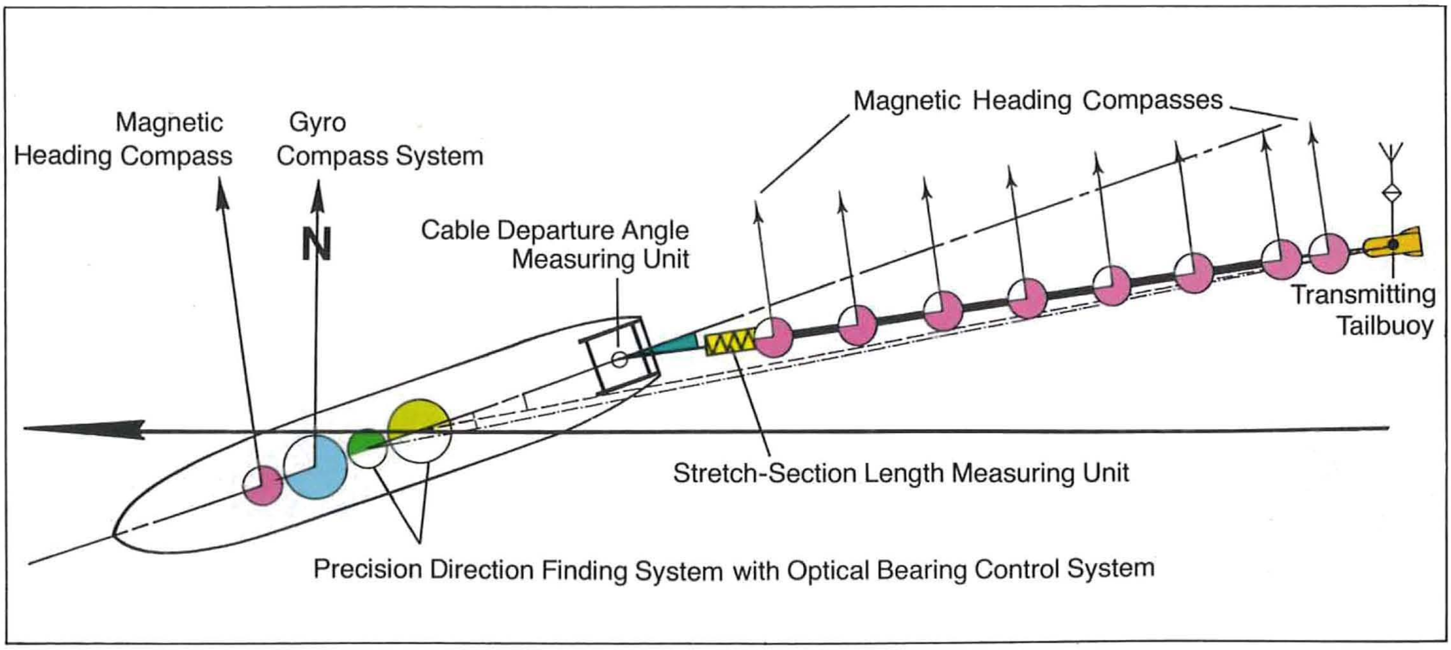
1. **Magnetic Heading Compasses:** arrayed along the streamer to record the subsurface direction of the streamer sections.
2. **Bearing Reference**

2.1: Precision Direction Finding System to determine the tail end of the streamer to within ± 0.2 degree.

2.2: Manual Direction Finders to determine the residual installation errors of the gyro system and to calibrate and check the Precision Direction Finding System.

- **Cable Departure Angle Measuring Unit:** to record the horizontal angle between the vessel's axis and the towing cable of the streamer to within ± 0.2 degree.
- **Stretch Section Length Measuring Unit:** to record the actual distance between the towing cable and the first hydrophone group to within ± 1.0 metre.
- **Realtime Processing and Quality Control:** to provide a quick reference of headings, positions and coverage on monitors, hardcopies and plotter.

Fig. 1: Presentation of Hardware Components

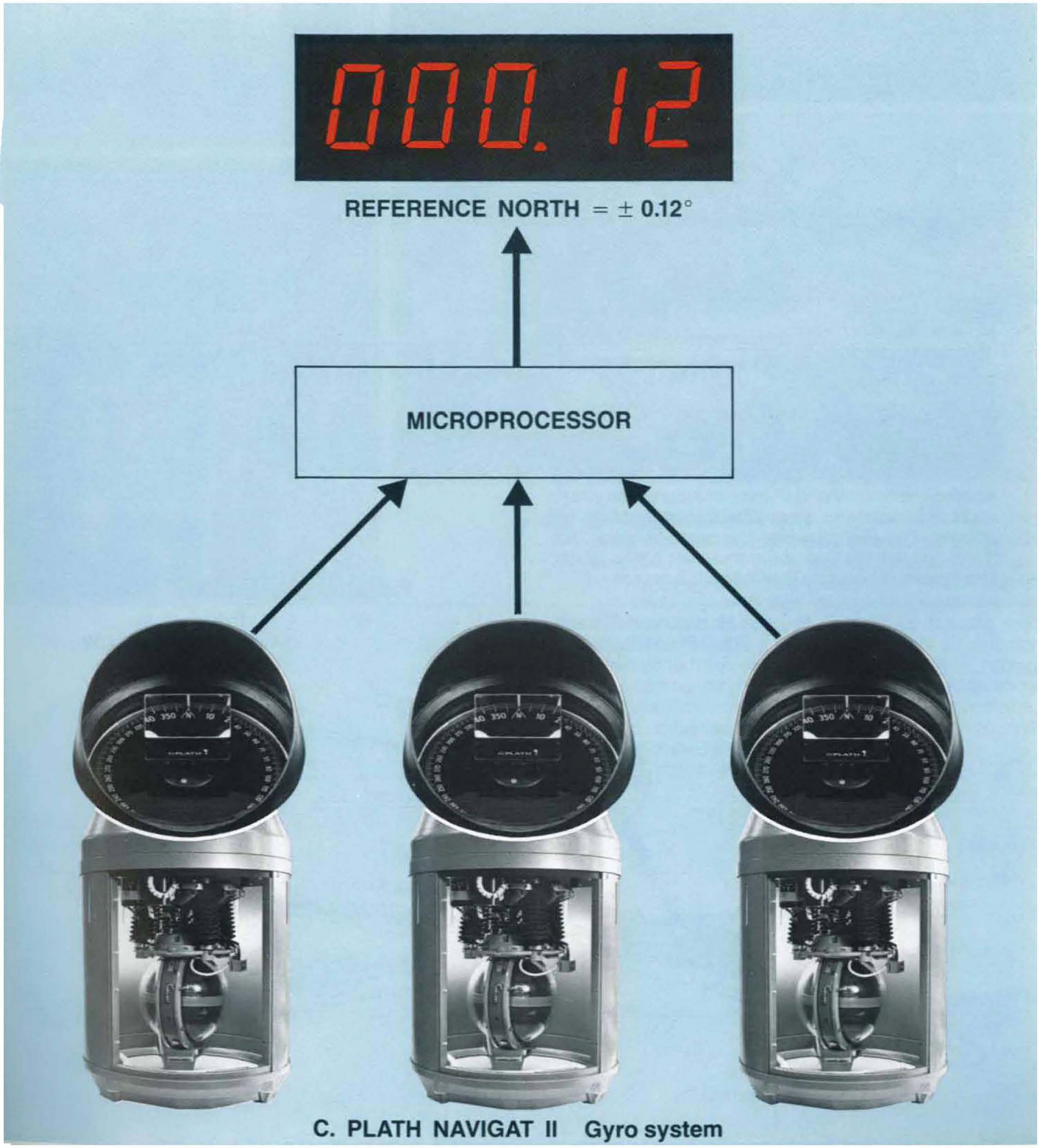


Description of Components:

Gyro Compass System

The gyro system is the master instrument which provides the reference North for all bearing measurements conducted from the survey vessel. The optimization of the reference North is achived by integrating a multiple set of gyro compasses specially designed and manufactured for PRAKLA-SEISMOS by C. PLATH. A microprocessor checks the plausibility of the individual gyro readings and computes an improved true North to within ± 0.12 degree.

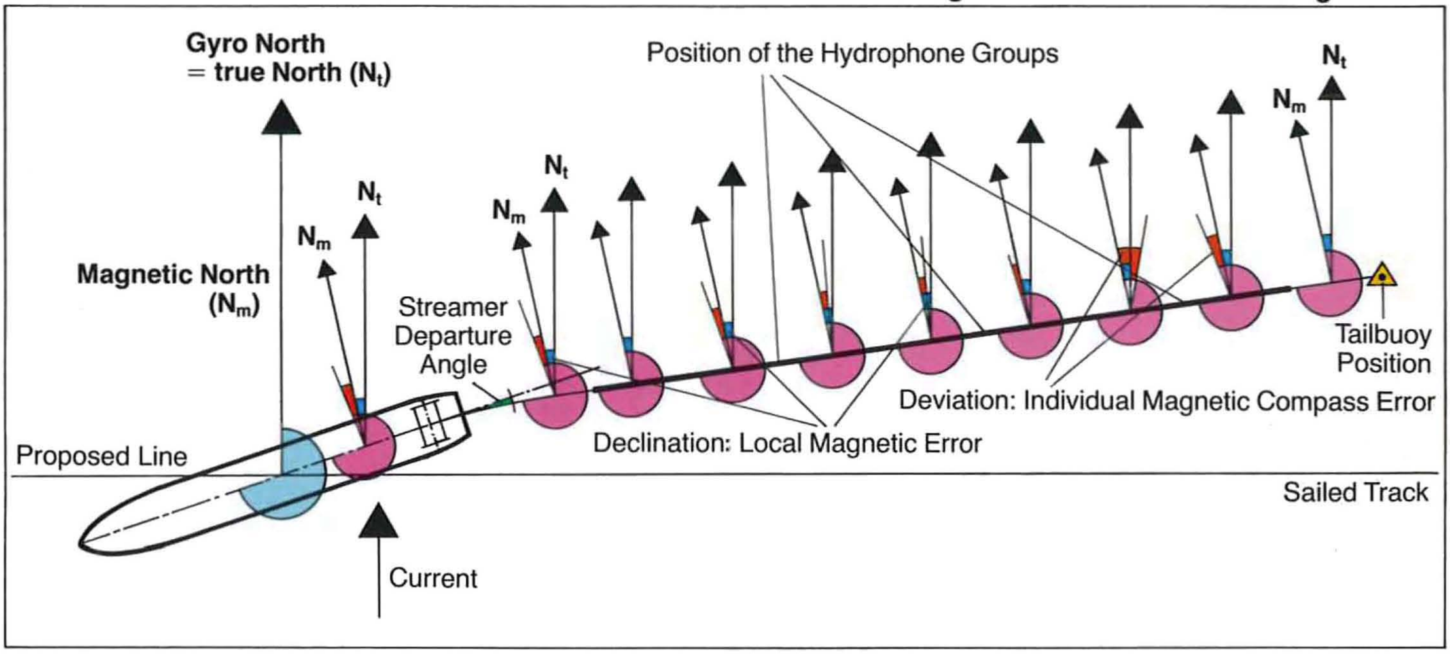
Fig. 2: Improved Reference North



Two Independent Streamer Tracking Systems:

1. **Magnetic Heading Compasses:** the relative positions of the streamer are derived from the angle indications of miniature magnetic compasses arrayed along the streamer at set intervals. The compasses used are manufactured by SYNTRON.

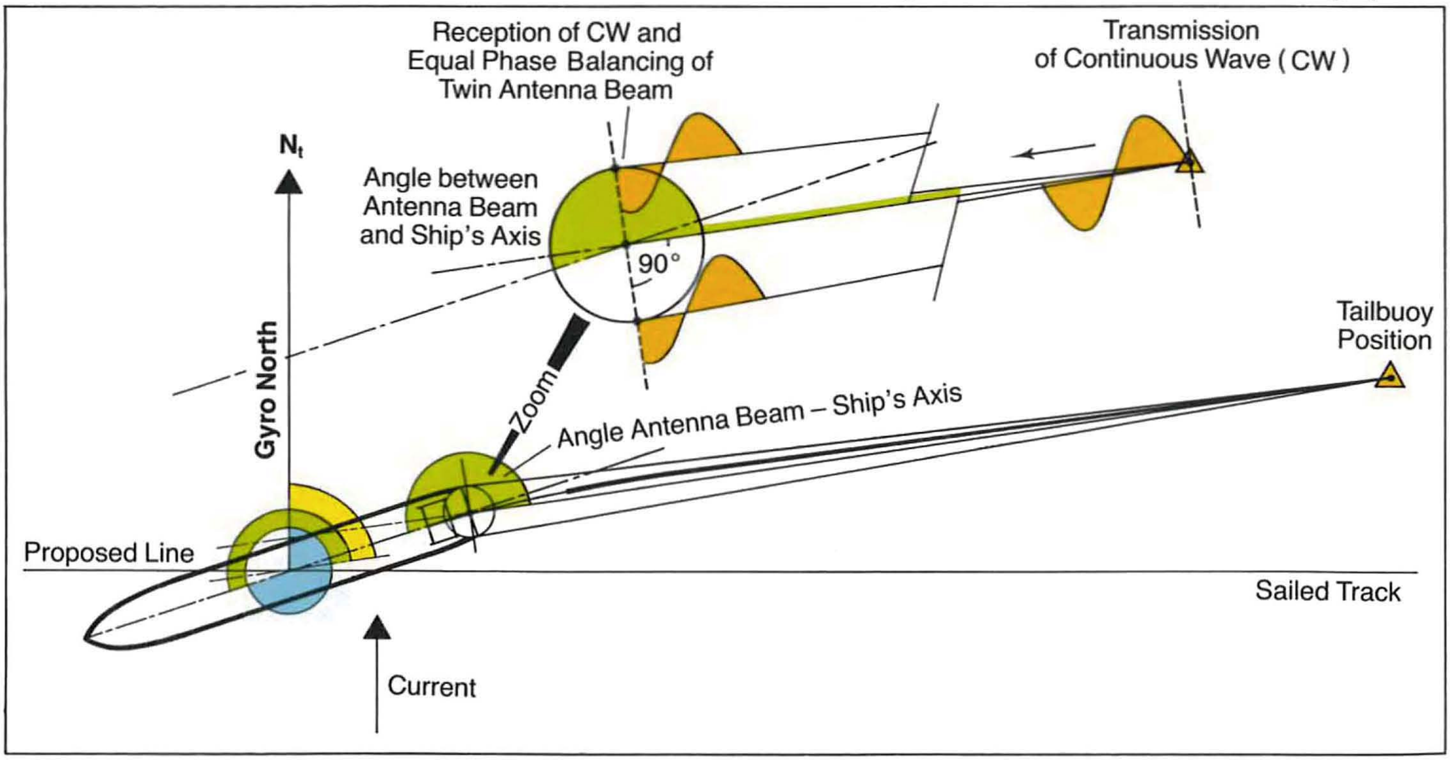
Fig. 3: Streamer with Heading Sensors

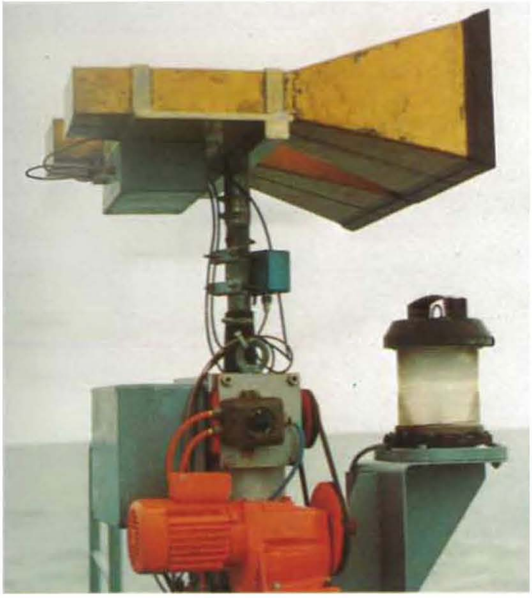


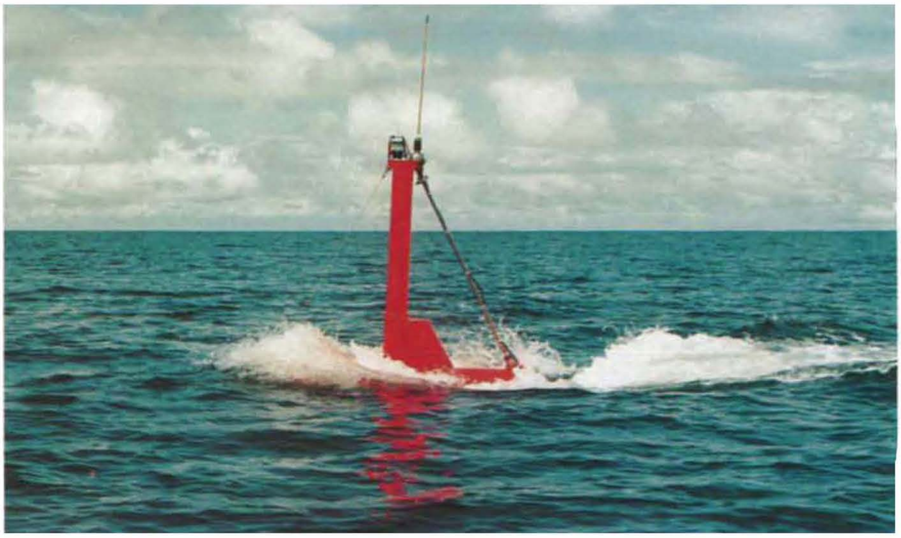
2. **Bearing Reference**

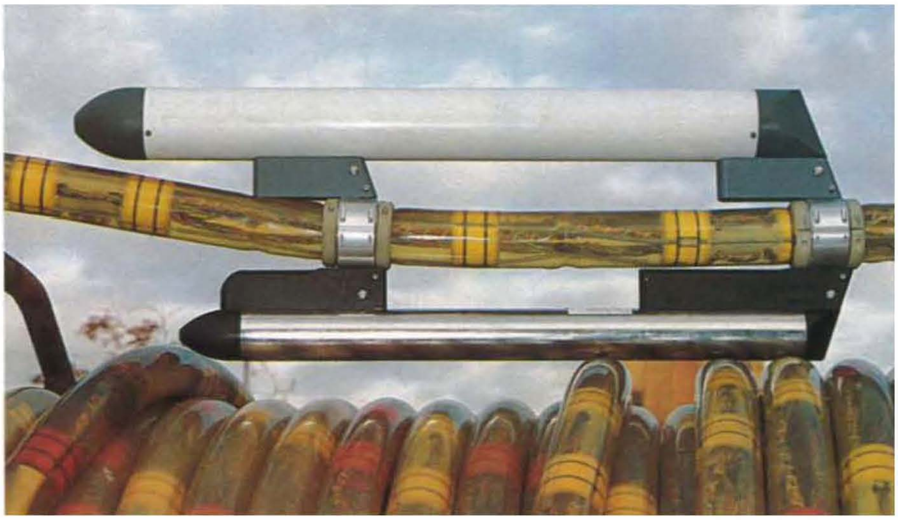
2.1. **Precision Direction Finding System (PDF)**
The PRAKLA-SEISMOS Precision Direction Finder which operates in the VHF band compares the phase angle of a continuous wave (CW) transmitted from the tailbuoy. The PDF provides the angle between true North and the tail end of the streamer continuously. The system is accurate to within ± 0.2 degree.

Fig. 4: Precision Direction Finding System





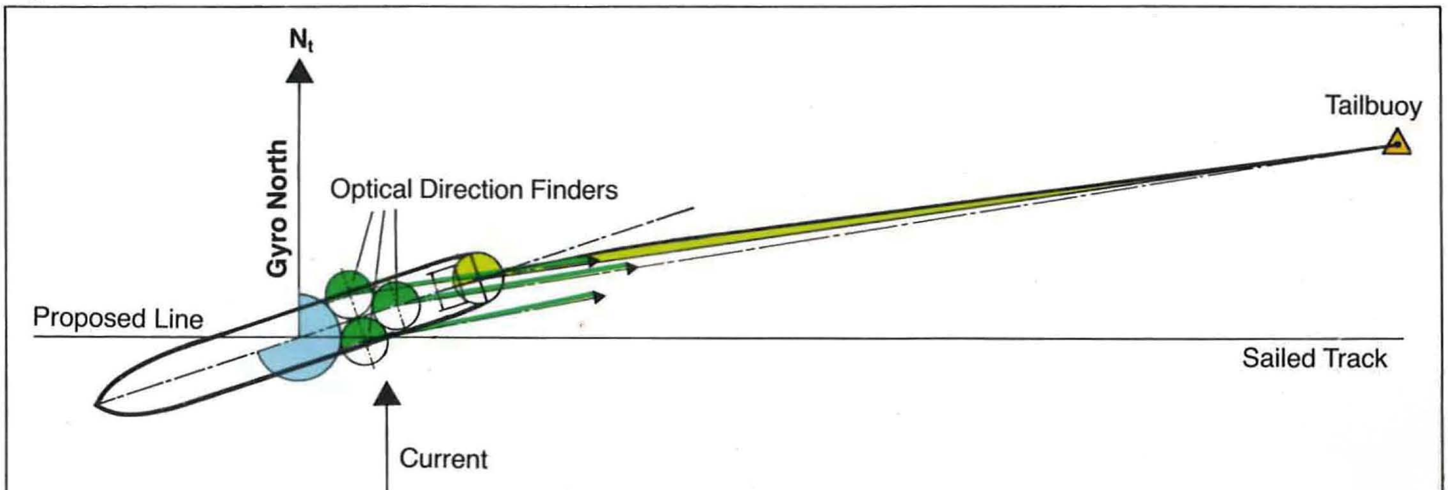




2.2. Manual Direction Finders

Three Manual Direction Finders serve as the function control for the PDF. They are installed such that uninterrupted sighting of the tailbuoy may be maintained at all times. A push-button release mechanism permits instantaneous freezing of the tailbuoy bearing with respect to the ship's axis. The navigation computer derives the north orientation automatically by adding the ship's heading to this measurement. The statistical average of a set of observations, computed in realtime, provides the adjusted bearings for calibration and control of the PDF.

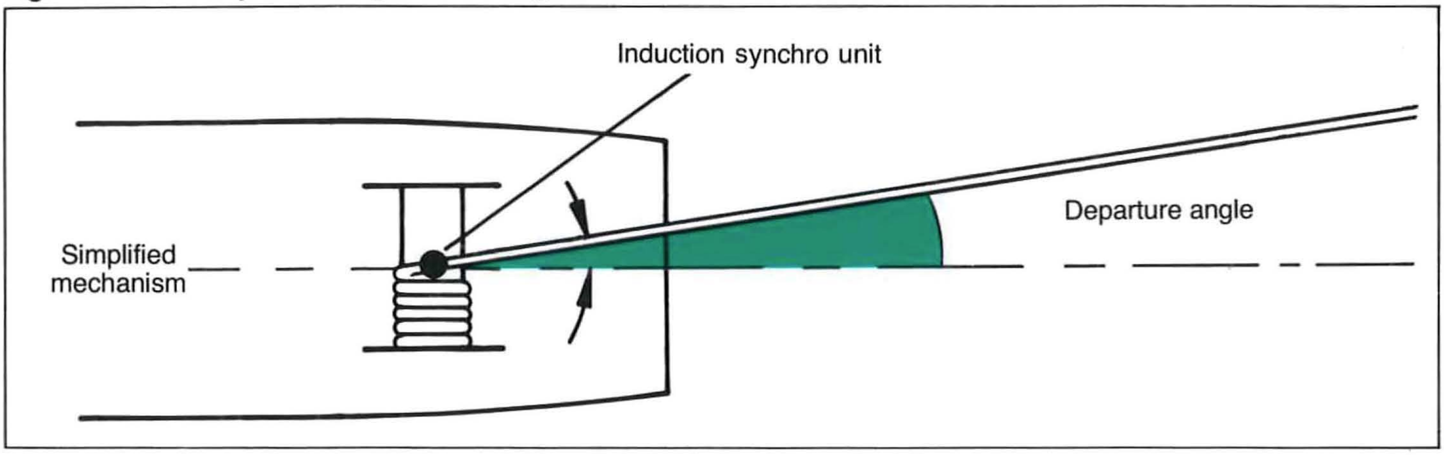
Fig. 5: Manual Direction Finders



Cable Departure Angle Measuring Unit

The deflection angle between the ship's axis and the towing cable is continuously recorded to determine the ship/streamer lateral offset. The device consists of universal joints, flexible shafts and synchro units. Angles are recorded to within ± 0.2 degree.

Fig. 6: Cable Departure Angle Measuring Unit



Stretch Section Length Measuring Unit

Variations in streamer stretch section length are sensed by a sounding system developed by HONEYWELL ELAC. It records the required data to within ± 1.0 m.

Fig. 7: Stretch Section Length Measuring Unit

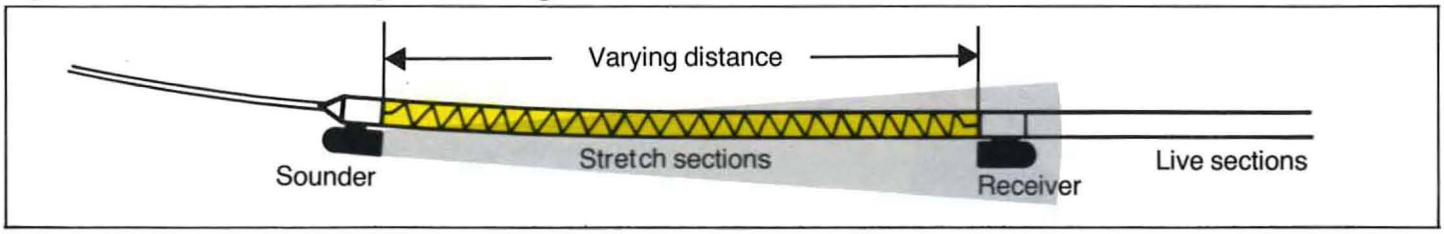
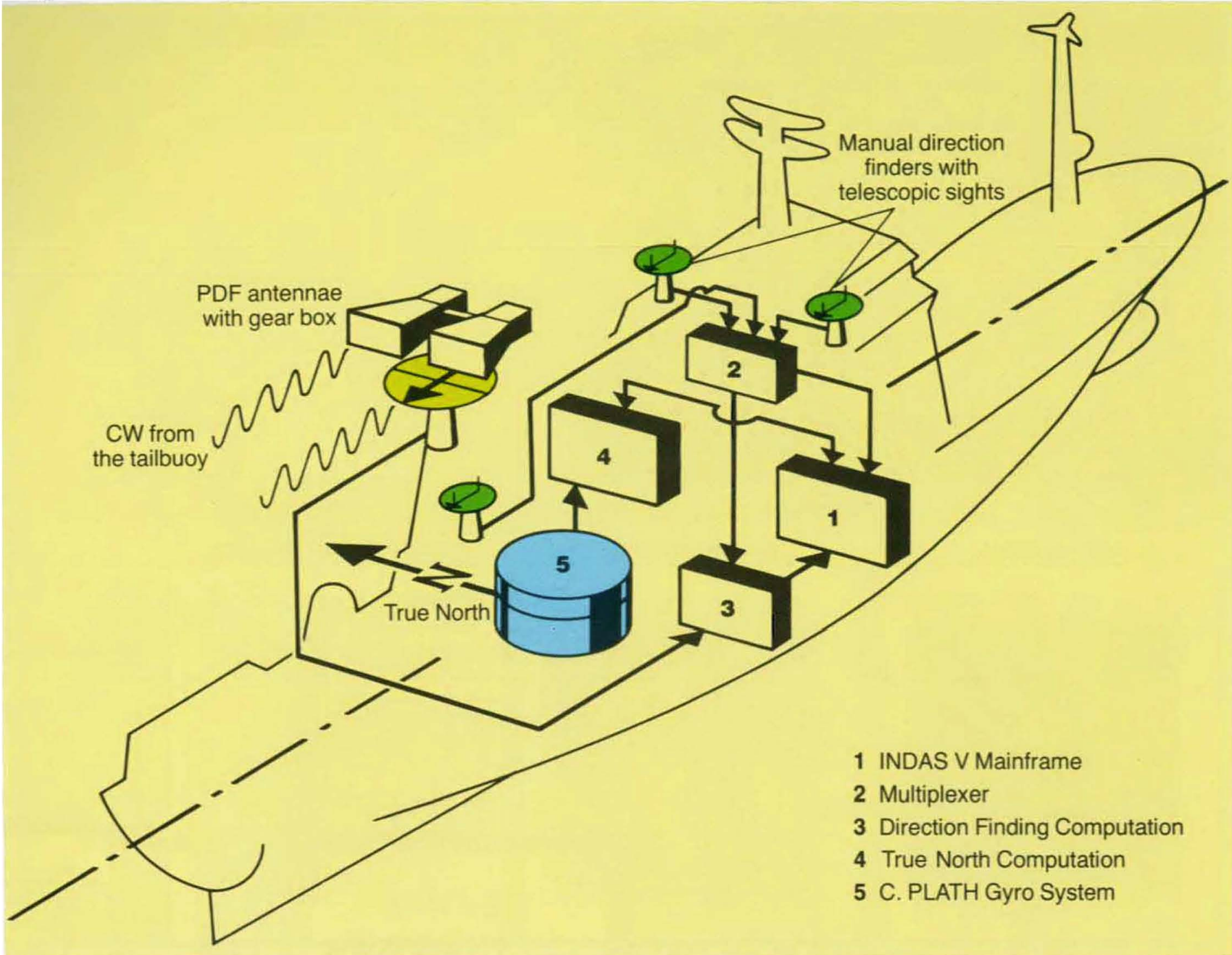


Fig. 8: Block Diagram of the PDF System with Manual Direction Finders and Hardware Components



Realtime Processing and 3-D Quality Control

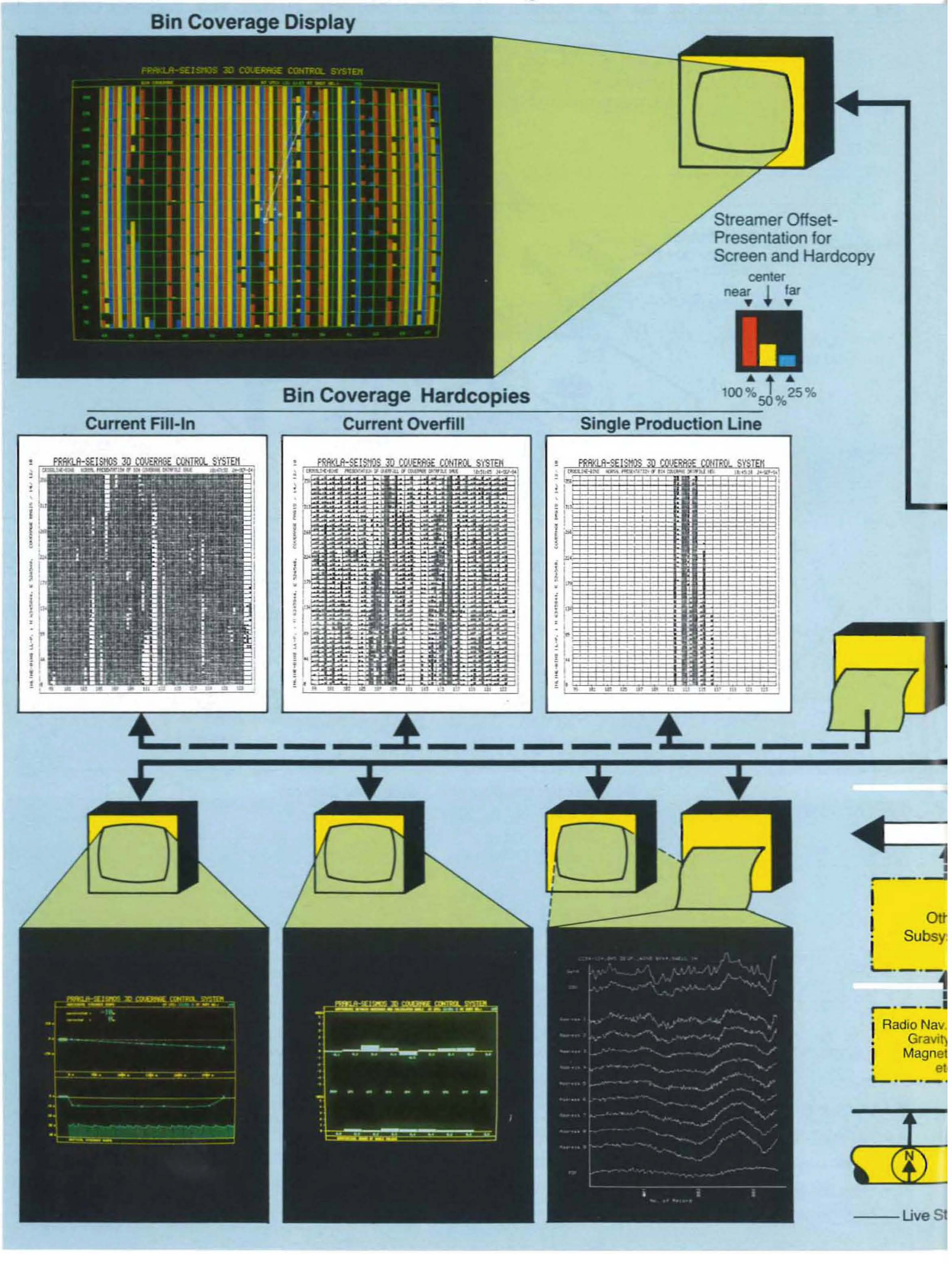
Streamer tracking data are controlled and processed in realtime to attain optimized and reliable coverage. These tasks are performed with the streamer- and 3-D subsystems of the **I**ntegrated **N**avigation and **D**ata **A**cquisition **S**ystem INDAS V (see block diagram on the next page).

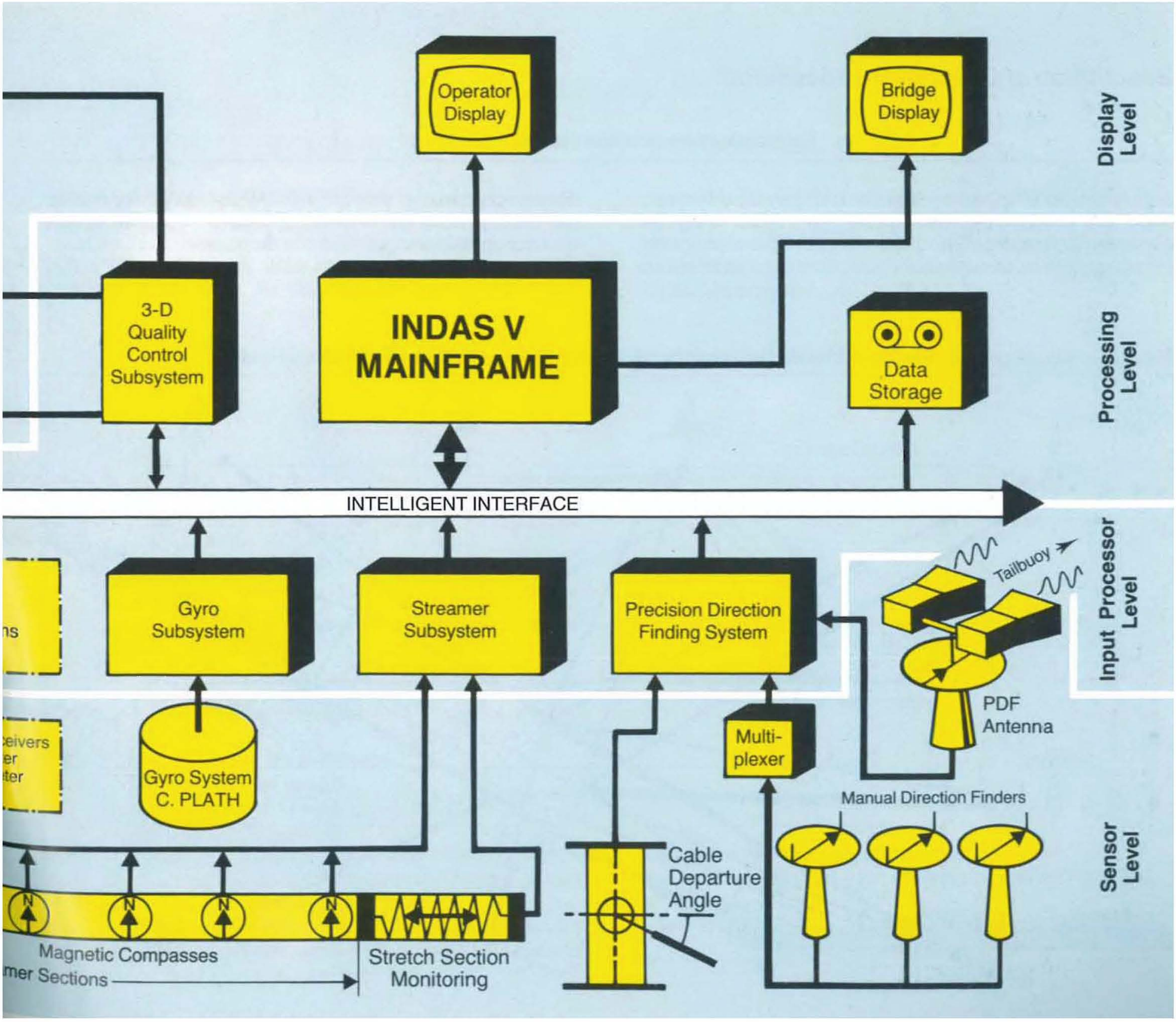
- The advanced streamer shape calculation technique with polynomial regression and weighted polynom closure to the independent PDF tailbuoy reference provides highly accurate streamer positions.

Essential control components of the 3-D subsystems are: (see figures on the next page)

- Plausibility control and error statistics
- Dynamic offset navigation
- Heading control display (bottom right)
  - displays all relevant heading sensors dynamically
  - enables correlation of heading sensors by time lag display
- Display of the horizontal and vertical streamer positions with polynomial closure to PDF (bottom left)
- Histogramm of the standard deviations of all sensors (bottom centre)
- Bin coverage display (centre and top)
  - updates bin coverage dynamically
  - reports coverage for three selected streamer offsets (usually near/centre/far)
  - shows past and future situations to support coverage tracking.

Fig. 9: Realtime Processing and 3-D Quality Control Block Diagram




Operator Display
Bridge Display
Display Level
3-D Quality Control Subsystem
INDAS V MAINFRAME
Data Storage
Processing Level
INTELLIGENT INTERFACE
Gyro Subsystem
Streamer Subsystem
Precision Direction Finding System
Tailbuoy
Input Processor Level
PDF Antenna
Gyro System C. PLATH
Multi-plexer
Manual Direction Finders
Cable Departure Angle
Sensor Level
Magnetic Compasses
Stretch Section Monitoring

General

Recent experiences have proven that the newly designed streamer positioning and quality control subsystems are perfectly suitable to determine and supervise the calibration values of the gyro master reference, of the different bearings and of the magnetic compass headings.

In order to maintain systems' functioning, high precision performance and self test capabilities at all times during a survey an extensive pre-mission calibration sequence is employed:

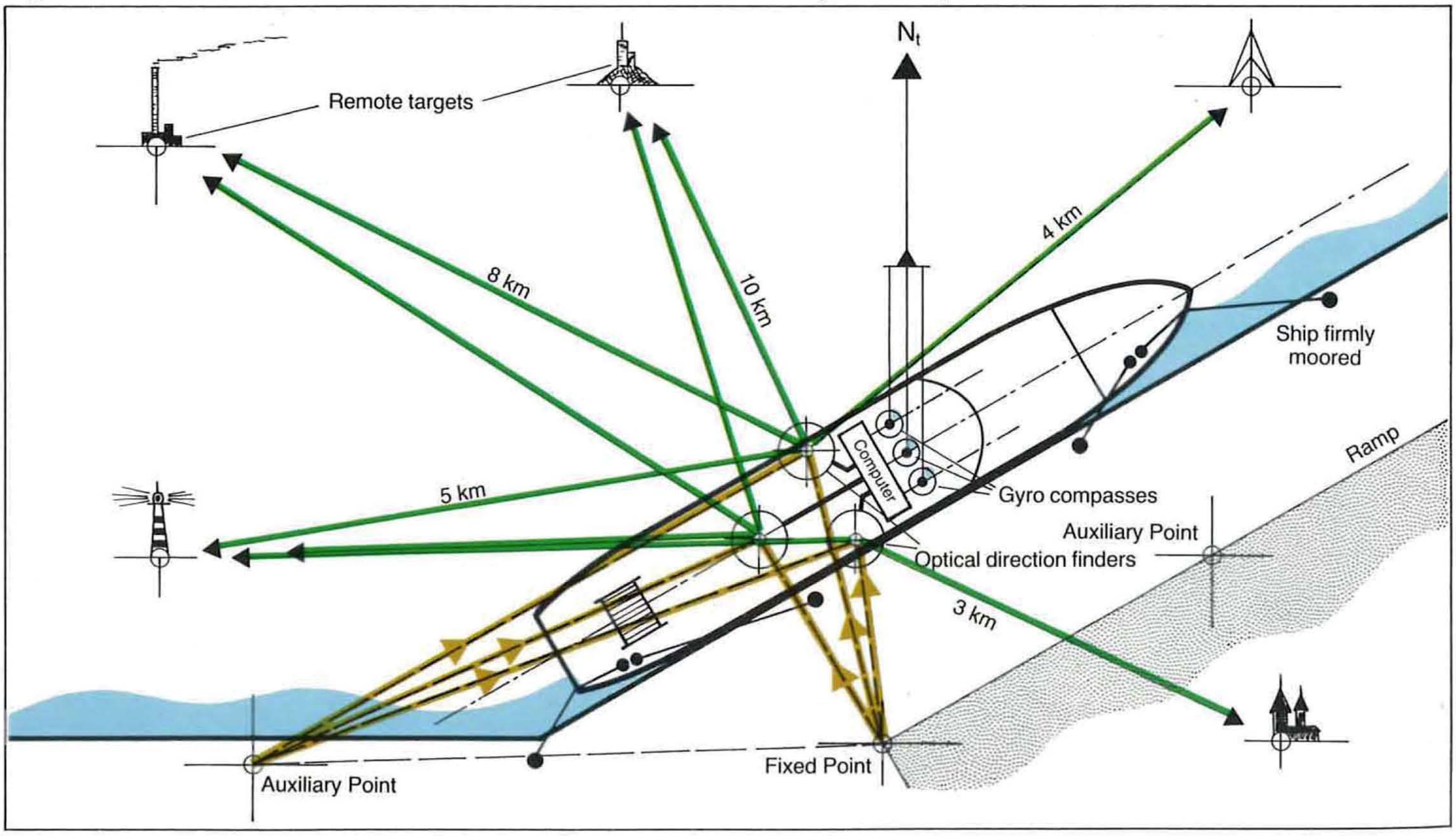
- Stationary calibrations of the multigyro system and manual direction finders using geodetic targets
- Calibration of the PDF system under operational survey conditions using the pre-calibrated manual direction finders
- Performance check of the magnetic compasses and determination of their instrumental and mounting fixed errors by calibration against the PDF reference.

Description of Calibration Procedures:

Stationary Check of the "North Reference"

A port with suitable remote targets is required for this very important pre survey check procedure. After fixing the geodetic coordinates of the onboard optical direction finders these are aimed at remote targets. The computed minus observed azimuths provide reliable correction figures for the residual installation errors. The cable departure angle measuring unit is checked at the same time.

Fig. 10: Check of the Residual Installation Errors of Master Gyro and Optical Direction Finders



Optional:

- Dynamic gyro test by cruising past a fix point under survey conditions, thereby continuously taking bearings using the manual direction finders.
- Overall system check by comparing computed with observed tail end positions using a second boat.

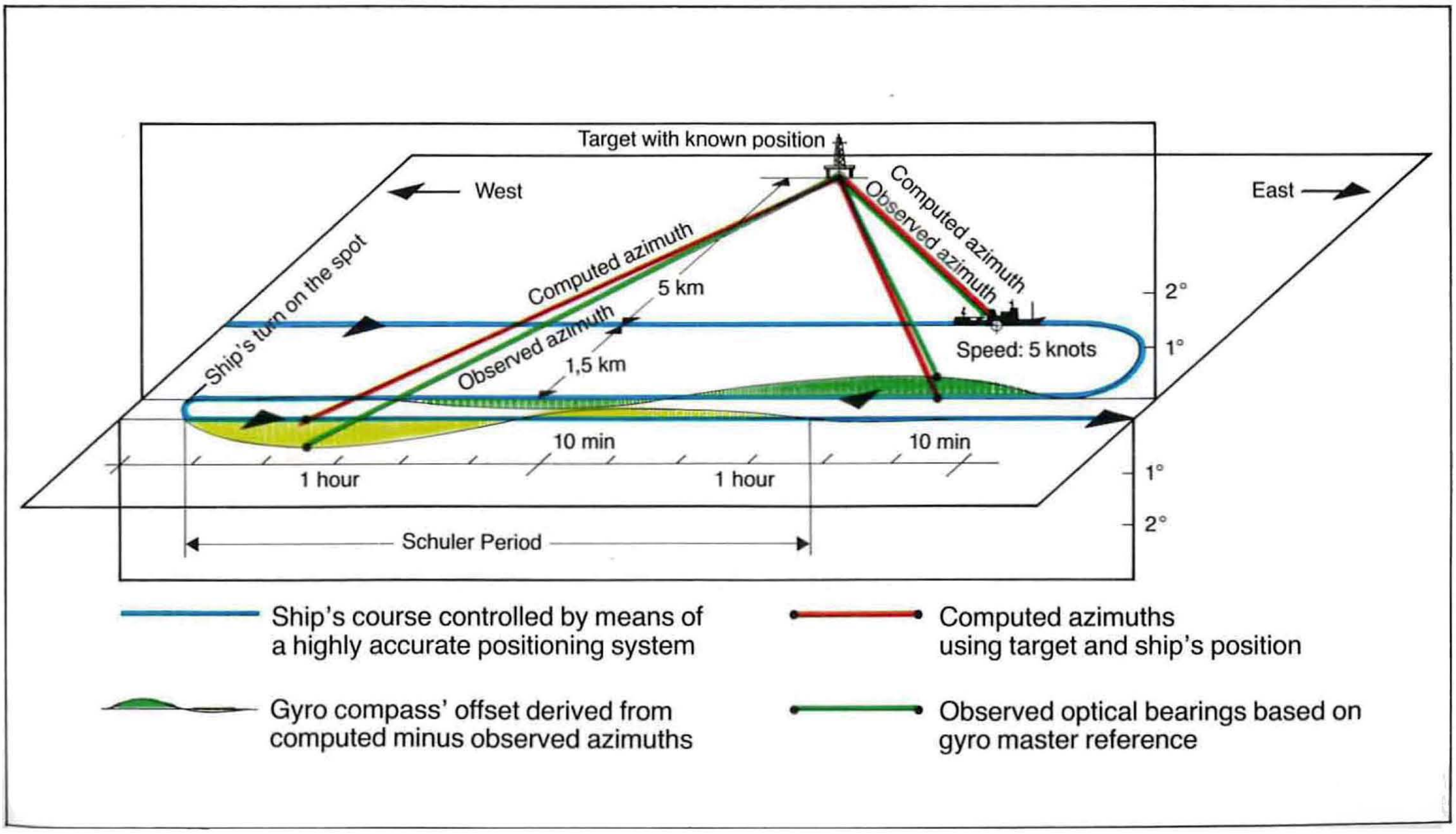
In contrast to commonly used systems even varying calibration values are derived from the unique configuration and performance of the system:

- Geomagnetic daily and long term variations are indicated
- Sporadic jumps and instrumental variations of the magnetic compasses are revealed

Dynamic Check of the "North Reference"

The accuracy of the PDF System in a dynamic situation is dependent on the stability of the gyro compass system. The main source of errors is the oscillating characteristic of the gyros after significant ship maneuvers such as course changes or full turns. By cruising with the survey vessel past fixed targets it has been proven that the gyro system remains stable even after ship's turns (see fig. 11). The second peak of the "Schuler period" (84.4 minutes) is reduced to ± 0.1 degree. This allows run-in distances to be significantly reduced.

Fig. 11: Check of the Oscillating Characteristic of the Master Gyro Compass System



Calibration of the PDF

The PDF is the master reference for streamer positioning. Therefore, careful calibration is performed as follows:

Whilst sailing slowly on a zig zaging course, alternating by +/− 30 degrees, the observers aim at the tailbuoy and take bearings frequently with the manual direction finders. The electronically logged optical bearings are compared with the PDF bearings, displayed on a monitor and plotted as computed minus observed values on a graph as shown below.

Fig. 12: Calibration of the PDF System

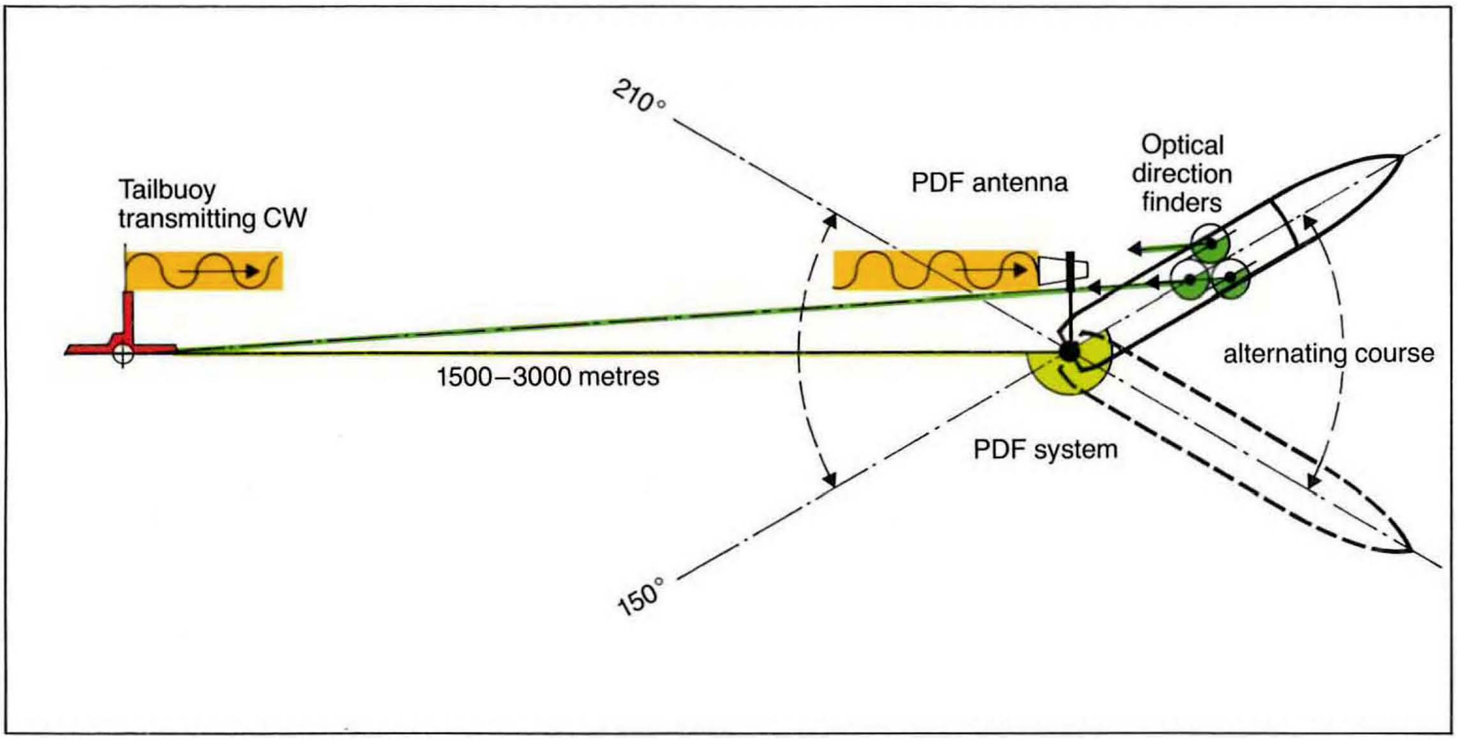
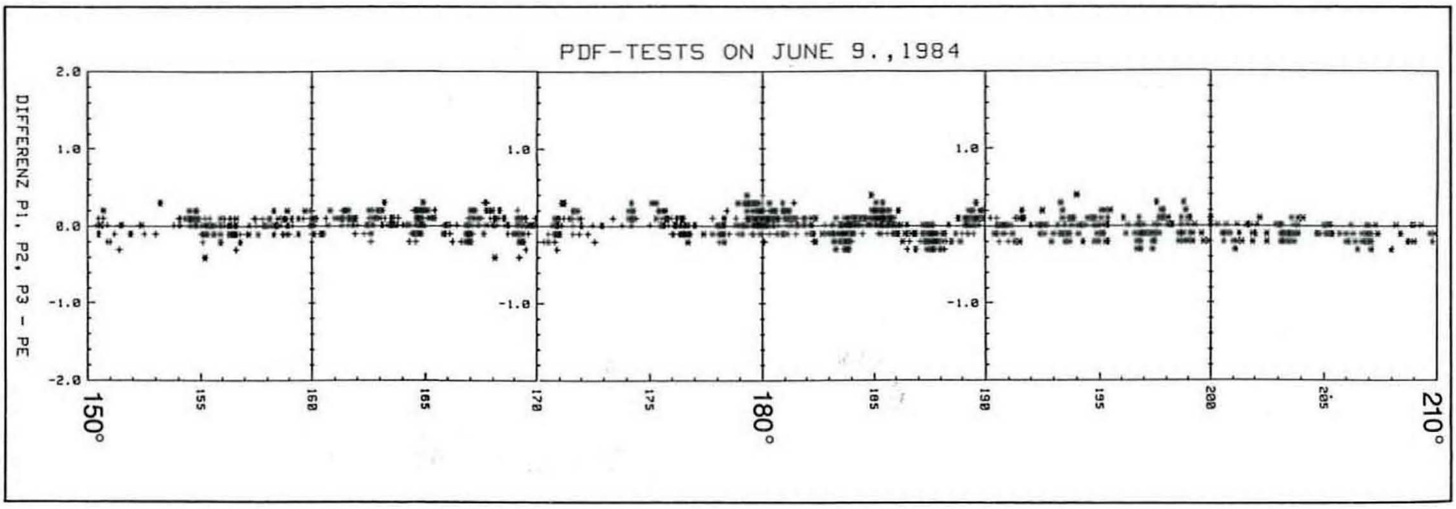


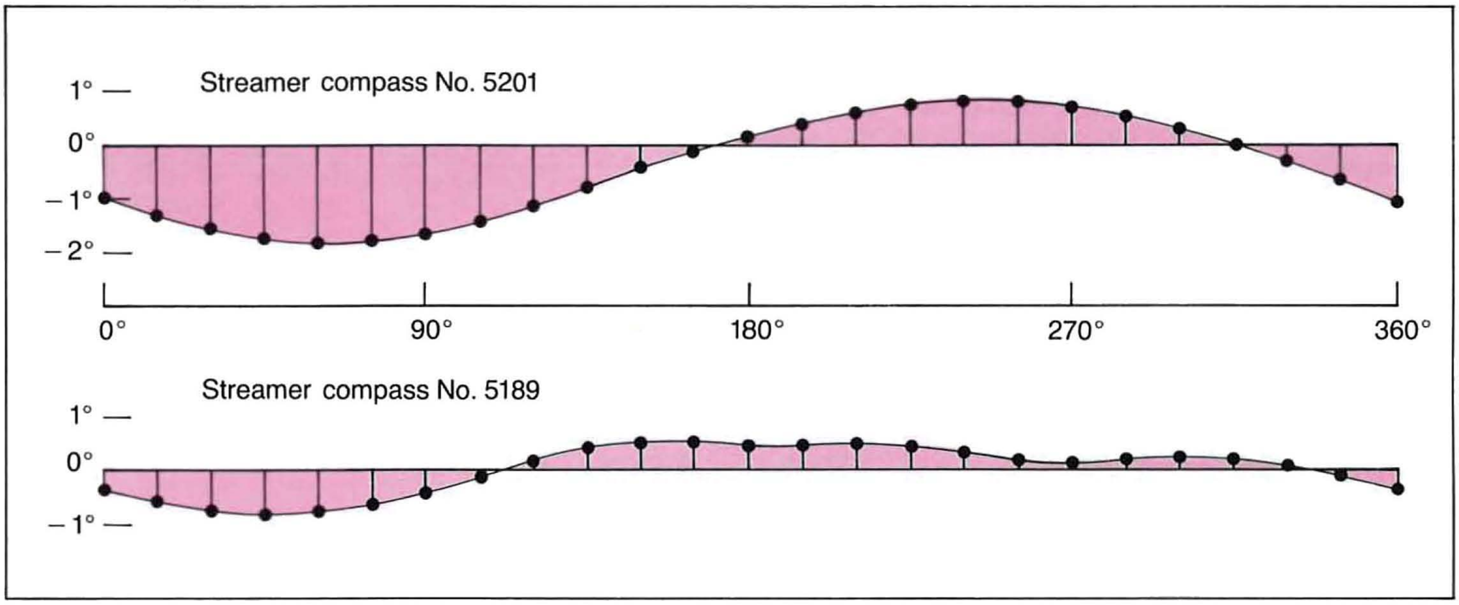
Fig. 13: Scatterplot of the PDF Calibration



Calibration of the Streamer Heading Sensors

Stationary Calibration: Before using the magnetic compasses in the streamer each sensor is calibrated in a laboratory which is completely compensated for any magnetic variations. Thereafter an individual deviation table, in steps of 15 degrees, is established for each sensor and fed into the navigation computer.

Fig. 14: Stationary Heading Sensor Deviation Function
The individual deviations of two streamer heading sensors are depicted as function graphs for two typical sensors.



Dynamic Calibration: During the seismic survey the individual deviation tables of the heading sensors are updated based on statistical evalutions. The updates are established by comparison of the heading sensors with each other and with the PDF in time-lag mode.

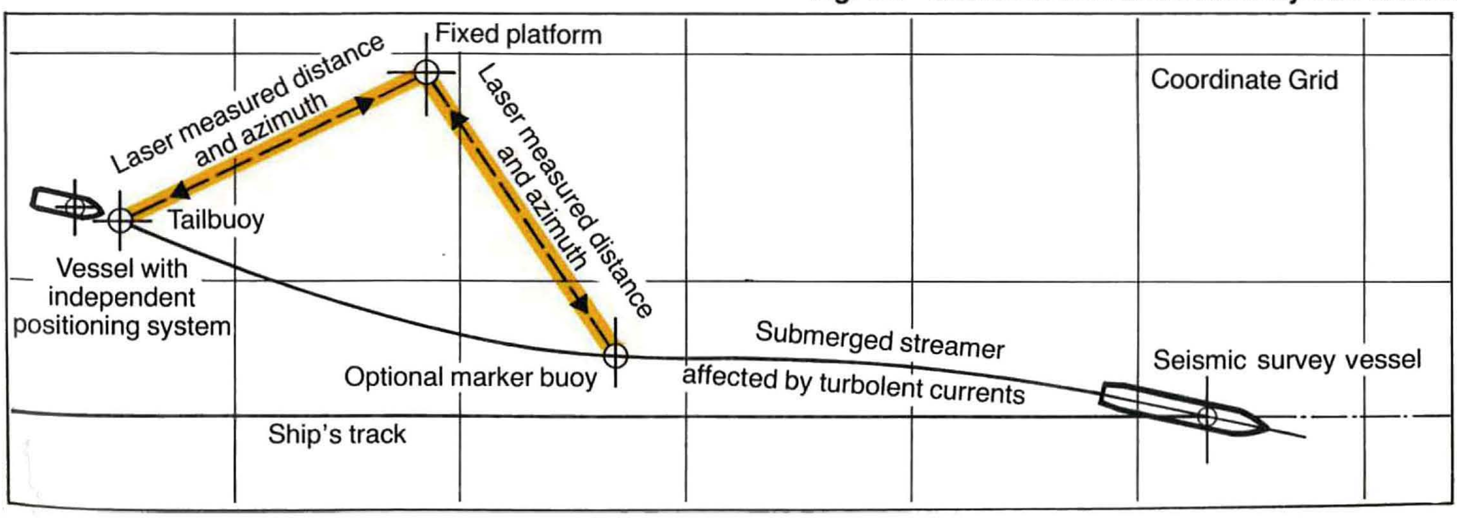
Based on the updated sensor deviation corrections the streamer shape determination process, as part of the PRAKLA-SEISMOS Realtime Processing System, computes an adjusted streamer polynomial, which matches the PDF reference bearing to within ± 10 m at the tailbuoy.

Final Overall System Check (Optional)

To prove correct functioning of the streamer tracking system and the streamer shape as calculated by the realtime processing system the following check can be performed at the clients's request:

A second vessel, equipped with an independent positioning system, sails very closely behind the tailbuoy, logs its own position and measures the distance to the tailbuoy. The derived tailbuoy coordinates are compared with the respective coordinates computed by the realtime processing system. Instead of a second ship it is possible to use a fixed laser to measure the coordinates.

Fig. 15: Sketch of the Final Overall System Check



General

Post-mission processing is to enhance the realtime streamer positions and to determine the locations of all streamer segments in the geodetic grid and thus to derive the most accurate subsurface positions. The processed data is stored on a positioning data file for use in further seismic processing. Various graphic representations are plotted at suitable scales for control purposes and to support the seismic processing.

The raw information from all sensors is reprocessed using an **integrated, advanced processing technique** in order to observe a positioning accuracy to **within ± 5 metres** for subsurface locations **in any given streamer environment.**

Built in streamer compasses are strongly influenced by varying torsion and tension forces. Experience shows that their calibration state changes with variations in the local environment. Therefore, one major task in post-processing is to **redefine the pre-mission calibration values** on a continuous basis, and not to consider them invariant over the whole survey.

Special correlation techniques in conjunction with the independent PRAKLA-SEISMOS PDF system result in **linewise calibration functions** for the streamer heading sensor system.

The **outstanding accuracy of the PDF system** becomes evident from the correlation between magnetic variations as recorded by a ground station and PDF functions (see part B in figure 17b).

Processing

The 3-D positioning sequence consists of 4 main phases (see flow diagram):

Phase 1

- Sensor data preparation

Phase 2

- Positioning of ship based locations
- Processing of sensor data

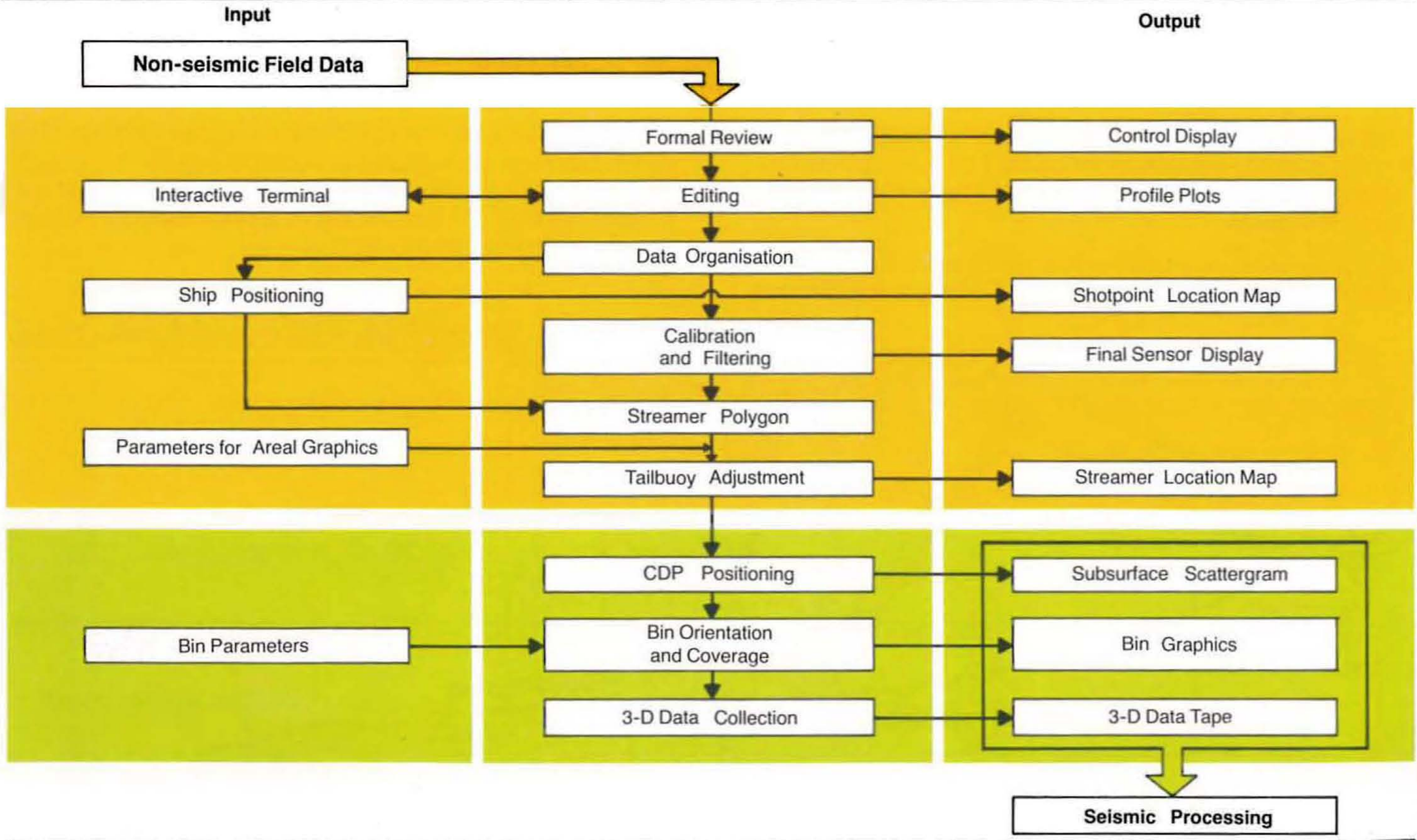
Phase 3

- Determination of the streamer shape
- Weighted closure to tailbuoy

Phase 4

- Positioning of common reflection points
- Graphics representation

Streamer Positioning Sequence



Editing of gaps, spikes and sensor malfunctions along with a formal review of all input data are the main tasks during **Phase 1**. Plots and displays as shown in fig. 17c assist editing.

Phase 2 splits into ship positioning and 3-D sensor data processing.
Ship positioning results in highly accurate geodetic positions for antenna and source (see fig. 16a).

3-D sensor data processing is performed in an "instantaneous position domain", by removing the time-lag of the individual heading functions. They are now referenced to positions rather than times. This processing stage comprises correlation, fine editing, filtering and calibration. The compasses are calibrated relative to each other for the time being. Individual corrections are derived and updated blockwise for continuous survey periods. The fixed deviation of the local magnetic field was reduced beforehand. In a second step the whole system is calibrated against the PDF reference (see figs. 17a und 17b).

In the instantaneous position domain additional reference headings can be interpolated between the observed compass functions to improve the integration of the streamer shape function (see fig. 18a).

Final sensor displays as shown in figure 17c are produced in the reincorporated time domain after completion of the phase 2 processing stage.

Cable departure angles, streamer headings and stretch section variations are input into the streamer shape determination process in **Phase 3**. The deviations of the tailbuoy PDF bearings from those derived from the streamer compass system result in a linewise calibration function for the streamer, which is itself examined for reliability. The reviewed function represents the residual installation error of the streamer heading sensors (see phase 2). The **residual error is removed by a weighted closure to the tailbuoy PDF bearing** (see fig. 18b).

Phase 4 consists of final steps such as the positioning of the reference data points, which are kept on the proposed line during the survey (see fig. 16b). Positioning of common reflection points from source and receiver locations terminates with the generation of a 3-D positioning data file. In addition, various graphic representations are produced. Special streamer control maps with rotated streamer polygons for enhanced control are plotted, as well as the subsurface scattergram, which is shown as an example in fig. 19. Part of a bin coverage map is shown as a perspective view (2-D and 3-D) on the backcover as an example of bin graphics.

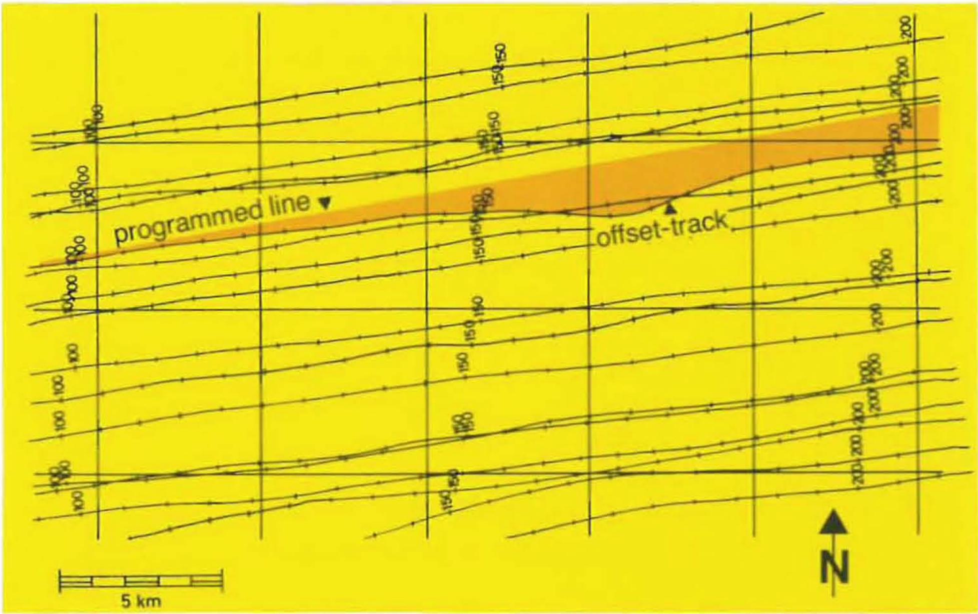


Fig. 16a: Location Map Based on Antenna Positions

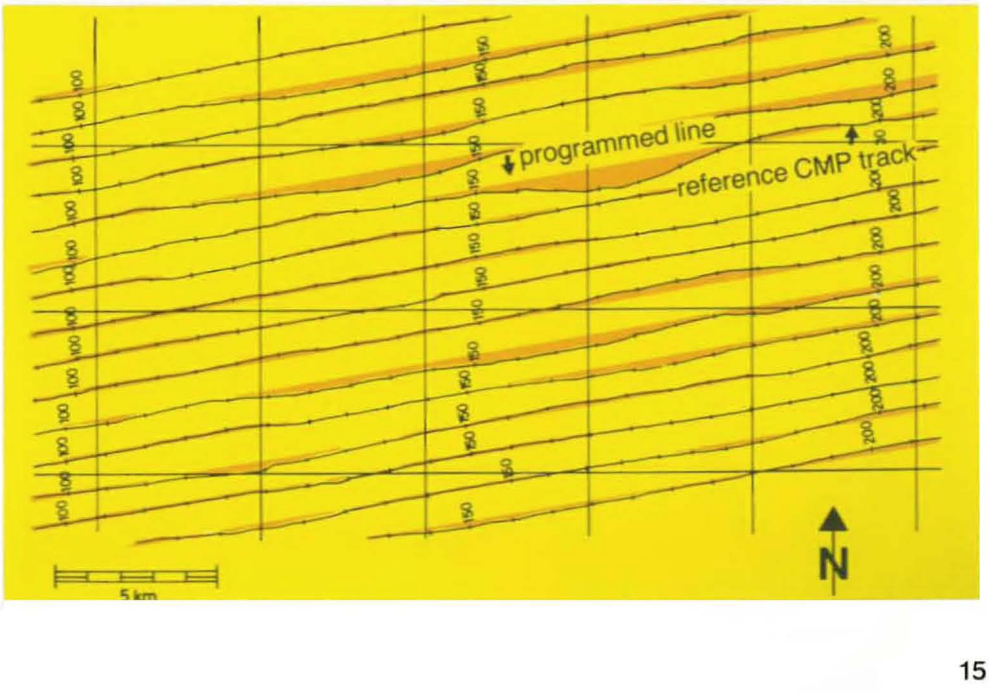


Fig. 16b: Location Map Based on Reference Reflection Points

Fig. 17a: Calibration (Individual Sensors)
Linewise average heading deviations of the individual streamer heading sensors relative to each other for one shooting direction.

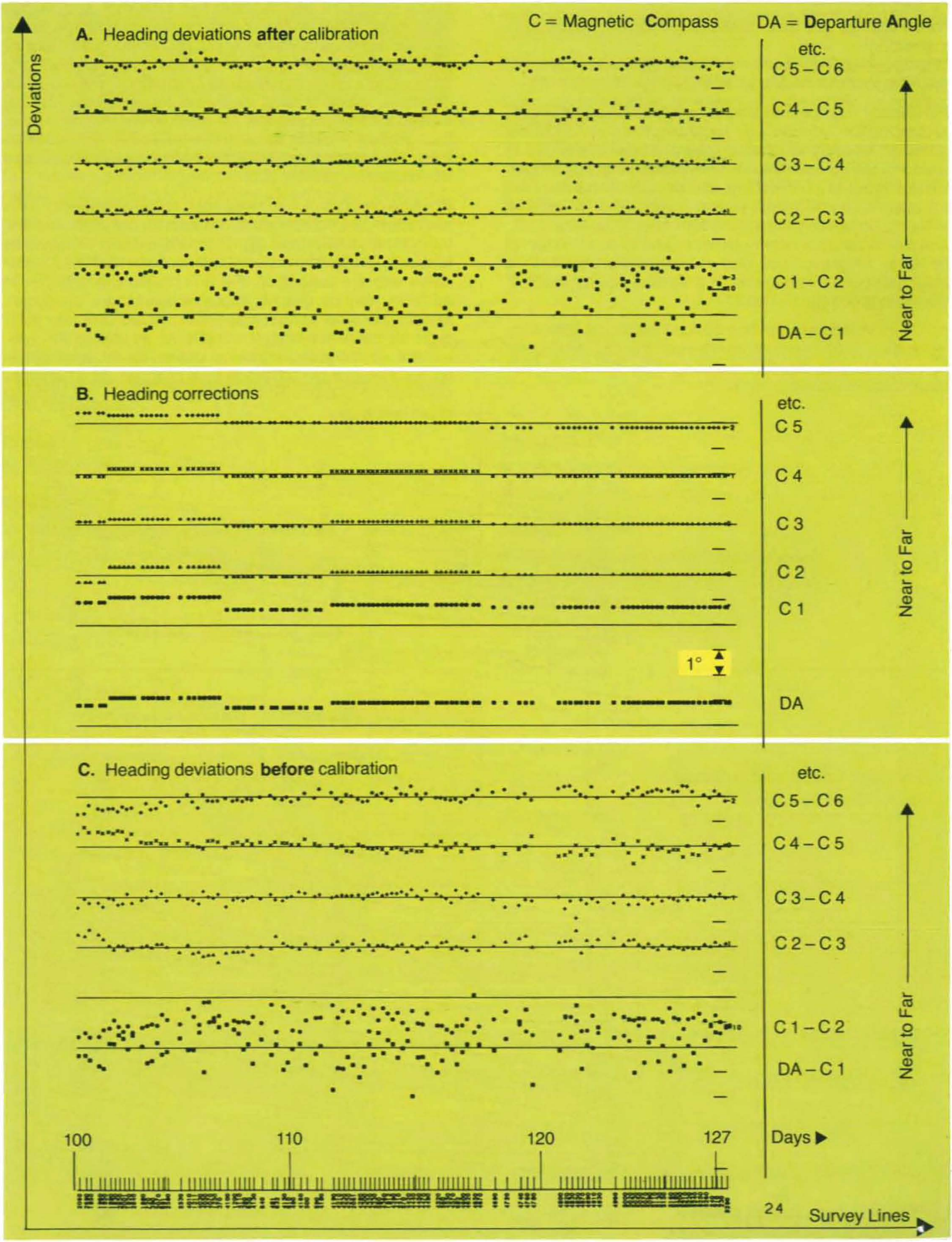
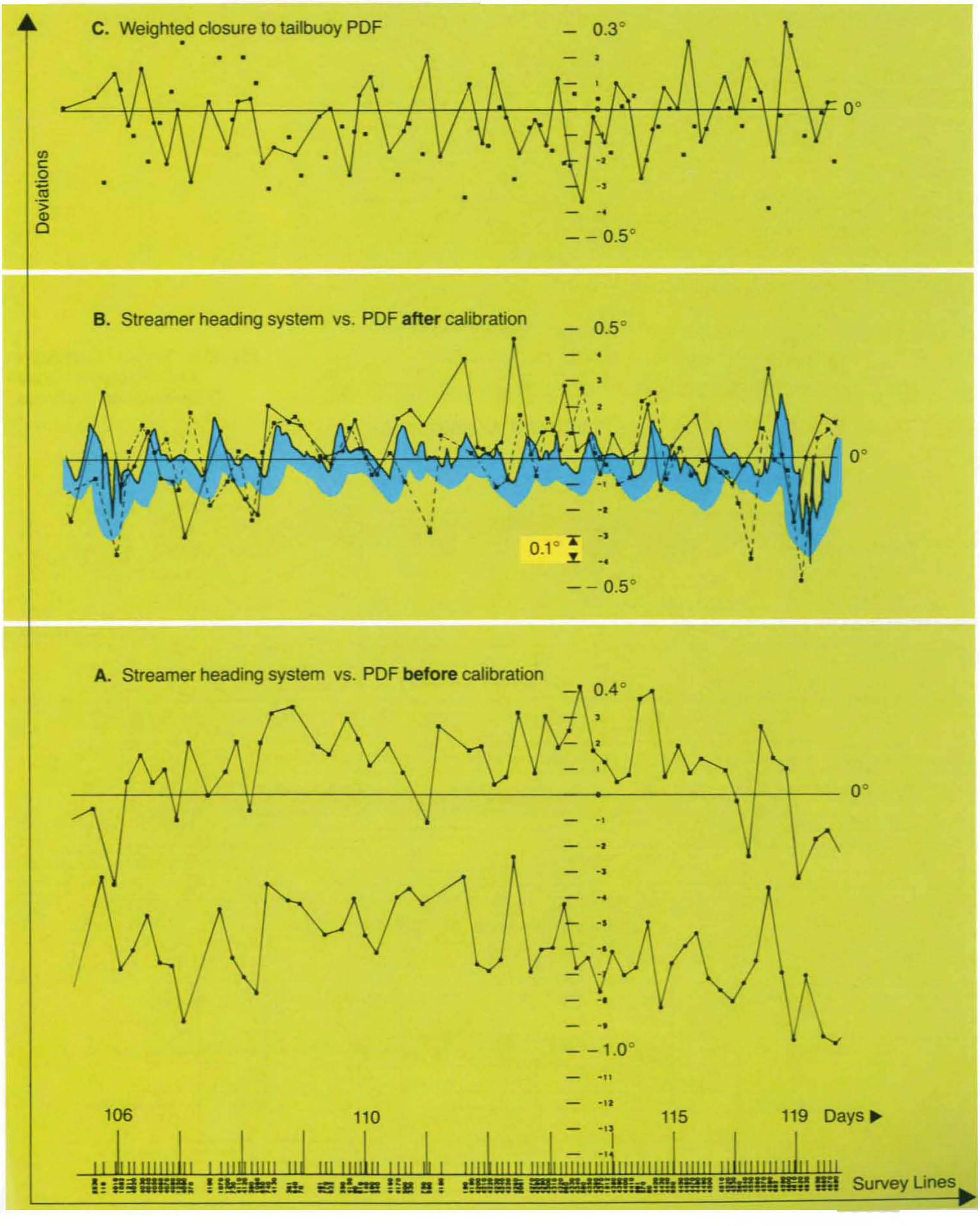


Fig. 17b: Calibration (Complete Sensor System)
Linewise average heading deviations of the complete streamer heading sensor system from the PDF reference shown separately for the two alternate shooting directions. A and B are the average deviations of all compass headings from PDF. C is the average weighted closure function after application of the individual compass corrections. B is overlayed with a magnetic variation function from a shorebased ground-station showing a remarkable correlation with PDF reference readings.



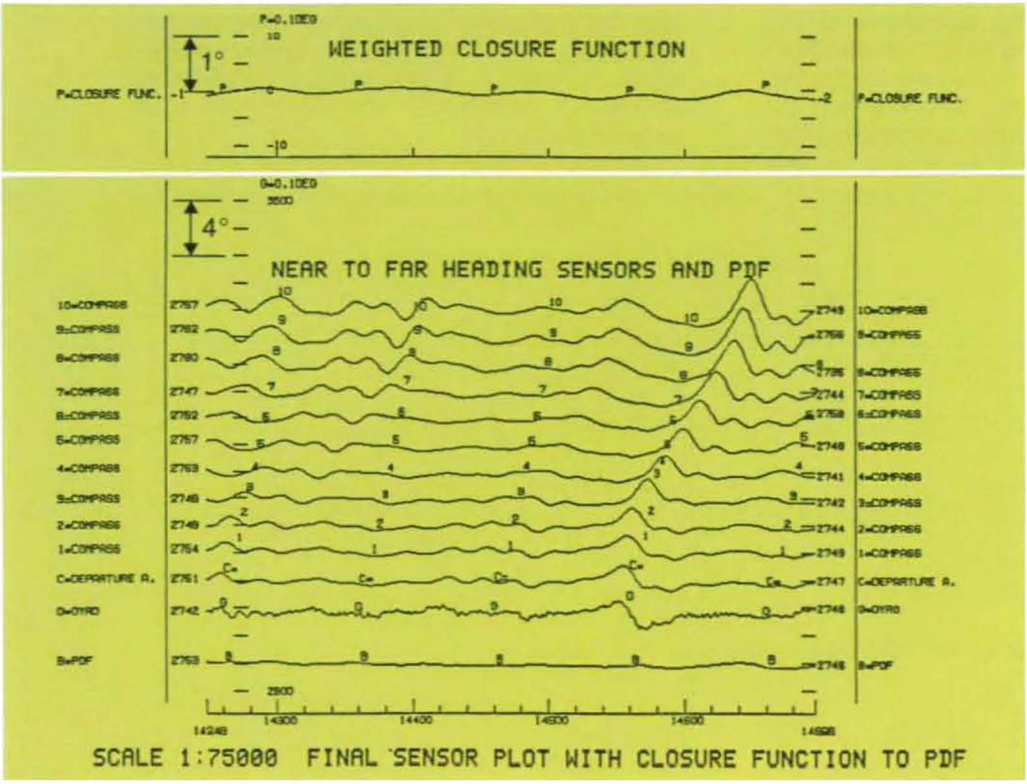


Fig. 17c: Final Sensor Plot (with closure function to PDF)

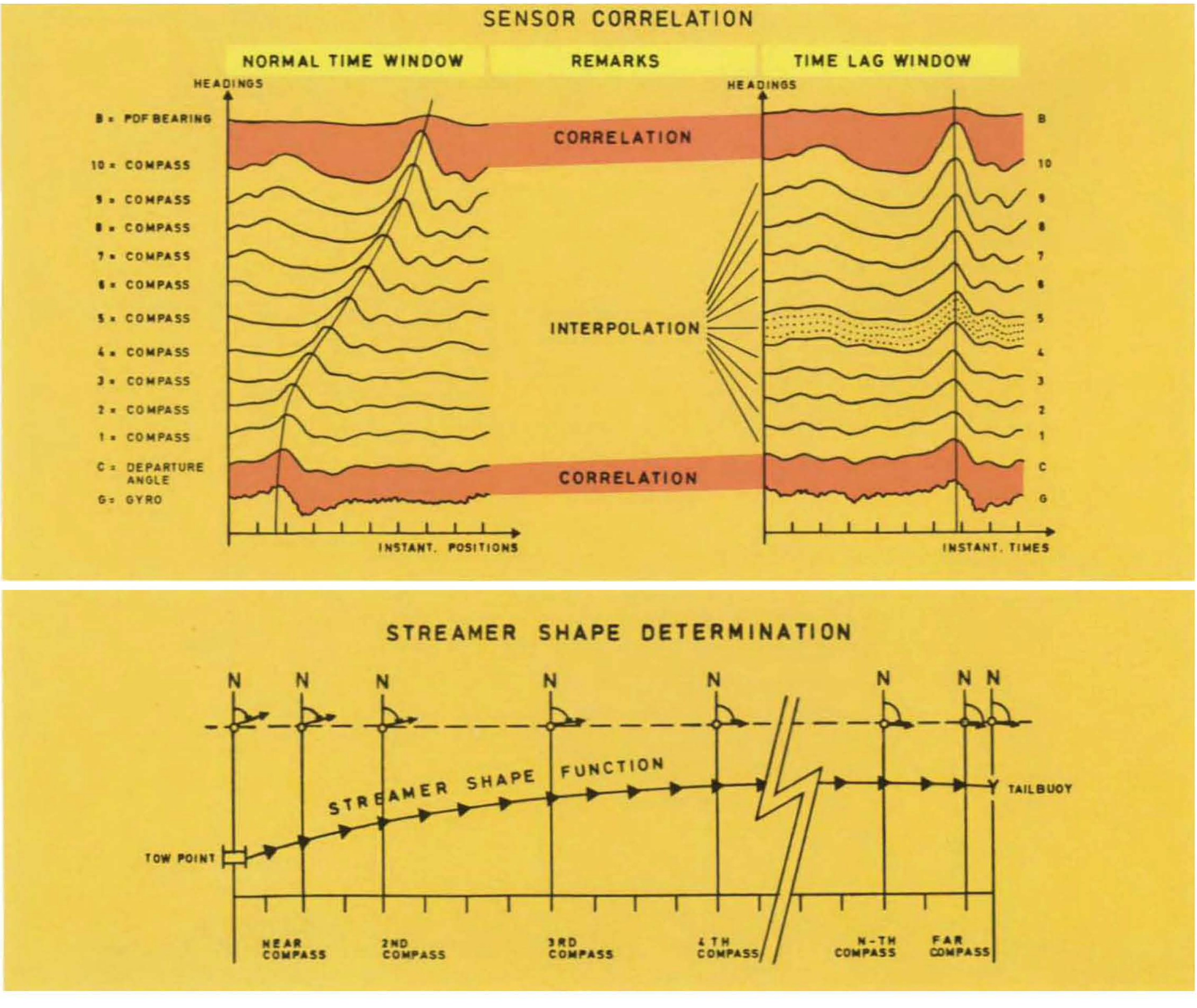


Fig. 18a: Sensor Correlation and Streamer Shape Determination Technique

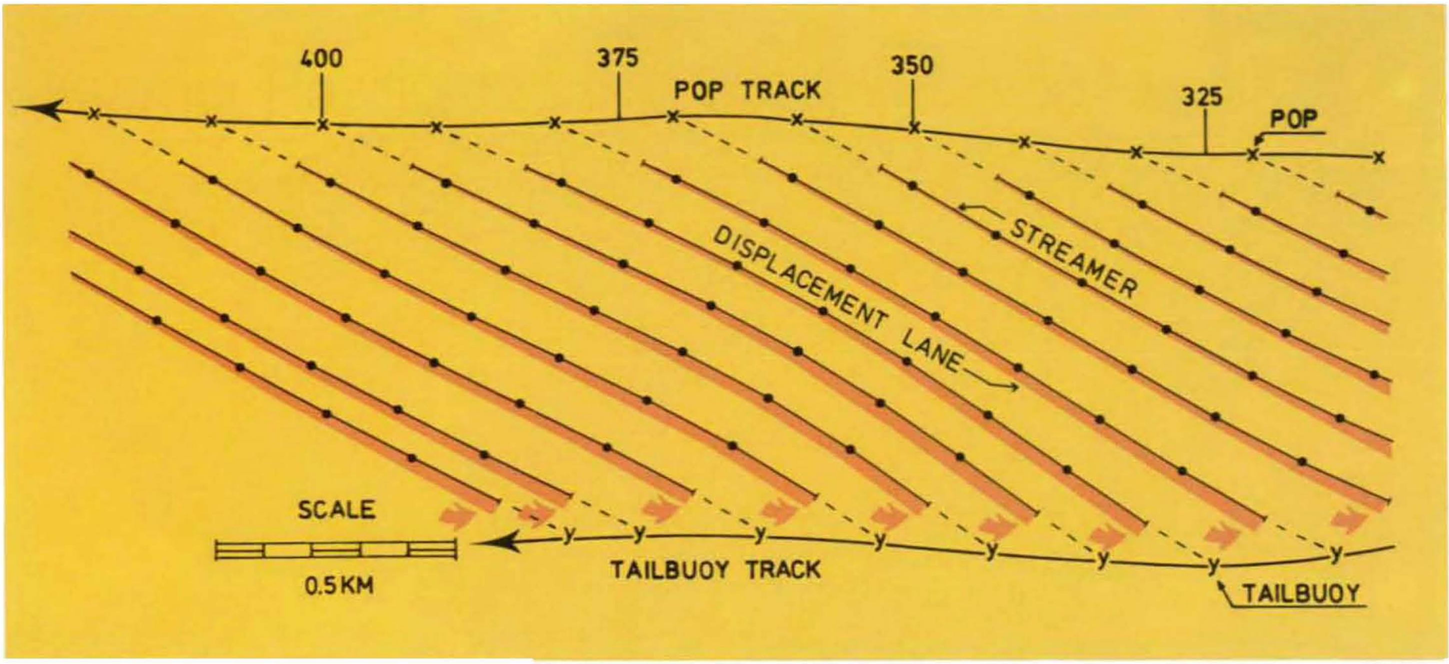
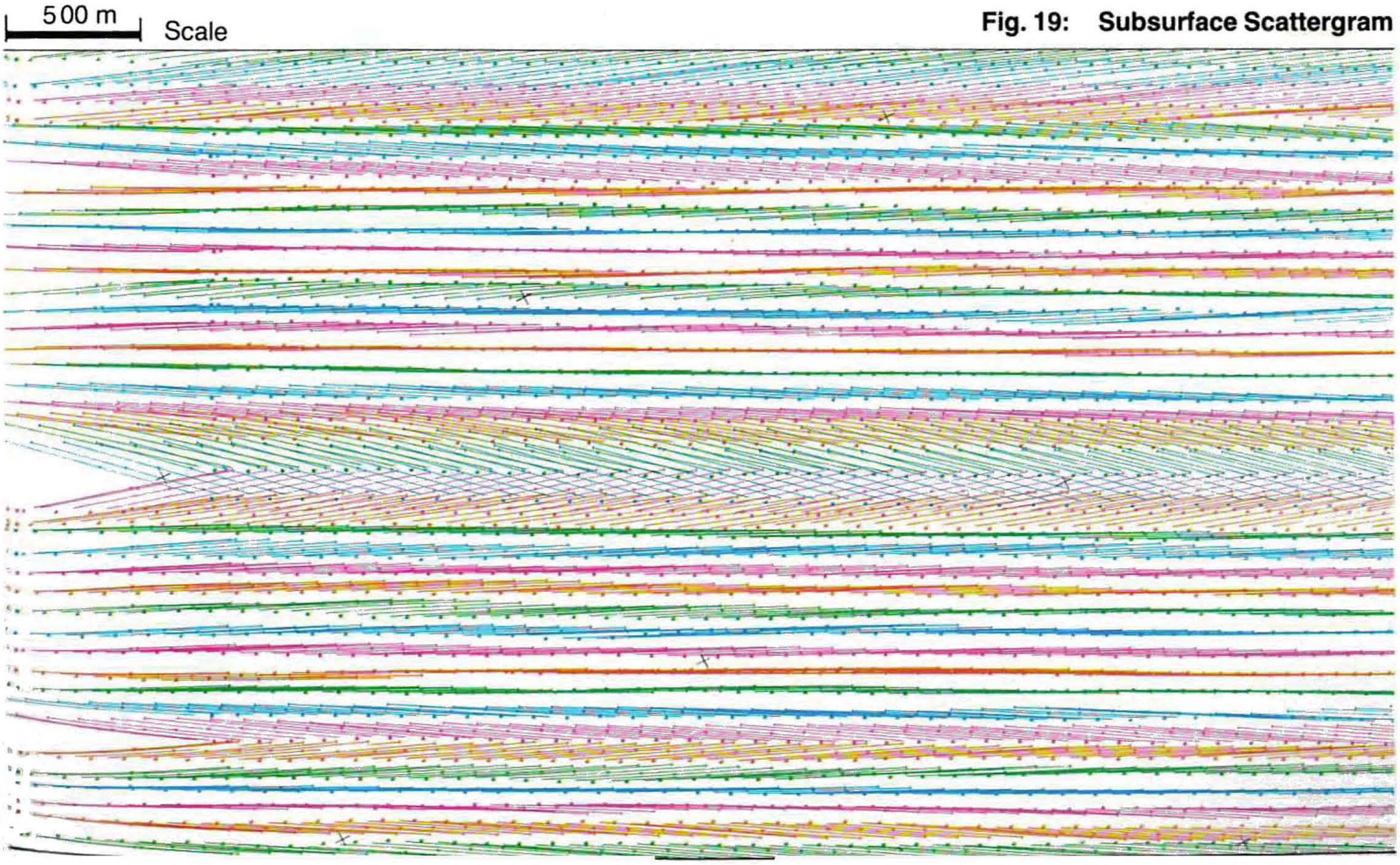
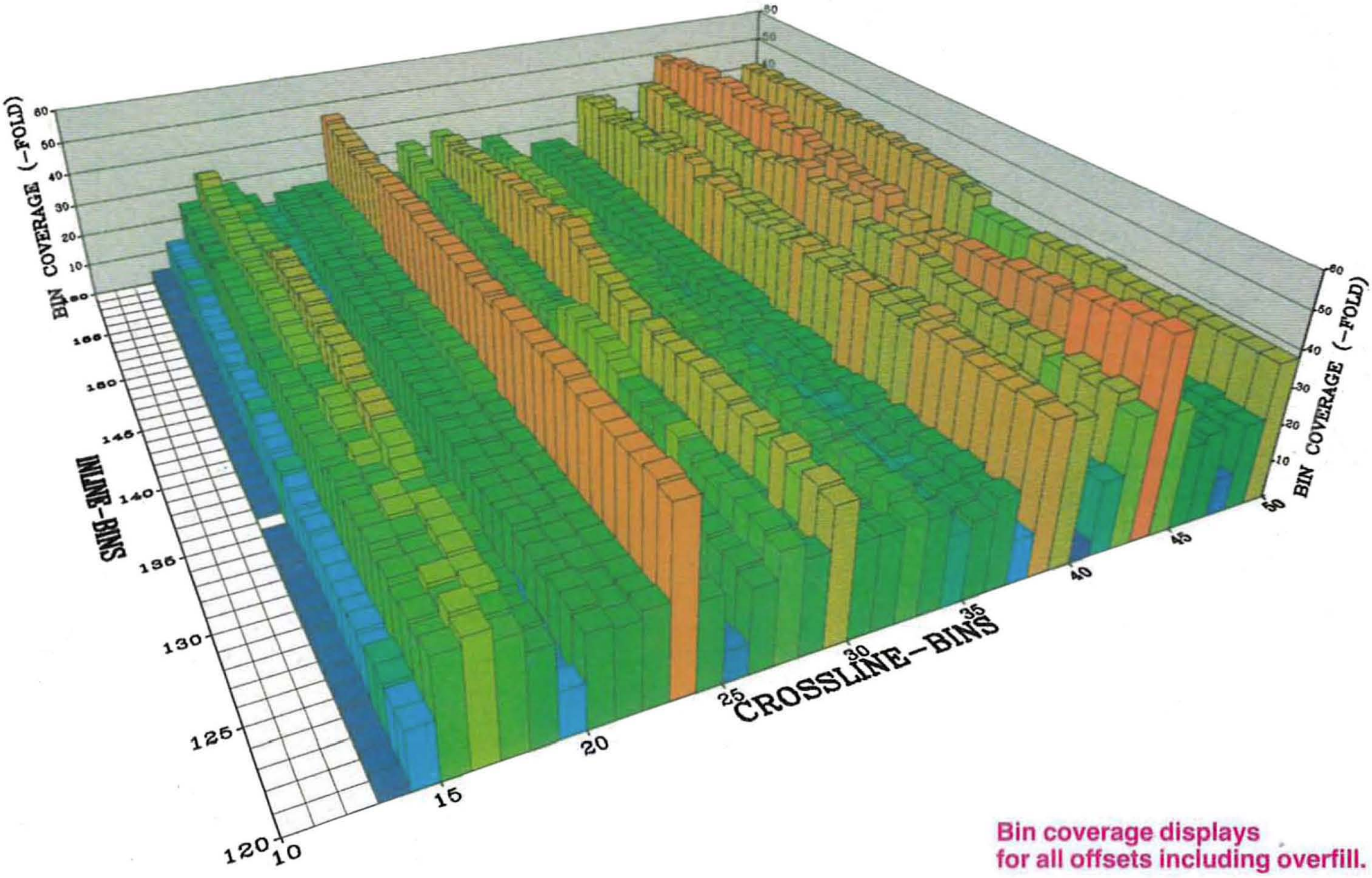


Fig. 18b: Weigthed Closure of the Streamer Shape Function to PDF

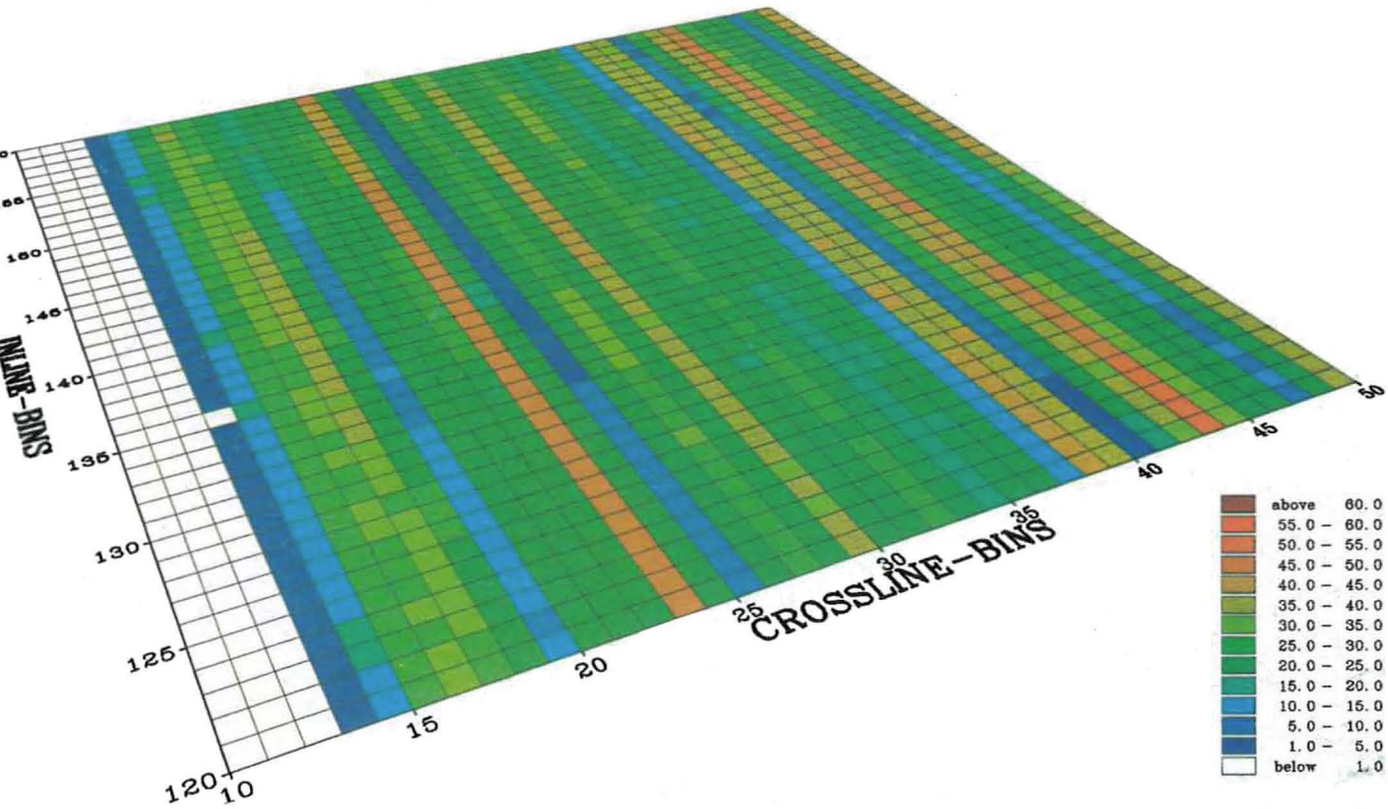
Fig. 19: Subsurface Scattergram



BIN COVERAGE



Bin coverage displays
for all offsets including overfill.



PRAKLA-SEISMOS GMBH · BUCHHOLZER STR. 100 · P.O.B. 51 05 30
D-3000 HANNOVER 51 · FEDERAL REPUBLIC OF GERMANY
PHONE: (511) 6420 · TELEX: 922847 + 922419 + 923250 · CABLE: PRAKLA GERMANY

5000 11 84