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FARO®
LASER SCANNER LS

Recording reality's digital fingerprint

The measure of success

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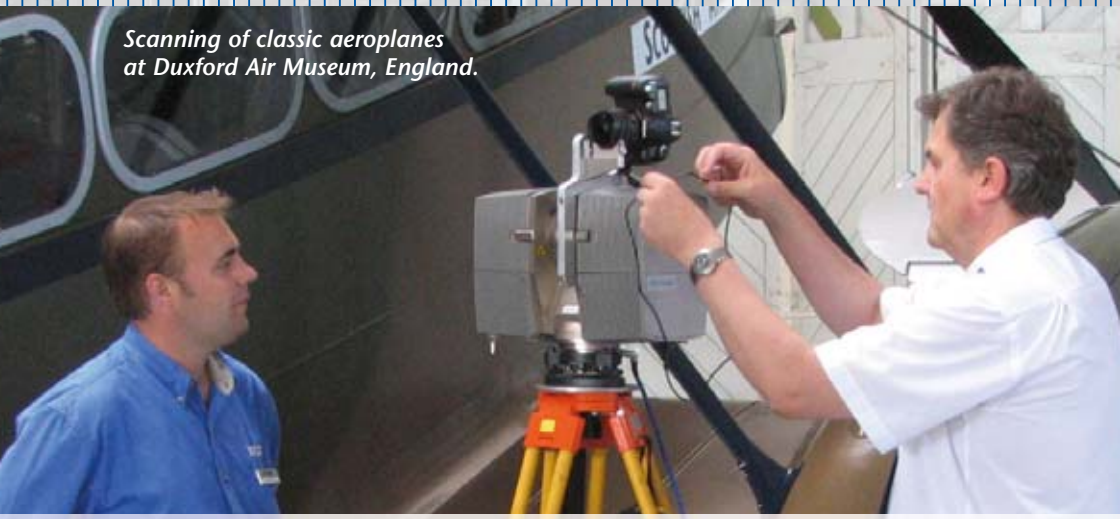


Scanning of classic aeroplanes at Duxford Air Museum, England.

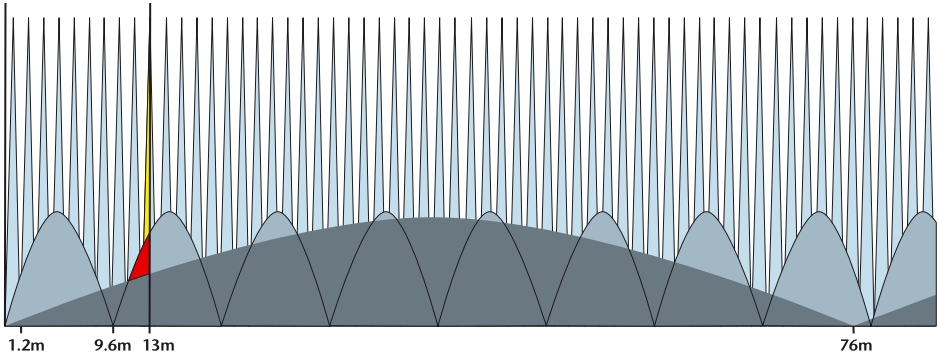
Focus:
on the technology

The FARO Laser Scanner LS works by sending an infrared beam into the centre of a rotating mirror. This deflects the laser on a vertical rotation around the environment being scanned, the beam is then reflected back into the scanner and the "Phase Shift" of the infrared is measured giving the distance of the laser from the object. Using encoders to measure the mirror rotation and the horizontal rotation of the Laser Scanner, the X,Y,Z coordinates of each point can be calculated. Once a scan has been made the user can easily navigate a 3D view where the entire scan data can be inspected and analysed. The on-board PC enables the scanner to be operated without the use of a laptop.

To measure distance FARO's Laser Scanner LS uses „Phase Shift" technology as opposed to „time of flight" distance recording. This means that instead of a single pulse being reflected and the time of flight being measured, constant waves of varying length are projected. Upon contact with an object they are reflected back to the scanner. The distance from the scanner to the object is accurately measured by measuring the phase shifts in the waves of infrared light.

The Laser Scanner LS splits the laser beam into 3 component parts operating on 3 different modulation lengths 76m, 9.6m and 1.2m, as shown in the wave modulation diagram on the next page. The distance of the reflecting object from the scanner is determined by identifying the location oof the reflection in the 1.2m cycle. Firstly the cycle the reflection occured has to be iden-

Phase shift laser measurement



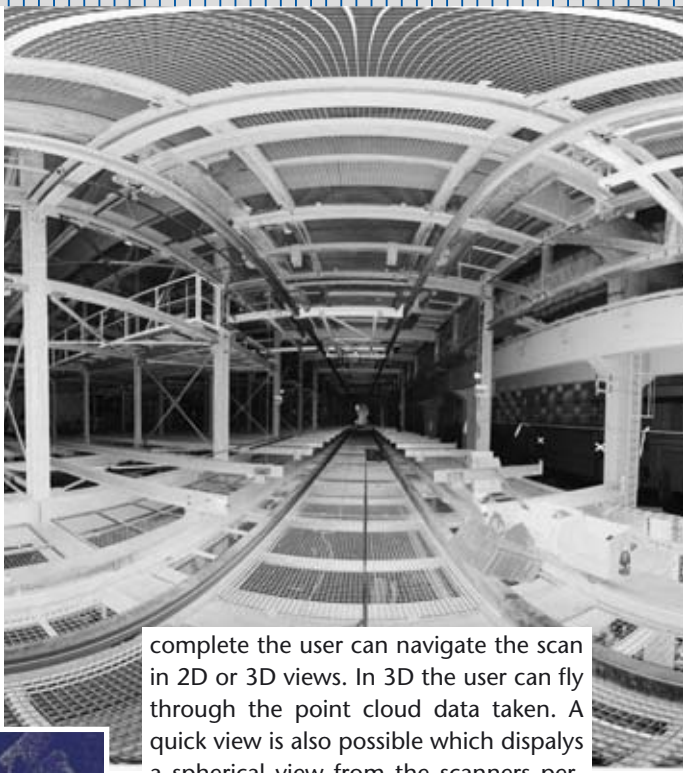
tified as the beginning of each cycle will begin the distance reading again. I.e. a distance of 2m measured only on the 1.2m modulation would only read as 0.8m as the measurement was in the second cycle but there is no longer modulation length to indicate this. This is known as inambiguity. For example a reflection from 13 meters will register within the 76m range as shown by the light green area on the diagram. This is within the second cycle of the 9.6m range as shown in light red, and The accuracy is achieved by measuring in the 2nd cycle of the 1.2m range after the beginning of the second cycle of the 9.6m range. Due to the 76m modulation length the FARO Laser Scanner LS is capable of measuring up to 76m without inambiguity. Points measured beyond 76m may be pushed back by the user through the software command.

The main advantage of the phase shift technology is the speed of point capture, 120,000 points per second, compared to approximatly 4,000 points per second for traditional "time of flight based scanners".

The use of 3 varied ranges means a higher degree of accuracy can be achieved over a greater distance as the specific range of the target is measured with a resolution of 17bit or 0.58mm.

The scanner consists of four interchangable component parts. The laser module, the mirror module, PC module and base module. These modules can be exchanged and upgraded by the user giving a flexibile solution for all applications

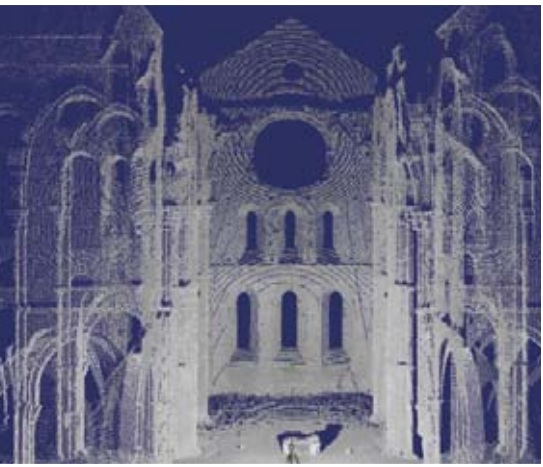
FARO Software: the next dimension of digital photography



The scanner is capable of recognising the shade of the reflected surface. This builds a 360° point cloud with grey scale which results in a black and white image similar to a 3D photograph.

The Laser Scanner LS is linked to FARO Scout software which allows the scan settings to be adjusted i.e. resolution, scan speed, scan storage location, user identification or even to select a smaller area to be scanned rather than the full 360 x 320 degrees.

With the click of one button the scan will begin and the captured data is displayed live on screen. Once the scan is complete the user can navigate the scan in 2D or 3D views. In 3D the user can fly through the point cloud data taken. A quick view is also possible which dispalys a spherical view from the scanners perspective giving a good overview of the data captured.



In order to capture objects out of the line of sight of the laser scanner, registration spheres can be placed within the area to be scanned and the device repositioned. Scans taken from a different viewpoint can then be taken. Once complete the registration spheres can be recognised within different scans and the scans linked together to complete the 3D image.

The 3D world in colour

The colour option camera

FARO Scene software is the next step, expanding the functionality of Scout by enabling tomography, data filtering and allowing the user to export data in different CAD formats such as IGES, DXF and AutoCAD. Basic features such as planes and pipes can be recognised and several scans can be registered allowing multiple views of a scanned environment.

Through the addition of a colour option, digital images can be overlaid on top of the point cloud giving a coloured image, which can also be seen in the 3D view, for enhanced realism. This offers numerous advantages in different applications such as the identification of specific pipes in a complex oil refinery or different rock types in a mine.

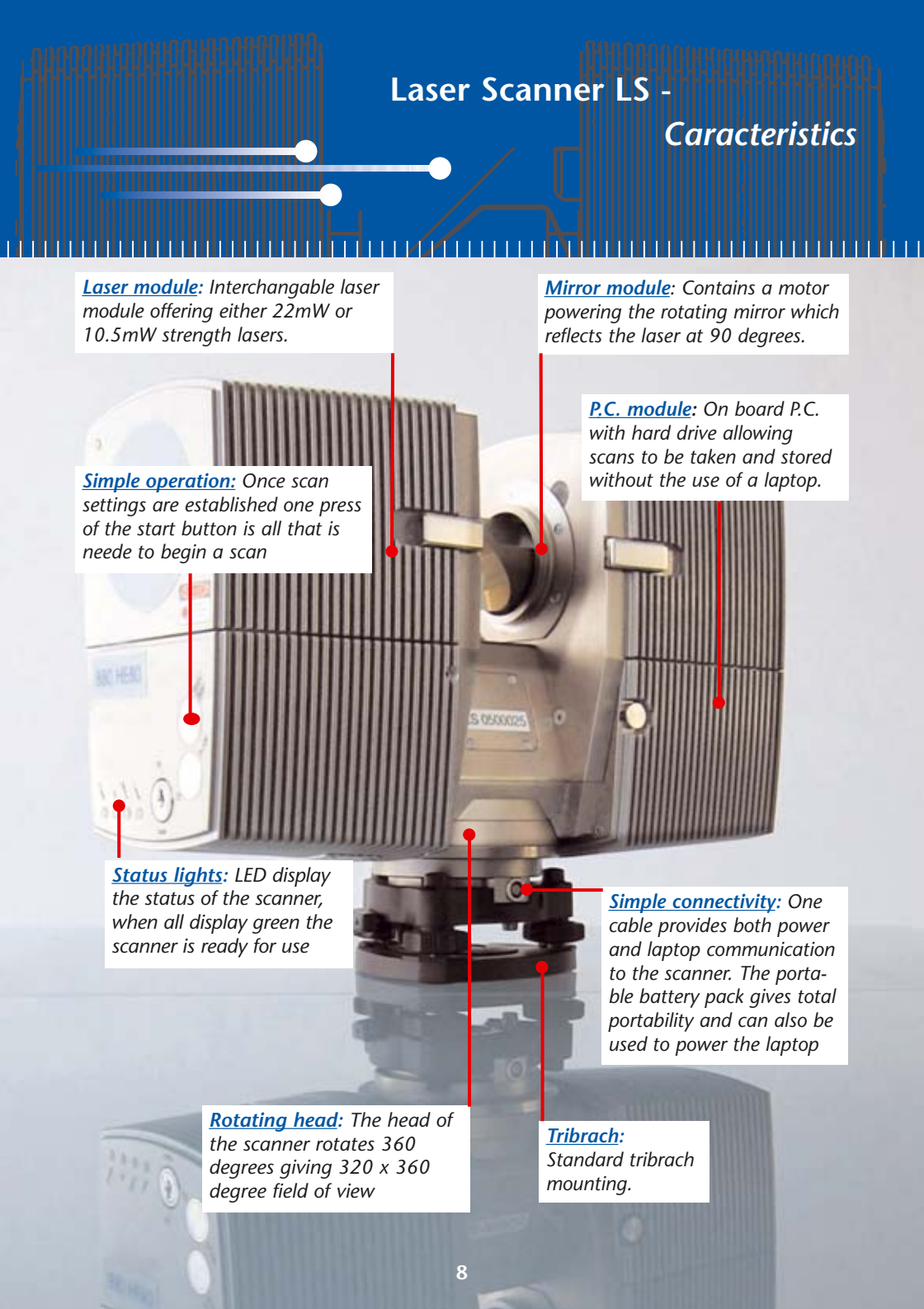
Focus on applications - *Forensic science & Accident investigation*

Digitising of Crime and Accident scenes is the next step in the analysis of reconstructing events following a crime or incident. Important factors to be considered are non intrusion, speed of scan and quality of the scan data produced. Using the Faro Laser Scanner LS a crime scene can be digitised in minutes rather than hours, this provides high quality 3D data which can be reviewed by experts over longer periods of time. As soon as a crime scene is made available to a scanning team the entire area can be captured as point cloud data. The positioning of objects and surfaces within the scan can be seen in a 3D environment giving the user a perspective which cannot be achieved through conventional recording methods such as digital photography. From this 3D dimensional viewpoint bullet trajectories can be calculated and line of sight can be demonstrated. This means that once analysed the personal viewpoints of each individual involved can be evaluated giving an accurate insight into the sequence of events as the crime was committed.

As the technique of Laser Scanning is non- contact the crime scene can be captured with minimal intrusion. This means that the scanning of the crime scene will not interfere with the object being scanned. The addition of the colour option available for the Laser Scanner LS enables colourization of the point cloud data enhancing the realism of the image and enabling easier recognition of blood patterns and details in the event scene.

The HE40 Laser scanner can be used in any indoor environment where a laptop can be operated and the HE80 model with its more powerful laser can also be used outdoors, if a lower powered laser is required for a specific application the modular nature of the scanner allows the laser module to simply and quickly be exchanged making the scanner flexible for multiple environments and conditions.

Laser Scanner LS - *Caracteristics*



Laser module: *Interchangable laser module offering either 22mW or 10.5mW strength lasers.*

Mirror module: *Contains a motor powering the rotating mirror which reflects the laser at 90 degrees.*

P.C. module: *On board P.C. with hard drive allowing scans to be taken and stored without the use of a laptop.*

Simple operation: *Once scan settings are established one press of the start button is all that is neede to begin a scan*

Status lights: *LED display the status of the scanner, when all display green the scanner is ready for use*

Simple connectivity: *One cable provides both power and laptop communication to the scanner. The portable battery pack gives total portability and can also be used to power the laptop*

Rotating head: *The head of the scanner rotates 360 degrees giving 320 x 360 degree field of view*

Tribrach: *Standard tribrach mounting.*

Laser Scanner LS-

Specifications

Ranging Unit

Distance:	35m (HE40), 70m (HE80)
Resolution:	17 Bit Range / 9 Bit Intensity
Measurement Range:	120 kHz
Linearity Error:	3 mm at 10 m[1)]

Laser (Optical Transmitter)

Laserpower (CW, average):	HE 40 10.5 mW, HE 80 22 mW
Wavelength:	785 nm
Beam Divergence:	0.25 mrad (0.014°)
Beam Diameter (at exit):	±3 mm, circular

Deflection Unit

Vertical Field of View:	320°
Horizontal Field of View:	360°
Vertical Resolution:	0.009° (40.000 3D-Pixel on 360°)
Horizontal Resolution:	0.00076° (470.000 3D-Pixel on 360°)

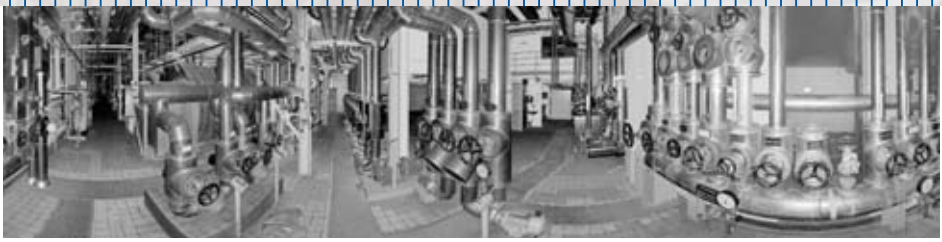
Max. vertical scanning speed: 3000 rpm

Scanning Time at 4450x2500 measurement points: ca. 104 sec.

Handling of Data

Internal PC:	Pentium III with 700 MHz, 256 MB RAM 40GB Harddisk; Windows 2000, Windows XP
Data Storage local:	on internal hard disc drive (for most resolutions) remote: via Ethernet on external PC or laptop
Data Transfer:	online during scanning via Fast-Ethernet

1) measured on a non moving orthogonal Kodak 84% reflectivity reference paper in averging mode in 1 cm steps.



In production environments where complex piping structures are in place 3D planning and design of alterations to the plant make the alterations as efficient as possible. As pipes may be be coloured according to what is being carried within them, for example gas or liquid, hot or under high pressure, the addition of the colour option enables the user to more easily identify the correct pipe section from the scan data. The colourized point cloud can be seen in this screen shot from FARO Scene software.

Often when a new product is introduced the entire pipe system has to be replaced. If the exisiting status is first documented in point cloud data and if necessary reverse engineered into CAD, then potential collisions of new structures can be assessed and the installation can be planned based on actual existing structures minimising any surprises where existing structures differ from the plans.

In potentially hazardous environments where special safety training is required minimal disruption to the working area is of the highest consideration. The Laser Scanner LS with its "phase shift" technology is up to 100 times faster than traditional "time of flight" based scanners. This enables the user to quickly capture the data required, also the software requires the user to merely set the scan parameters and with the click of one button the scan begins. This ease of use means that the scanner can be used with minimal training and minimises disruption to the production environment and potential contamination of the hardware.

Point Cloud Data

CAD Data

In the field of Architecture and Construction the Laser Scanner HE80 has the advantage, through its 70m range, 28 million points per scan and 120,000 points per second scan rate, of accurately capturing large point cloud data for the internal reconstruction of entire buildings.

Using registration spheres scans can be linked to one another to construct 3D views of specific areas or entire buildings.

Over years buildings may undergo major alterations and in many instances these alterations are not recorded in the original construction plans. For example door positions or windows may change. When planning a future addition or alteration to a building an initial 3D laser scan survey will accurately document the current layout, this means that any future plans made are based on the exact current status of the building, not on previous plans made which may or may not be correct. This naturally has the advantage of not having to rework plans during the reworking saving time and money.

Architecture scanning to Trevi, Umbria/Italy.

By cutting a cross section through a scan the 2D floor layout can be displayed. This can be overlayed over the original design plan, as above, to demonstrate alterations made to the floor layout. For example a movement of a pillar position or the removal of a The 2D design plans can then be updated for accurate as built documentation.

FARO Scene software allows simple measurements to be taken within the point cloud data, this means that immediately following a scan distances between walls and objects or lengths of pipes can be made with an instant readout. The software also has an automatic recognition feature for edges, pipes and planes such as floors and walls meaning that basic 3D models can be constructed. selected areas can the be meshed, reducing point density in flatter areas whilst maintaining detail on curved surfaces.

Using software such as Microstation a full CAD model of the structure can be recorded and accurate „as built" 3D CAD plans of the building can be produced.

Therefore any deviations from the original construction plans are included in the 3D documentation. Using 3D plans heating, ventilation and air conditioning ducts can be planned into the building and collision hazards can be identified.

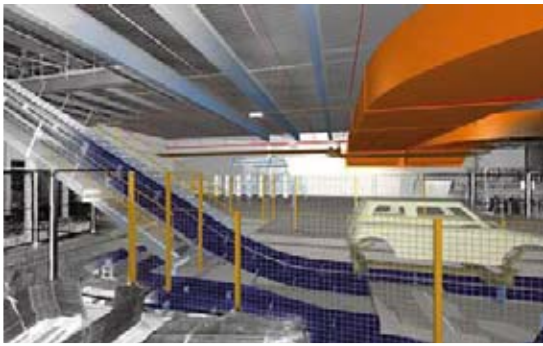
Scanning in tunnel construction

Automotive

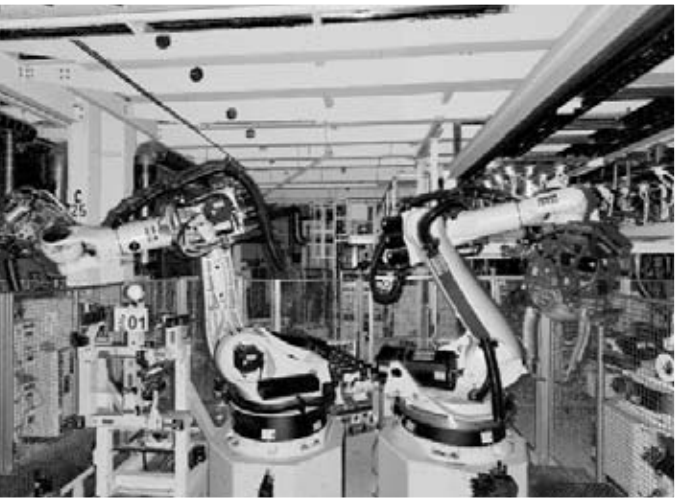
The FARO Laser Scanner LS has already been used extensively within the automotive industry for the digitizing of entire production environments and for verification of specific machines and jigs. Examples include BMW, Audi, & Nissan. Applications within the Automotive industry fall into two categories, level 1 and level 2.

Level 1 refers to larger scale applications where accuracy requirements are lower, such as the digital reproduction of an entire production line. Initially a map of reference points is created, this is done by surveying positioning bolts in visible positions around the environment to be scanned. Reference spheres are then attached to the bolts visible in each scan and the area is scanned, repositioning the scanner for each scan enables objects to be scanned from different sides.

Scans are the linked to one another within the FARO Scene software, this gives a highly detailed point cloud of the production environment allowing the user to view details as well as the complete area. VRML data can be imported directly into the point cloud to assess collision hazards when installing new equipment or modifying the production area planning the changes with the as built data.



VRML Data import into point cloud



Point cloud

appropriate correction or compensation. For the reworking or assessment of a complex production area intelligent planning will lead to more efficient implementation of new equipment and accurate documentation of current systems.

The accuracy of these Level 2 applications can be achieved with the same scanner used for Level 1.

CAD data

Level 2 Automotive applications refer to higher accuracy applications in smaller areas of the production floor. The compact and lightweight nature of the FARO Laser Scanner LS means that scans can be taken in relatively confined areas. A typical example is the verification of jig and tool alignment comparing the design to the build. This analysis will clearly show the user where the jig differs from design and allow

All about the customer - The best service

The FARO European headquaters in Stuttgart

Kiki Telliadou from FARO customer service

Following your purchase you are not just left on your own. A qualified customer-service team is at your disposal to provide advice on the telephone or on the spot. Whether to help with an application-specific query or with technical problems. Our enthusiastic customer service provides rapid and simple assistance.

For our systems FARO offers competent training courses so that you can optimally prepare your employees for working with any FARO system.

Either directly with you on your premises, or in one of our modern, well equipped training centres. Highly qualified, customer-focused trainers cater for the individual needs of the participants and their applications.

FARO products are maintained by FARO. We service all products with a pick-up and bring-in service. With the pick-up service, a replacement unit is loaned to customers while theirs is away. FARO inform users on innovations and users' experience, also organising a customer forum and maintaining regular contacts with our customers.

Special maintenance programs make sure that any FARO product is regularly certified (to comply with ISO 9000) Premium Warranty cover guarantees a loaner unit whilst your system is in service.

FARO

The product family

From the smallest to the largest measuring volumes

With the launch of the FARO Gage, FARO is offering an optimum product range for measurements between 5µm and up to 70m.

With its user-friendly software and accuracy of up to ± 0.005mm, the FARO Gage is the latest addition to the FARO family. The FARO Laser Tracker covers the large measurement volumes in the FARO product family. With a working radius of up to 70m, it uses a laser beam to measure large components with absolute precision and with the simplest of handling.

The two measurement arms, the Titanium and the Platinum, complete the measuring range up to a max. working volume of 3.7m.

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