IMCA

The International Marine Contractors Association

A Review of Marine Laser Positioning Systems

Includes:

Part 1 – MK IV Fanbeam (June 2003)

Part 2 – CyScan (November 2003)

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IMCA M 170
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The International Marine Contractors Association

A Review of Marine Laser Positioning Systems

Part 1 – MK IV Fanbeam

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The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies.

IMCA promotes improvements in quality, health, safety, environmental and technical standards through the publication of information notes, codes of practice and by other appropriate means.

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IMCA M 170 Part 1

Part 1 of this document was prepared for IMCA, under the direction of its Marine Division Management Committee, by Noble Denton.

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A Review of Marine Laser Positioning Systems
Part 1 – MK IV Fanbeam

IMCA M 170 Part 1 – July 2003 (Reprinted November 2003)

1 Executive Summary

This report has been prepared to give IMCA members a review of the MDL Fanbeam® 4 system when used as a positioning reference for the automatic dynamic positioning (DP) of marine vessels.

The MDL Fanbeam® 4 is a laser radar system designed for repetitive, high accuracy positioning of marine vessels and static and semi-static structures. Currently (September 2002) 450 units are in operation, of which 75% are in use to provide a relative positioning input for marine vessel DP.

This report describes and reviews the current system (MK4), using software version 2.01 or above, considers the advantages, disadvantages, required training and maintenance, failure modes and provides operational feedback from users.

2 Introduction

2.1 Purpose of Report

This report has been prepared by Noble Denton Europe Limited for IMCA to provide a review of the Fanbeam® system, particularly for the members that are considering using this system as a positioning reference for dynamic positioning. A description of the current system MK4 is provided along with installation, maintenance requirements and training recommendations. The advantages and disadvantages of the system are considered along with the likely failure modes.

Currently two versions of the Fanbeam® system are available – MK 4.1 and MK 4.2. The only difference between the two systems is in terms of range – Fanbeam 4.1 has a range of 1000m and 4.2 a range of 2000m.

Operational experience has been drawn upon from current users as well as from MDL, the manufacturer. MDL has co-operated with the research for this report, provided technical information and assisted by checking this report's contents. This report is in addition to document IMCA M 131 "*A Review of the Use of the Fanbeam® Laser System for Dynamic Positioning*", produced for IMCA by Global Maritime in 1995. M131 reviewed the Fan Beam Laser Mk 1.

2.2 Principle of Operation

The system uses the principle of laser range finding by measuring the time taken for a pulse of laser light to travel from the laser source to a target and back to the detector. The disadvantage of using a traditional narrow beam laser is that the laser has to be accurately pointed at the target. The Fanbeam® system overcomes this problem by using special laser optics that produce a laser beam in a 20° vertical fan at the Fanbeam® optics. It should be noted that the vertical beam is reduced, due to dissipation, to 6° at 2000 metres. By scanning this fan horizontally in a controlled manner a fixed target can be tracked from a moving vessel and its bearing, relative to the vessels heading, and range, can be determined.

The system comprises a laser/scanning unit mounted on a motorised yoke that can rotate 360° at up to 50° per second. The laser unit measures ranges up to 2000 metres, and the scanner unit measures the bearing, to a target, relative to the vessels heading. As an option the MK4 Fanbeam® incorporates an auto tilt mechanism built into the yoke that allows the laser scanning head to be adjusted by ± 15°, in 5° steps, giving a total laser beam range of ±25° This allows for large variations in height between the vessel and target. A 'universal control unit' (UCU) runs the software that controls the operation of the Fanbeam® and provides the bi-directional RS 232 interface to the customers own equipment. Several different output formats can be selected from the UCU software package. In addition the system has a stand alone 28.5 volt dc power supply (Fanbeam® operates between 22 and 30 volts dc) and requires a passive reflective target, diamond grade reflective tape for short range (<200m) or retro prisms (>200m) for the Fanbeam® to track. The scan rate of the laser is software controlled, based on range, and varies between 10° and 50° per second.

2.3 Range and Accuracy

Using retro prisms in good visibility, the maximum range stated by the manufacturer, depending on the version used, is currently 2000 metres. The range accuracy is stated as ± 20 cm and the bearing resolution from the bearing encoder is stated as ± 0.02°, both values based on receiving five returns from a target. The bearing is measured relative to the vessel's heading, and therefore the accuracy and resolution of the vessel's gyrocompass will affect the overall bearing accuracy measured to the target. The combined repeatable bearing accuracy will limit the range at which stable position inputs can be obtained, suitable for automatic dynamic positioning. The maximum range for use with DP is therefore likely to be < 150 metres using reflective targets and < 500 metres using retro prisms. Only targets of the type and dimensions set out in section 5 of this report should be used as a reference for DP. Use of a "few inches of reflective tape", regardless of type or quality, can produce unreliable results and should not be contemplated.

3 Conclusions

The Fanbeam® offers a useful, relatively cheap and transportable positioning reference, for use in conjunction with other positioning reference systems, for the dynamic positioning of marine vessels. The system utilises non-powered static targets that are intrinsically safe and can be easily mounted in almost all areas of an offshore platform or drilling rig. Fog, heavy rain and snow will reduce the operating range of the Fanbeam® but with visibility of between 30% and 50% better than the human eye, close range working is usually possible.

The system can operate using only one target to give a single range and bearing for input into a DP system. Operating with a single target can be undertaken without the need for any complicated calibration or data manipulation. The use of multiple targets is recommended and this does require the reduction of ranges to horizontal and referencing of the Fanbeam® scanning head to the vessels heading and centre line.

The system is relatively straight forward to install and use. It is recommended that manufacturers training be undertaken onboard, so that system limitations relating to visibility and target identification are fully appreciated, software and data output options understood.

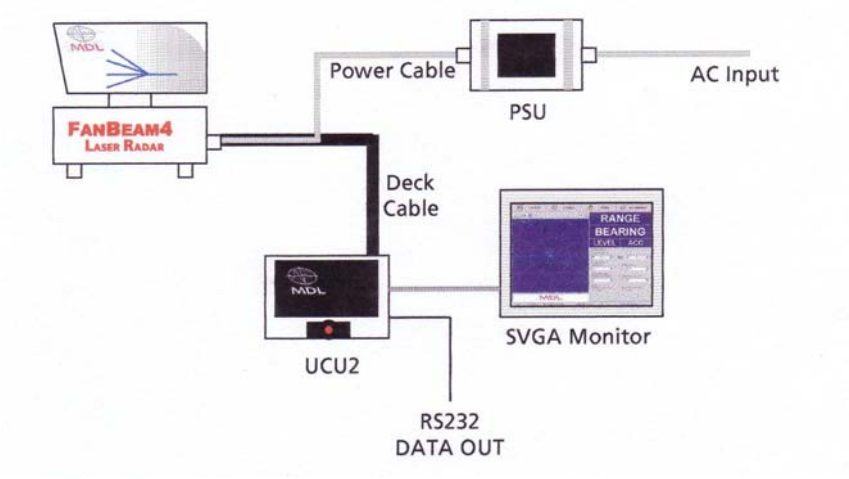
Bearing accuracy, quoted as $\pm$ 0.02°, is not dependant on target size. During each scan, multiple target echoes are averaged to give the bearing to the target centre. Likewise all range measurements to the target are averaged. To obtain range accuracies of $\pm$20cm a minimum of five measured ranges are required. For a range accuracy of $\pm$ 10 cm nine or more ranges are required. The number of echoes received (up to a maximum of nine) is displayed on the universal control unit along with the received signal strength. This display along with preset alarms allows the DP operator to assess the quality of the data being received.

The Fanbeam® does not present the DP system with any error messages in the data output string. Data falling outwith gating parameters, set for individual targets, including minimum signal strength, minimum accuracy and maximum/minimum bearing and range, will not be output to the DP system.

The system should be tested, in conjunction with the DP control system, for the failure modes (Section 10) to ensure that they cannot produce a drive off, large change of position or a gradual drift in position.

4 System Description

4.1 Equipment Configuration



4.2 Laser

An electrical pulse generator drives the infrared semiconductor laser diode at a repetition rate of 7500 Hz to produce a laser beam with a 20° vertical fan and a horizontal divergence of 2.5 milli-radians. These light impulses, which are collimated (adjusted for the line of sight) and emitted by the transmitting lens, produce a vertically diverging and horizontally parallel beam. Via the receiving lens, the reflected signal hits a photo diode that in turn generates an electrical receiver signal. The time interval between the transmitted and received pulses is measured and used in conjunction with the speed of light to compute the range. The laser outputs the range data along with signal level and timing information for further processing.

The high accuracy of the horizontal angle is achieved by detecting every echo from the laser and reading the angle for each echo. Once the laser has passed over the target, the angles are averaged, providing an angle to the centre of the target. This means that the angular accuracy is not dependent on target size. The echo signals are averaged to increase the range accuracy. To achieve a range accuracy of ± 20cm at least five echoes are required from the target.

4.3 Scanner

The scanner is housed in a die-cast aluminium case. The laser cradle assembly mounts on top of a stainless steel shaft that protrudes through a watertight seal. (See Section 6, Service and Maintenance) A rotating table within the scanner is driven by a stepper motor through a reduction gear and a precision worm and wheel that results in a resolution of 0.01°. A high accuracy optical encoder that is mounted directly on the laser shaft to avoid backlash, measures the angular position of the laser. The assembly measures horizontal angles to a resolution of 0.01° and an accuracy of 0.02°.

Electrical connections between the scanner and the laser are passed through slip rings that allow continuous rotation of the Fanbeam® should this be required.

The scan speed is automatically controlled by the software according to target range, as set out below:

Target Range	**Fanbeam® Speed**
<100m	50° / second
100-250m	30° / second
250-500m	15° / second
500-1400m	10° / second
>1400m	5° / second

If the scanner rotates at < 3° per second the laser transmission is turned off.

4.4 Universal Control Unit (UCU)

The UCU is housed in cast aluminium with a backlit keypad (upgraded from earlier models to be visible at night) at the front and three connectors at the rear. The UCU is supplied with a "U" bracket for mounting.

The UCU provides all the control functions for the Fanbeam® and can be mounted beside the Fanbeam®, or mounted several hundred metres away, when control is required on a vessels bridge or computer room. To facilitate easy operation of the UCU widows based software the UCU has been designed to operate with a monitor and keyboard

Power is supplied to the unit via the Fanbeam®, along with the bi-directional current loop data link and control signals. All the control functions between the UCU and the Fanbeam® are carried out over the current loop data link.

If the system is required to be interfaced to client's equipment, for example the DP control system, the serial port on the UCU is used. The connector is a bi-directional RS232 interface that at the simplest level is set to output target information. Several different output formats are available and can be selected from the UCU software.

The UCU provides VGA graphics when connected to a monitor. The UCU can be supplied with one of several programs and this has to be defined at the time of ordering.

4.5 Control and Drive Electronics

There are three printed circuit boards in the scanner, a motherboard, a stepper board and a control board. There are no components on the motherboard; its only function is to provide connections between all the wiring and the plug in boards. The stepper board is in two halves. The first is a dual switch mode regulator, which converts the input voltage (28VDC) to the voltages required by the system. These are 5V DC for the logic circuitry and 20V DC for the laser. The second half of this board contains the driver for the stepper motor. It is fed two signals from the control board, namely clock and direction, and translates them into four wire 2 phase signals. Current limiting and circuitry to improve step response are included on this board. The control board is also in two halves. The first consists of three protection fuses, F1 20V/20mA current loop Txbbb circuit for communications with the UCU, F2 20V laser power supply and F3 28 V Fanbeam® power supply. Normally the interface is configured for 20mA current loop. The current loop is capable of driving several hundred metres of cable. If required, this interface may be re-configured to RS232 Tx and Rx. The second half of the board contains four micro controllers, that interface to and control all parts of the Fanbeam®, namely the laser, the stepper drive card, the encoder and the communications between the Fanbeam® and the UCU.

4.6 Power Supply

The power supply unit is housed in a cast aluminium case that is sealed against the ingress of moisture. The power supply consists of a switched mode supply, and has a universal mains input capable of operating over the range 86 to 265volts AC at 40 to 400Hz. It supplies a DC output at up to 3.5 amps. The output is adjustable between 24 and 30 volts and is supplied with an output of 28.5 volts. The voltage is preset at this value to compensate for the voltage drop in the connecting cable between the power supply and the Fanbeam®. The operating voltage of the Fanbeam® can be between 22 and 30 volts.

4.7 Data Outputs

To facilitate interfacing to various dynamic positioning systems, data output from the Fanbeam® is available in RS232 format at 9600 baud in the following data formats:

1 MDL Standard

2 MDL Single Target

3 Kongsberg Simrad Standard

4 Kongsberg Simrad Legacy

5 Cegelec Standard

6 Cegelec Legacy

7 Nautronix Standard

8 Nautronix Legacy

The formats listed above transmit range and bearing data of the targets in ASCII code with control characters. No fault flags are included in the data string, if there are problems with the Fanbeam®, data transmission to the DP is suspended.

Additional formats or conversion of RS232 format to that required by a DP control system can be provided.

Users should contact the suppliers of their DP systems before attempting to connect or interface the Fanbeam®; some systems are not capable of taking a Fanbeam® input without hardware and/or software modifications.

4.8 Software

4.8.1 Main Target Display

MDL's single target DP software is supplied as standard with the Fanbeam® and is embedded within the universal control unit. The single target software is designed to constantly display range and bearing information from the Fanbeam®.

The operator can select a target to track, tilt the Fanbeam® head and adjust the gating parameters.

4.8.2 Fanbeam® Command

The dialog box allows the operator to set the Fanbeam®'s gating parameters to maximise the systems performance. Gating parameters can be used to filter out unwanted reflections and help with target identification.

4.8.3 Software Configuration

Other dialog boxes allow the operator to set audio and visual alarms, range and bearing limits and choose appropriate colour schemes according to lighting conditions in the vessels control room.

4.8.4 Additional Software

Additional software can be supplied enabling up to 20 targets to be tracked.

5 Installation

5.1 Scanner Location

The location and mounting of the Fanbeam® on the vessel is an important consideration. Before work is carried out, due attention should be paid to the following issues. The scanner should be installed in an area that allows 360° rotation and has easy access to allow for routine maintenance and servicing. The mounting location should avoid areas where high vibrations are experienced and away from funnels to reduce the risk of the optics becoming covered in soot. It has been found that the ideal place to install the scanner is on the vessel's centre line directly above the bridge. It is essential that the scanner be positioned to give a clear line of site in all directions where targets are to be installed.

Prior to use, the scanner's 0° axis should be aligned with the vessels head. This can be done by placing a target on the vessel's centre line and commanding the laser to scan the sector containing the target. Any difference in angle can be noted and a correction entered into the software.

5.2 Universal Control Unit

The UCU and monitor should be securely mounted, at normal working height, in or near the vessel's bridge. Care should be taken not to obstruct the ventilation holes in the UCU. Although the upgraded UCU has back lighting consideration should be given to the siting of the UCU and monitor relative to bright sunlight.

5.3 Targets

There are two main types of targets, reflective tape and retro prisms. Care should be taken to mount both types of target vertically. This is particularly important with vertically stacked prisms for long-range use. Poor targets are harder to track, are more difficult to gate and this increases the chance of picking up spurious targets. The minimum requirement for targets used as a positioning reference for dynamic positioning are set out below.

5.3.1 Reflective Tape

Only good quality, for example Diamond White, reflective tape should be used. Targets made from tape will generally give ranges up to 150 metres depending on conditions. It is recommended that targets be cylindrical, to allow viewing from all angles, 150mm in diameter, but not exceeding 250mm, and 1000mm in length.

5.3.2 Retro Prisms

Retro prisms are required for ranges from150 metres to 1000 metres. A single prism will give reflections from ± 30° either side of the prism centre line. For 360° working, a minimum of 8 prisms are recommended. For ranges between 1000 and 2000 metres, a stack of 6 prisms is required.

5.3.3 Target Installation

The desired target should be the best reflector in the vicinity. Targets should be installed in a place appropriate for the vessel's operations, preferably at the same height as the scanner head and further away rather than nearer, as this will reduce the risk of the target dropping out during pitching and rolling of the vessel.

It is essential that the targets be mounted in areas that are clear of obstructions and away from lights and other surfaces containing reflective material such as life rafts and lifeboats. Target installation should not be close to walkways where personnel wearing reflective jackets can be confused with the target.

The use of cranes should be anticipated to ensure crane booms or loads do not obstruct targets during operations.

Thought should be given to access, to allow for cleaning of the targets.

Gating parameters can be set up in the software to gate out unwanted targets. Gating parameters include minimum/maximum range, maximum/minimum bearing (target window), signal strength and accuracy.

The position of the targets, relative to the vessel and the rising /setting sun should be addressed to avoid possible interference with target returns caused by the sun shining directly into the lens.

5.3.4 Cables

Cables should not be run close to high voltage AC cables or unscreened data cables. The deck cable connecting the scanner and the UCU can be up to 300 metres long. The cable is 7 core (24/0.02) with an overall screen and terminated with cannon type connectors at both ends.

The 28 volt power supply unit is connected to the scanner with up to 80 metres of three core (32/0.02) screened cable rated to 10 amps. The cable is terminated at both ends with cannon type connectors.

The UCU data cable, for connection to the users equipment, is a 3 core screened cable terminated at both ends with a 9-way 'D' type connector.

It should be noted that all external connections should be taped and greased to protect them from salt spray and soot.

6 Operation

Due to the optical nature of the sensor, there are a number of operational parameters that can change on a daily basis, depending on the weather and lighting conditions.

These parameters should be fully understood before the user attempts to use the sensor for DP.

Disconnecting the cable between the scanner and the UCU before a full system shut down has been completed, this takes approximately 25 seconds from pressing the 'OFF' button, can corrupt the software embedded in the UCU.

The operation of the system is controlled via menu selection using the UCU. Four basic menus are available:

SETUP	Setup of data adjustments and output, alarms, colours and input of vessel shape.
TRACK	Initiates tracking of a target, user selection of the desired target.
	Edit gating parameters, tilting the laser ± 15°, target selection.
PARK	To place the scanning head in the correct position for shipping.
COMMAND	Fanbeam® settings, gating parameters and scan controls.

The scan speed is automatically controlled by the software according to target range, as set out below:

Target Range	**Fanbeam Speed**
< 100m	50°/Second
100 – 250m	30°/Second
250 – 500m	15°/Second
500 – 1400m	10°/Second
> 1400m	5°/Second

If the scanner rotates at < 3° per second the laser transmission is turned off.

7 Servicing & Maintenance

The scanning head should be checked for cracks and corrosion at regular intervals and kept clean by washing with fresh water and a mild detergent. The laser's lenses should be cleaned using a proprietary lens cleaner.

The shaft seals should be lubricated at three monthly intervals by applying lithium based multi purpose grease via the grease nipple. The Fanbeam® should be rotated through 90° intervals to ensure even greasing.

If routine maintenance of the shaft seals is neglected or after prolonged use, the shaft seals will require replacement and this should only be done at an approved MDL service centre.

The Fanbeam® connectors should be checked for corrosion or moisture ingress. Connectors should be kept taped and greased.

8 Training

Feedback from the manufacturer indicate that many reported problems occur due to operating personnel being unaware of the operating limitations of the Fanbeam® or unfamiliar with the Windows® based software.

To ensure that DP operators understand the limitations of the system, are fully conversant with setting up software and target tracking parameters, it is recommended that onboard training be given by the manufacturers.

9 System Assessment

9.1 System Advantages

- High repeatable accuracy.
- Easy and quick to install offshore.
- Passive Targets that can be installed almost anywhere on an offshore platform or drilling rig.
- Targets do not require any support services from installation.
- Low cost compared to other reference systems.
- Data output to suit most DP systems.
- Easy to use. (Training is required to fully understand how the system operates and avoid "finger trouble" during DP operations.)
- UCU uses Windows® based software with an external monitor. Gating parameters can be changed online.
- 15° tilting laser scanning head to assist in close range operations.

9.2 System Disadvantages

- Reduced operating range in fog, snow and heavy rain. Operational range 30% to 50% better than the human eye in poor visibility. Note the operating frequency of the Mk 4 has been increased from 5000 Hz to 7500Hz to improve performance in poor visibility.
- Will not operate, or at best, performance is degraded with the sun shining directly into the lens.
- Requires care in selecting target locations. Locations must be away from reflective surfaces such as reflective tape on jackets, lifeboats, liferafts etc and other reflective surfaces such as lights and safety notices. The correct use of the gating software can overcome most problems but a better reflective surface, close to a chosen target location, is difficult to suppress.

9.3 Operational Experience

The Fanbeam® has undergone several modifications since conception and the current Mk 4 incorporates many improvements based on customer feedback.

The following customer feedback, the following improvements have been undertaken:

Corrosion – Metals now anodised or etched primed

Lenses affected by condensation – Sealed lens modification

UDU not easily read – UCU backlit and monitor added

Will not work in Poor Visibility – Operating frequency of the Mk 4 has been increased from 5000 Hz to 7500Hz to improve performance in poor visibility.

Target selection – Gating can be changed online.

With over 450 systems in use, very few problems, except for those above that have been addressed, have been reported. In general the system performs well, is easy to install offshore and, given correct treatment and maintenance, robust and reliable.

Operators point out the need to keep targets clean if they are left for some time.

Operators also point out that the sun's reflection early morning and late evening causes occasional loss of the Fanbeam® signal but never for more than for a few minutes with quick reacquisition. Lens filters have been incorporated and the scanning head can be tilted ± 15° horizontally but there are still occasions when the sun is either too bright or directly in line with a target.

10 Failure Modes

It is not the object of this report to detail the failure modes and effects of the system, but if a vessel is having an FMEA performed then the following failures should be considered and tested for:

- Failure of the vessel's vertical reference sensor as ranges and bearings input into the DP system will require correction for roll and pitch.
- Signals blocked by dirty lenses or obstructions.
- Acquisition of a false target.
- Low sun.
- Loss of serial link.
- Loss of 28 volt supply and recovery.
- Loss of encoder feedback.

11 Technical Specifications

The following section covers the technical specifications of the various components of the Fanbeam® MK4 system.

11.1 Laser

Type	Semi-conducting Laser Diode 7.5KHz Rep Rate
Wavelength	0.905μm
Vertical Beam Divergence	20°
Horizontal Beam Divergence	2.5 milli-radians
Eye Safety	Class 1 CENELEC EN60825-11
Maximum Range	2000m
Accuracy	10cm possible (depending upon target and scan speed)

11.2 Optional Tilt Mechanism

Gear Box	Servo Driven Worm and Wheel
Range	- 15 ° to +15° (5° increments)

11.3 Scanner

Construction	Die-cast Aluminium with Marine Grade Paint
Dimensions (WxLxH)	200 x 300 x 290 mm
Weight	13.4 kgs
Operating Temperature	-10°C to +45°C
Water and Dust Resistant	IP66
Scan Speed	Up to 50°/s
Optical Encoder	0° to 360°
Angular Resolution	0.01°
Angular Accuracy	±0.02°
Current Loop	20mA
Baud Rate	9600 bps

11.4 Universal Control Unit

PC Specifications	
CPU	Cyrix Media GX 266Mhz
Memory	32Mb RAM
Storage	32Mb Compact Flash Module
Display	800 x 600 x 256 VGA
Sound	16 Bit Stereo
Operating System	Windows® NT 4.0 Embedded
I/O	2 x 16550 UART RS232

[1] *The laser is Class 1 (in accordance with IEC 60825-1 Edition 1.2) and the manufacturer advises that no particular restrictions on proximity of personnel to the equipment are necessary in this regard.*

User Input	
Keyboard	Custom back-lit with numeric/cursors/DEL/ENT/ON/OFF
Mouse	Micro-module Mini Joystick Two Button Mouse
Connectors	
Fanbeam	8 Way PT02A128P Deck Cable Male
Monitor	15 Way VGA Female D-Type
Data	9 Way RS232 Male D-Type

11.5 Scanner

Housing	
Type	Die-Cast Aluminium Al Si 12
Dimensions (WxHxD)	240 x 160 x 67 mm (not including connectors or bracket mounts)
Mount	250 x 100 x 48 mm U-Bracket
Environmental	IP41 (Not designed for outside use)
Temperature	
Operating	-10°C to 55°C
Storage	- 20° to + 75°C
Weight	6 kgs
PSU	
Universal Input	85V - 264V AC / 47 - 440Hz
Universal Output	28V DC 3.5 amps
Dimensions (WxLxH)	160 x 260 x 140 mm
Weight	3.75 kgs

The International Marine Contractors Association

A Review of Marine Laser Positioning Systems

Part 2 – CyScan

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November 2003

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IMCA M 170 Part 2

Part 2 of this document was prepared for IMCA, under the direction of its Marine Division Management Committee, by ALSTOM.

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A Review of Marine Laser Positioning Systems
Part 2 - CyScan

IMCA M 170 Part 2 – November 2003

1 Executive Summary

This report has been prepared to give IMCA members a review of the CyScan II System when used as a positioning reference for the automatic dynamic positioning (DP) of marine vessels.

The CyScan II is a software-driven laser reflective position measurement system designed to be a suitable position reference sensor for DP control. The present system has been on the market for about two years and the manufacturer advises that currently (July 2003) there are about 40 units operating in the field.

This report, *Part 2: CyScan* is the sister document to IMCA M 170 – *A Review of Laser Positioning Systems Part 1: MK IV Fanbeam* – of June 2003. It describes and reviews the CyScan system, considers advantages, disadvantages, required training and maintenance, failure modes and provides operational feedback from users.

2 Introduction

2.1 Purpose of Report

This report has been prepared by Guidance Control Systems Ltd, with input from ALSTOM. Operational experience has also been drawn upon by IMCA from current users.

CyScan is manufactured in the UK by the specialist engineering and software company, Guidance Control Systems Ltd, while the Marine & Offshore division of ALSTOM provides the marketing and sales activities, installation and after sales support.

2.2 Principle of Operation

CyScan is a software driven, opto-mechanical position measurement system. It operates on the principle of infra-red laser 'time-of-flight' to pre-positioned retro-reflective targets. It has proved a successful position reference sensor for dynamic positioning control.

Many industrial range-finding applications for laser utilise the ability to form a narrow well defined beam to achieve high accuracy. These applications are constrained by the need for great environmental stability however this is not a characteristic that is available in marine operations due to the various axes of wave motion. Compensation for this motion is achieved in two ways. Firstly by using a broad vertically divergent beam and secondly by dynamically stabilising the sensor head.

The system comprises two major components:

- A sensor, which incorporates the rotating scanner head with laser optics, the stabilisation hardware and electronics for control, signal processing and communications.

  The rotating scanner head design (as with a conventional microwave radar scanner) gives a continuous 360° panoramic view of the vessel's surroundings and possible target locations. It rotates at 360° per second while the laser pulses at 30 kHz thereby giving a potential of 80 measurements for every 1° of rotation.

  The time interval between transmission and reception of the reflection allows the distance to the target to be calculated with high accuracy. The signal output from the sensor feeds directly into the DP system.

- The console usually comprises a standard laptop computer running dedicated software on Windows XP™. This gives the operator a graphical display of the vessel in relation to the target layout and numeric data of range, bearing and heading together with information on the sensor operating mode and current status. Hardware options other than a laptop computer can be provided to suit a vessel owner's specific requirements.

Other components to complete the system include a 24VDC stabilised power supply and an RS232/485 converter. A range of retro-reflective targets is available to allow its use at different ranges and vessel orientation

2.3 Range and Accuracy

The maximum operating range is dependent on the type and size of the retro-reflective targets that are employed.

Ranges in excess of 1000 metres can be achieved with a sophisticated optical prism reflector and even greater ranges would be expected with a matrix of such prisms, but optical prism reflectors are costly, relatively fragile devices which for practical reasons are never used other than for experimental purposes. Thus range is limited to 400 metres in the majority of operating environments.

Use of targets which are not of equivalent specification to the units provided by the manufacturer may produce unreliable results.

For ranges up to 400m, a flat aluminium plate 2m x 0.35m covered in a high grade retro-reflective coating is used. Smaller 1m x 0.35m flat targets are effective up to 250m. It should be noted that flat targets have a relatively narrow angle of view requiring an angle of incidence of >45° to the reflective face.

Cylindrical targets overcome this limitation giving complete flexibility of approach angle. These are 1.5m high x 0.2m diameter and are entirely coated in the reflective material. Cylindrical targets are effective up to 200m.

The sensor head gives an angular resolution of 0.006° (0.1 mrad) with a range resolution of 10cm. Operationally, positional accuracy in an active marine environment is typically approximately 0.05% of the measurement range when used with an optimum target layout. This equates to 10 centimetres over a 200 metre range. The manufacturers emphasise that this is a likely realistic estimate in operating conditions.

2.4 Multiple Target Operation

The rotary sensor head design makes this system particularly suited to use in multi-target mode with up to five targets. With more than two targets a level of redundancy is available that can cope with the temporary obscuration of a single target. Non-equal spacing between targets strengthens this ability and enhances the tracking capability of the system particularly in relation to false reflections. This is because the differences in spacing tend to make the calibration unique and easier for the system to identify.

For one off, quick docking manoeuvres, it can be used adequately in single target mode to give range and bearing to a specific point.

However, multi-target mode makes enhanced levels of positional data available to both the system operator and directly to the DP system, particularly in relation to the heading of the vessel relative to the target layout.

This capability is especially beneficial in applications where the requirement is to maintain a close stand-off distance or where the target is moving due to weather or operational conditions such as in shuttle tanker, diver support or pipelaying applications. The vessel's position is calculated and maintained relative to the target layout's co-ordinate frame. Multi-target operations do not require inputs from other position references such as gyrocompasses, as the system is aligned with the ships head and is referenced to that. A DP system can take the information from the system and combine that with its gyrocompass and other input information.

3 Conclusions

The CyScan system offers a useful, relatively cheap positioning reference for positioning of marine vessels. The system uses non-powered static targets that are intrinsically safe and can be easily mounted in almost all areas of an offshore platform or drilling rig. Fog, snow and heavy rain will reduce its operating range, although the operational range is still 30% to 50% better than the human eye in poor visibility.

The system can operate in single target mode but is particularly suited to multi–target mode. It does not rely on gyro compass input.

The manufacturers recommend that any user of the system should be familiar with its underlying principles, particularly in appreciation of target placement, tracking and that onboard training should be given. There are training establishments in USA and UK.

The accuracy levels given in the text are based on operational use in a marine environment.

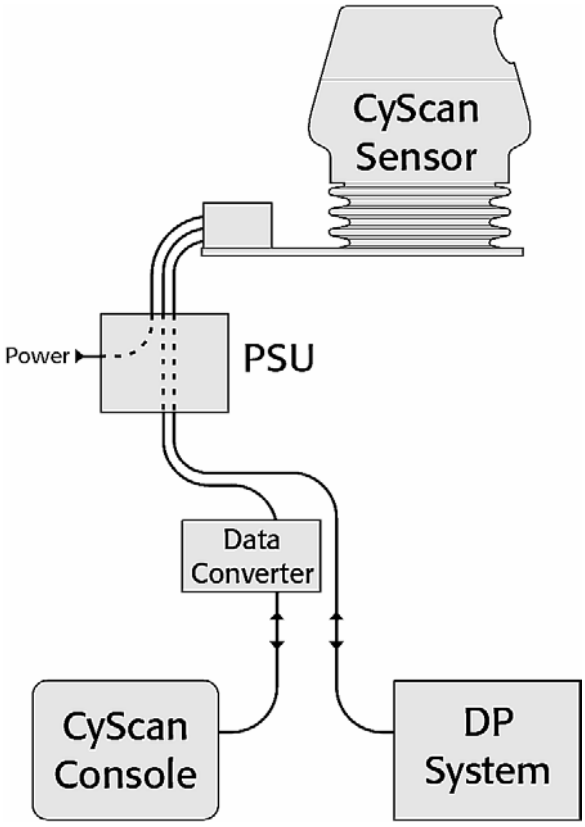
The system should be tested, in conjunction with the DP control system, for the failure modes (Section 10) to ensure that they cannot produce a drive off, large change of position or gradual drift in position.

4 System Description

4.1 Overview

A CyScan system comprises a sensor, console, stabilised power supply unit (PSU), and serial data converter.

The sensor is typically installed in a prominent position on the vessel to ensure a clear field of view in the likely direction of targets. The sensor is connected to the DP system via the power supply and independently from the display and control console. The display and control software is run on standard PC hardware.



4.2 Sensor

The unit is self-contained and incorporates the rotating scanner, self levelling platform and dedicated electronics for automatic control, signal processing, data logging and communications. The sensor unit is enclosed in an impact resistant composite shell and weighs 27kg.

4.2.1 Rotating Scanner

The rotating scanner is an integral part of the sensor unit and contains both transmitter and collector optics within an IP66 rated aluminium casing. The optics are sealed with a window and gasket.

The system uses a pulsed laser diode source operating at 904nm and optical design to produce a horizontally narrow (0.23°) and vertically divergent (16°) beam. The scanner rotates at a constant speed regardless of range. A high performance narrow bandpass optical filter prevents detector saturation from low sun and strong artificial lights. The laser system is constructed to be totally safe under all possible conditions including very close proximity. A safety interlock switches the laser off in the event of rotor failure.

CyScan has classification as a Class 1 laser device and the manufacturers advise that no particular restrictions on proximity of personnel to the equipment are necessary in this regard.

4.2.2 Self Levelling Platform

The scanner is mounted on an automatic self-levelling platform which dynamically compensates for the roll and pitch of the vessel due to wave motion. The tilt of the platform is driven by stepper motor actuators which are controlled by a sophisticated circuit taking inputs from solid state gyros.

Wave motion compensation of up to 10° for a 15 second wave period is available.

The self-levelling platform works in conjunction with the vertical divergence of the beam to give a total incline capability of 56°. This ensures continued target tracking even in high sea states.

4.3 Console

CyScan is entirely software driven; there are no manual controls. An intuitive user interface runs on standard PC hardware with Windows XP™ operating system.

The interface includes a simple high visibility display of real-time range, bearing and heading data which is colour coded, red through green, to show its statistical validity.

A screen graphic presents the vessel outline in relation to the observed target configuration. The system can be integrated into a suitable bridge console as a switchable independent application or run on a standalone PC.

4.4 Power Supply Unit (PSU)

An external power supply unit is available to ensure a stabilised 24VDC to the sensor head. The unit contains a switched mode supply and operates in the range 90 to 264 VAC.

The PSU is supplied complete with a data-cable assembly and is rated to IP66.

5 Installation

5.1 Sensor

The sensor head should be installed on a level, rigid, vibration free mount that allows free 360° rotation even at maximum incline of the self-levelling platform.

Care should be taken to mount the sensor away from sources of dust, smoke, water spray or radiant heat. Some operators may require more than one mounting point on a vessel for task flexibility. In such cases the installation can be considered semi-permanent, as fixing is straightforward with 4 locating bolts and military grade (IAC PP series) electrical connectors.

5.2 Console

The PC running the control and display console can be installed at any convenient internal location but typically in the vicinity of the DP control console.

5.3 Retro-Reflective Targets

The retro-reflective targets are installed at target locations to suit the application. The use of 3 or more targets imparts redundancy to the system and considerable immunity to false reflections or the temporary obscuration of targets. Multiple targets should be installed on approximately the same horizontal plane. It is recommended that target spacing be at least 10m, and when using 3 or more targets that the spacing between them is unequal in order to maximise tracking efficiency.

6 Operation

On arrival at a required DP station the operator can either use a previously archived target location file or carry out a new survey to find the available targets.

The use of archived files speeds its use as they contain data on the expected target positions, required sensor tilt angles and tracking sectors that are appropriate to that location. Once selected and confirmed, the system is switched into 'navigate' mode.

When approaching a new location the system is first used in Survey mode to find all available reflective targets. These are displayed graphically on the display for the operator to select those that are most appropriate to the DP manoeuvre. Once selected and confirmed, it is switched into 'navigate' mode. The operator is able to select angular sectors within the full 360° circumference in which the scanner will not take measurements. This concept of blanking zones can enhance target tracking by excluding reflections from other docking stations or potential interferences that are in the vicinity.

When navigating automatically the display shows the relative position of the vessel to the target(s) together with any selected blanking zone and the settings for the self-levelling platform. Real-time numerical values of target range and bearing and, where appropriate, heading are shown. A colour-coded bar graph shows the quality of the overall position measurement.

The operator can toggle between four different 'property' pages within the main console display:

- **Alarms page** - lists any messages that have been received from the scanner head. These are classified in importance with colour; Grey for Information, Orange for Warning and Red for Failure.
- **Reflections page** - gives a tabulated list of each target that has been seen during the last scanner head revolution.
- **Mooring Point page** - lists the currently stored mooring points and the reflectors associated with each.
- **Configuration page** - allows selection of DP Feed type and selection of the Day or Night display modes. The page also contains notes of CyScan serial number, software version and vessel identity.

The system can be Shut Down to close all functions completely, or set to Suspend which puts the system in stand-by for quick return to full operation.

A Help function loads Acrobat Reader and displays the operator's manual on the screen.

DP Message Format

The system has been designed to be fully compatible with all types of DP control system. A number of different message format types are available. These are selected from within the software package and include:

- Guidance Control Systems standard
- Simrad standard and legacy
- MDL standard and legacy
- Artemis standard

7 Servicing & Maintenance

The sensor head is relatively maintenance free and requires no calibration. Early models required that the gearbox be topped-up with grease through the available nipple on an annual basis but later models are fitted with 'a sealed for life' gearbox requiring no additional lubrication.

A regular inspection of the sensor head is recommended to ensure the integrity of the external housing as damage or cracking could lead to water ingress and damage to the internal mechanism.

The performance of the system is dependant on the clarity of the optical window. It is recommended that this is checked for integrity and cleanliness on a regular basis, depending on the operating environment. If necessary the window should be carefully cleaned using a lint-free cloth and alcohol based cleaner. If cracked or damaged the window must be replaced by a competent service engineer.

The signal and power connectors are of military sealed design but should be checked for fastness or damage, together with the associated cabling.

The system is manufactured in a modular format. This approach aids fault diagnosis in the event of hardware failure and simplifies the repair process, reducing downtime. Three colour coded LEDs are mounted on the external casing of the sensor. These give a visible indication of the status of the internal embedded PC, the leveller control circuit and the DP communication channel.

8 Training

CyScan is a sophisticated software driven electro-mechanical device with multiple operating modes and features to suit a number of different applications. It is considered essential that any user of the system is familiar with the underlying principles of the system, its operation and limitations. Particularly important is an appreciation of target placement and tracking.

It is recommended that onboard training be given by the ALSTOM representative on site. CyScan training can also be given at the ALSTOM Training Academy in Houston USA and GCS Ltd in the UK.

9 System Assessment

9.1 System Advantages

- Using a multiple target configuration provides the other vessel's heading which the operator or DP system can use to maintain a relative heading.
- Can operate to maintain heading to a moving target without the need for gyrocompass input;
- Multiple target configuration gives relative heading data;
- Passive targets require no power and little maintenance once installed;
- Low cost compared to many other reference systems;
- Data output to suit all DP systems;
- Sensor provides range, bearing, heading and status alarm messages to the DP system;
- Signal processing gives high level of immunity to false reflections and environmental clutter;
- Optical design gives high level of immunity to bright light sources including direct sunlight.

9.2 System Disadvantages

- Range is limited to 400m in the majority of operating environments;
- Operating range is greatly reduced in fog, snow and heavy rain although the operational range is still 30% to 50% better than the human eye in poor visibility;
- Care is required in selecting optimum target locations. Particular care should be taken to ensure unequal spacing of multiple targets and that line of sight is maintained throughout the operation. Permanent location of targets is recommended;
- Optimum performance requires the use of manufacturer's own targets.

9.3 Operational Experience

CyScan was first produced in small numbers in Mark I form during 2000. Feedback from marine users prompted a number of design and software changes leading to the launch of the Mark II model early in 2001.

The manufacturers advise that there are about 40 CyScan units in the field (as at July 2003). CyScan II has undergone a number of modifications to enhance performance, reliability and ease of use. These include:

- Strengthening universal joints;
- Strengthening actuator mechanisms;
- Introduction of 'sealed for life' gearbox;
- Introduction of a new graphical interface to separate installation and operation functions thereby improving day-to-day ease of use;
- A second set of status LEDs was added to improve visibility;
- The laser pulse frequency was increased from 7.5 to 30kHz to improve position measurement performance.

10 Failure Modes

It is not the intention of this report to detail the failure modes and effects of the system, but if a vessel is undergoing an FMEA, a number of failure modes can be envisaged. These can be the result of mechanical, electronic, communications, operational or services failure. The following are for illustrative purposes and not intended as an exhaustive list:

- Mechanical failure of any component module is likely to render the system inoperable.
- Electronic failure of any component is likely to restrict operation or render the system inoperable.
- Target(s) obscured by dirt or fog may lead to loss of positional awareness by the system.
- In single target mode, obscuration of the target by a solid object will lead to loss of positional awareness by the system.
- In multi-target mode, obscuration of 2 or more targets may lead to loss of positional awareness by the system.
- Loss of the power supply or serial connection between sensor head and DP system will render the system inoperable.
- Failure of the PC will prevent any change to the operational parameters of the sensor but will not interrupt message feed to the DP system.
- Incorrect setting of the blanking zone can lead to loss or inability to achieve of target tracking.

11 Technical Specifications

The following section covers the technical specifications of the CyScan system.

11.1 Scanner Optics

Type	Pulsed semi-conductor laser diode operating at 30kHz
Wavelength	904 nm
Beam divergence	16° vertical 0.23° horizontal
Eye safety	Class 1 CENELEC EN60825-11
Maximum range	400m depending on environmental conditions
Range accuracy	0.05% of range
Angular resolution	0.006°

11.2 Self-levelling Platform

Range	Continuous from - 20° to +20°
Operation	Automatic or manual (horizontal, fixed offset)
Pitch, roll, yaw sensors	Solid state gyros
Drive mechanism	Stepper motor controlled linear actuators
Maximum tilt speed	5°/sec
Wave motion compensation	±5° for 15 second wave period ±2.5° for 5 second wave period

11.3 Sensor

Construction	Aluminium frame with composite shell
Dimensions (WxLxD)	340 x 460 x 440 mm
Weight	27 kgs
Operating Temperature	-10°C to + 55°C (70°C)
Environmental	IP66 rated
Scan Speed	360°/s
Optical Encoder	0° to 360°

11.4 Console

PC Specification (minimum)	
Processor	Intel Pentium III or equivalent
RAM	128Mb RAM
Display	1024 x 768 XGA
Operating System	Windows XP Professional
I/O	9 Way RS232 Male D-Type at 38400 baud
User input	Keyboard and pointing device

1 The laser is Class 1 (in accordance with IEC 60825-1 Edition 1.2) and the manufacturer advises that no particular restrictions on proximity of personnel to the equipment are necessary in this regard.

11.5 Power Supply Unit

Enclosure	Die cast aluminium – powder coated, complete with cable connection to CyScan Sensor
Dimensions (WxLxD)	260 x 360 x 110 mm (including cable glands)
Environmental	IP66
Operating temperature	-10°C to 55°C
Storage temperature	- 20° to + 75°C
Weight	4 kg
Universal Input	90-264V / 63-47Hz
Output	22-26VDC 200W

11.6 Serial Converter

Enclosure	Plastic with Perspex lid
Dimensions (WxLxD)	130 x 200 x 130 mm (including cable glands)
Environmental	IP66
Operating temperature	-10°C to 55°C
Storage temperature	- 20° to + 75°C
Weight	1 kg