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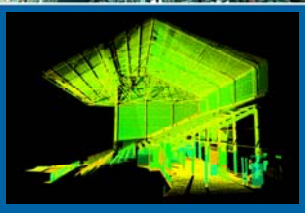
Working with Laser Scanning Survey Data



Chris Angus
Business Development Director – Bentley Professional Services

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Topics to Cover

- Introduction to Scanning Technology
- The issues that relate to the survey of the operational railway
- Some of the current business drivers
- Review of a number of case studies by scanning and data acquisition organisations
- A look into the future for track measuring and scanning
- Discussion and Question and Answer

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A BIG thank you to the following organisations

ABA Surveying

Leica Geosystems

PCA

Plowman Craven & Associates

Amberg Measuring Technique

Scantech International Ltd

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Where did the idea for Scanning come from ?

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3-d scanning – What is it ?

Most of us are familiar with digital photography and the image being made up of pixels

Pixels >>>> Image

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3-d scanning – What is it ?

In scanning jargon the Point is analogous to the pixel – with one important difference
It has a very precisely measured 3d position in space

Technical definition

a Point !

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3-d scanning – What is it ?

Just as lots of Pixels make a photograph
Lots of points make up a Point Cloud

Point >>>>> Point Cloud

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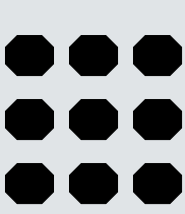
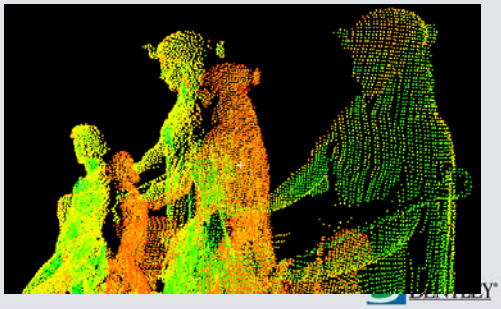
3-d scanning – What is it ?

We can control the spacing of the points to mimic the resolution of the photograph and the point cloud becomes identifiable

Points >>>>> Point Cloud





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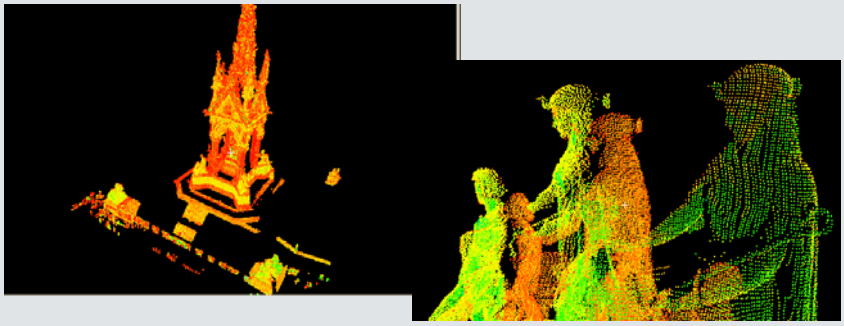
3-d scanning – What is it ?

- and one or more Point Clouds can build up the Scanworld

Scan World <<<<< Point Clouds



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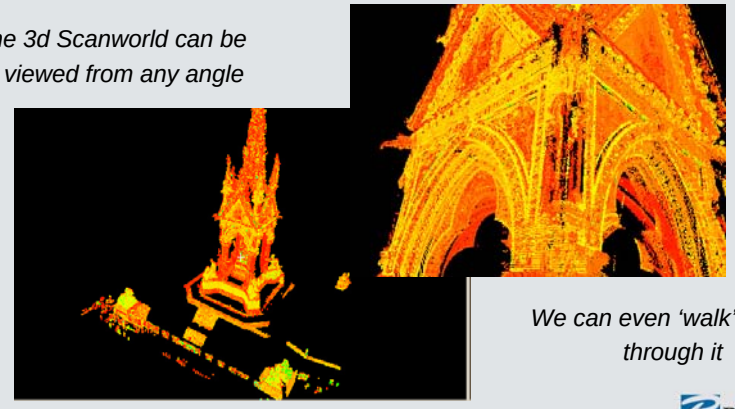
3-d scanning – What is it ?

The 3d Scanworld can be viewed from any angle



We can even 'walk' through it

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3-d scanning – What is it ?

When we combine a scanworld with a photograph we add dimensional integrity.

We obtain both condition and the ability to measure to any point in the scan for clearances or deformation purposes

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The first Hardware

- ***Cyrax***® 2500 laser scanning system
- 320 in use worldwide, several thousand successful projects
- 55 in use in Europe, 17 in UK
- Best of class for range/ accuracy characteristics

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Configuration

Laser Scanner

Laptop Computer & Software

Electronics & Power Supply

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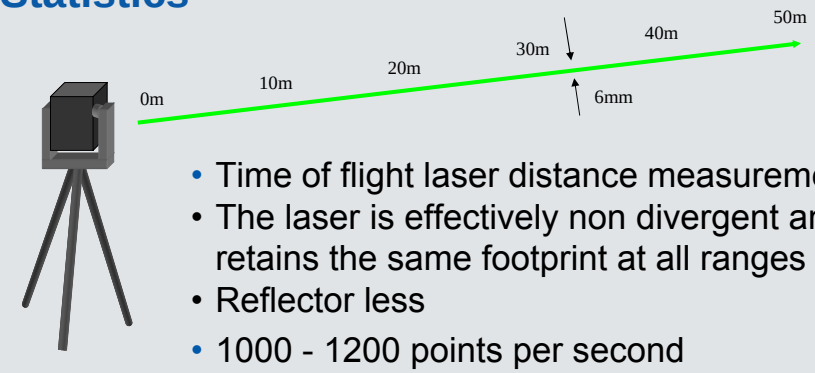
Statistics



- Time of flight laser distance measurement
- The laser is effectively non divergent and retains the same footprint at all ranges
- Reflector less
- 1000 - 1200 points per second
- 250m maximum range
- 40° x 40° aperture

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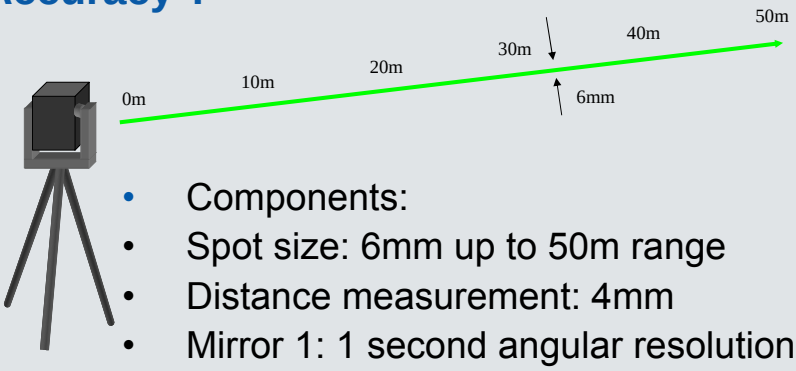
Accuracy ?



- Components:
- Spot size: 6mm up to 50m range
- Distance measurement: 4mm
- Mirror 1: 1 second angular resolution
- Mirror 2: 1 second angular resolution
- Computer driven – we have complete control over the Point Cloud density

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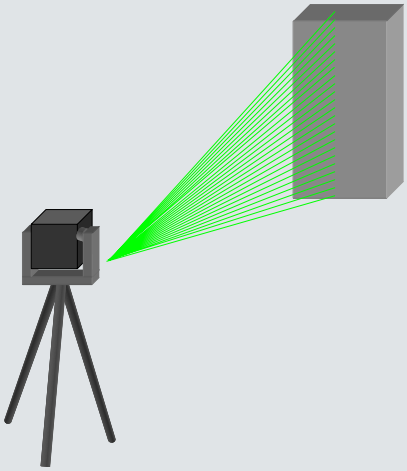
Scanning



- The movement of the beam is recorded by precise angular encoders
- The scan pattern is a series of vertical lines traversing from left to right
- Can capture 1.2mm grid at 50m
- Target fix to < 1mm
- Essential for accurate multiple scan registration

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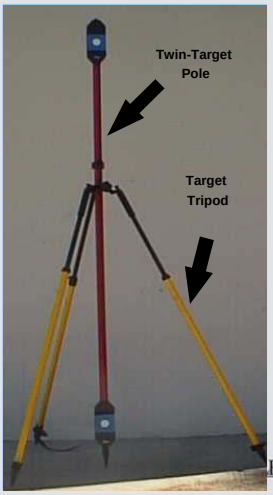
Registration

- Target based
- Cloud to Cloud
- Combination of two
- Verticality from target pole
- Change coordinate system in Cyclone



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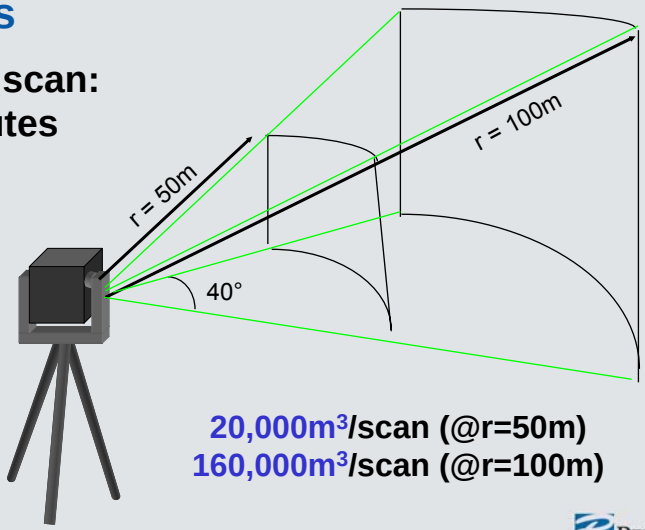
Volumes

Typical scan:
10 minutes



20,000m³/scan (@r=50m)
160,000m³/scan (@r=100m)

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ABA Surveying

The scanner is controlled through a laptop computer giving user selection of target area and resolutions etc

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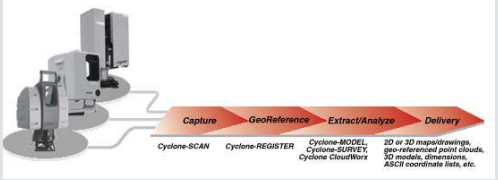
The Software



- CYCLONE 5.2 3D data visualisation, modelling and analysis software
  - More than 600 installed licenses worldwide
- CloudWorx 3.1 for MicroStation and AutoCAD
  - Provides point cloud analysis within MicroStation ONLY available from Bentley
  - AutoCAD versions from Leica Geosystems
- CYCLONE Viewer 5.2.1
  - Enables all professionals to exploit 3D point clouds
  - Freeware available at

  http://www.leica-geosystems.com/hds/en/lgs_3490.htm

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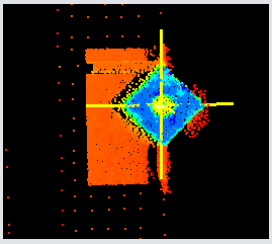
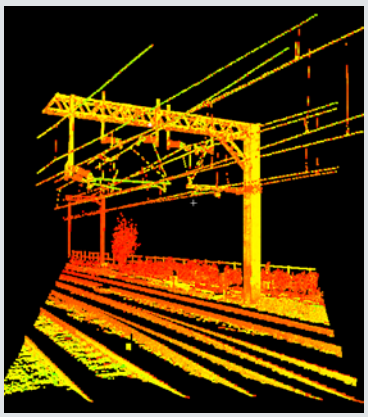
3-d scanning – What do we get ?

A dimensionally accurate point cloud that we can fit to real word coordinated points





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3-d scanning - Vs - traditional

What are the alternatives ?

- ***Total Stations***
  - *Contact measurement to a prism or non-contact by intersection*
- ***Reflectorless Total Stations***
  - *Non-contact measurement by manual pointing with an inbuilt laser EDM*
- ***Close range Photogrammetry***
  - *Non-contact measurement using stereoscopic metric photography*

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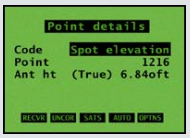
3-d scanning - Vs - traditional

- ***Total Station capture***

- *Datasets captured by total stations are based on discreet points*
- *Discreet point datasets must be fully specified by the client and thoroughly understood by the field surveyor*
- *Any missed or faulty data will require a revisit by the surveyor*

Optical



GPS

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3-d scanning - Vs - traditional

Close range photogrammetry

- *Photogrammetric accuracy requires good stereoscopic geometry (two viewpoints), good photography and good control*
- *The data is extracted from the stereo model under controlled conditions*
- *Further visible data may be extracted at any time without needing more site visits*
- *A photograph is still the best record of condition and quality*

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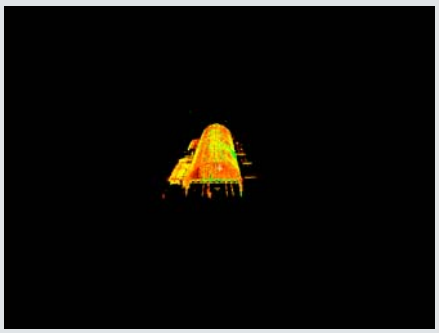
3-d scanning - Vs - traditional

Scan capture

- *Point cloud density may be defined to suite the task*
- *Data capture is typically less than 15 minutes*
- *Discreet points can be extracted easily under controlled conditions*
- *Discreet points can be validated statistically*
- *Datasets can be analysed for deviation and deformation without further site visits*
- *Datasets can be joined easily*



Flythrough of Kings Cross roof courtesy of PCA

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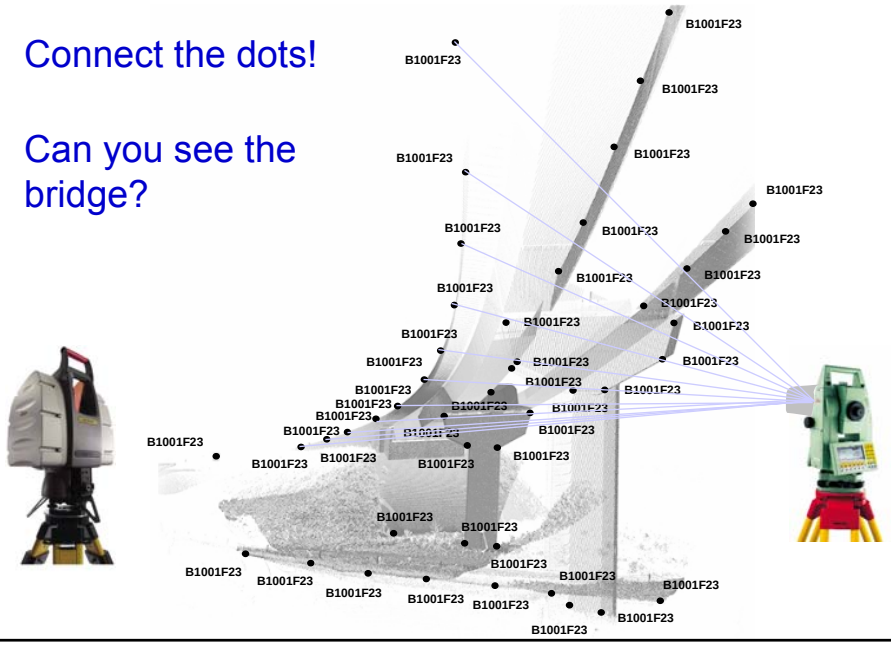
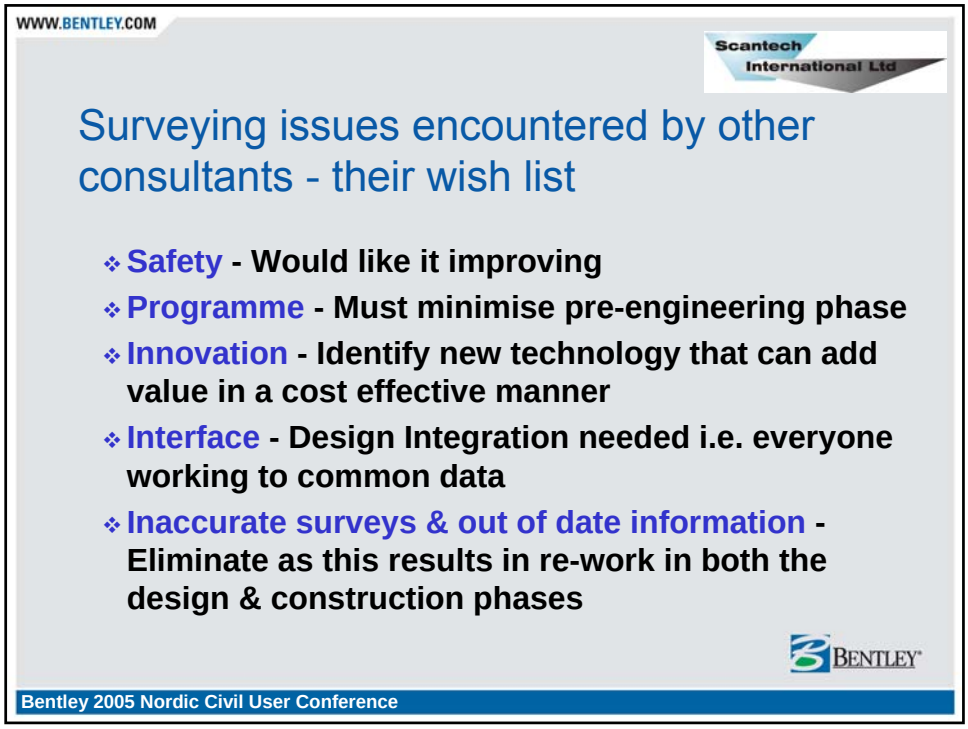
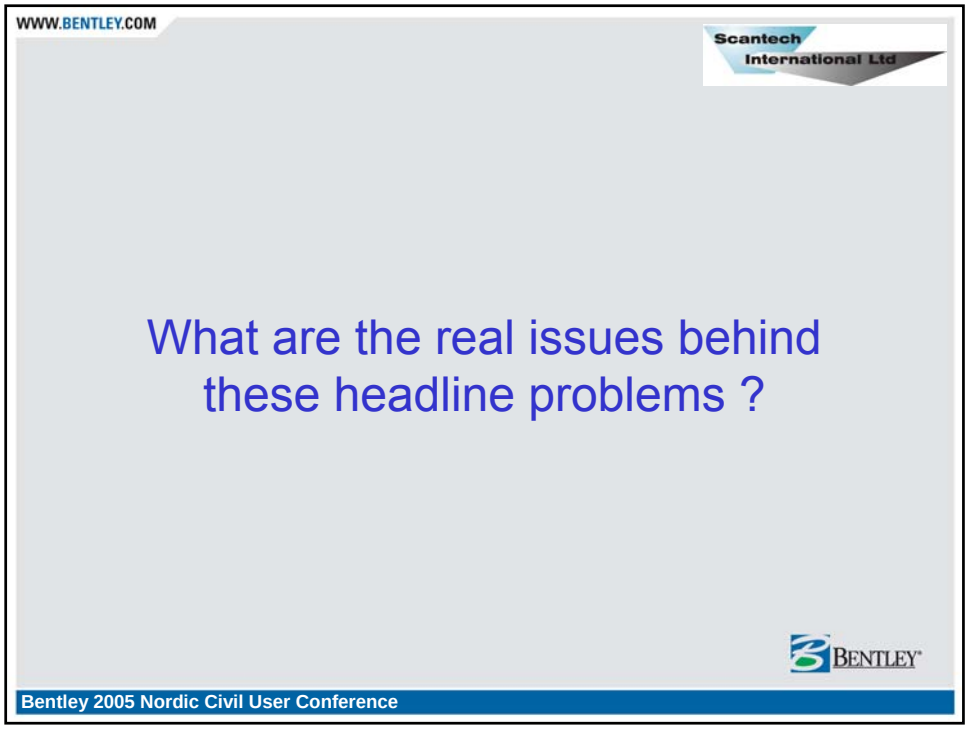
Connect the dots!

Can you see the bridge?







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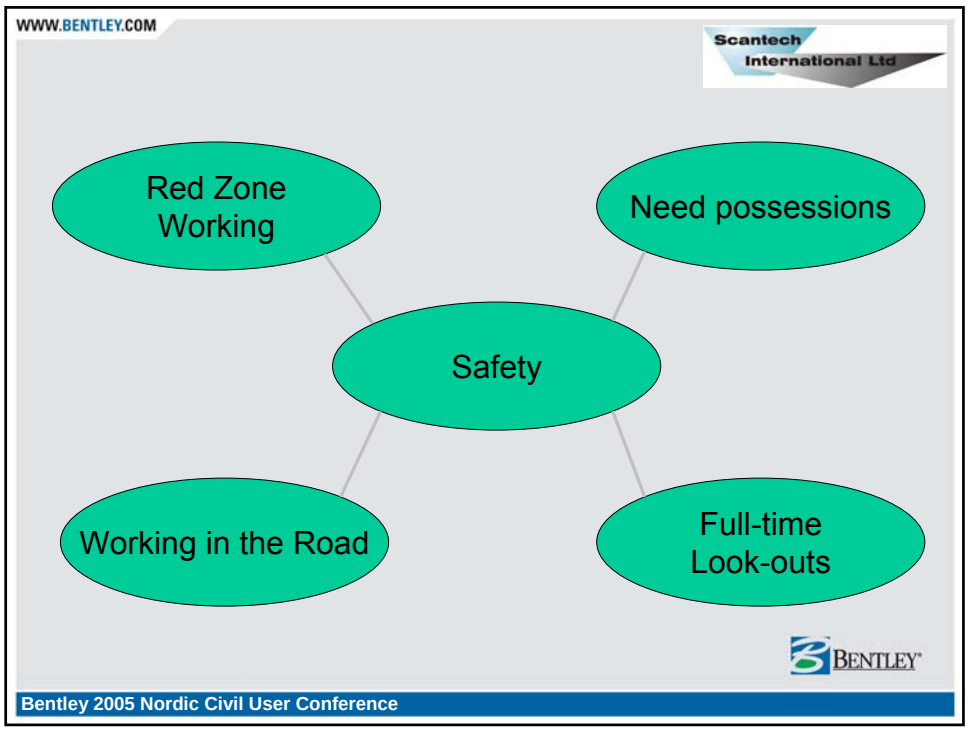

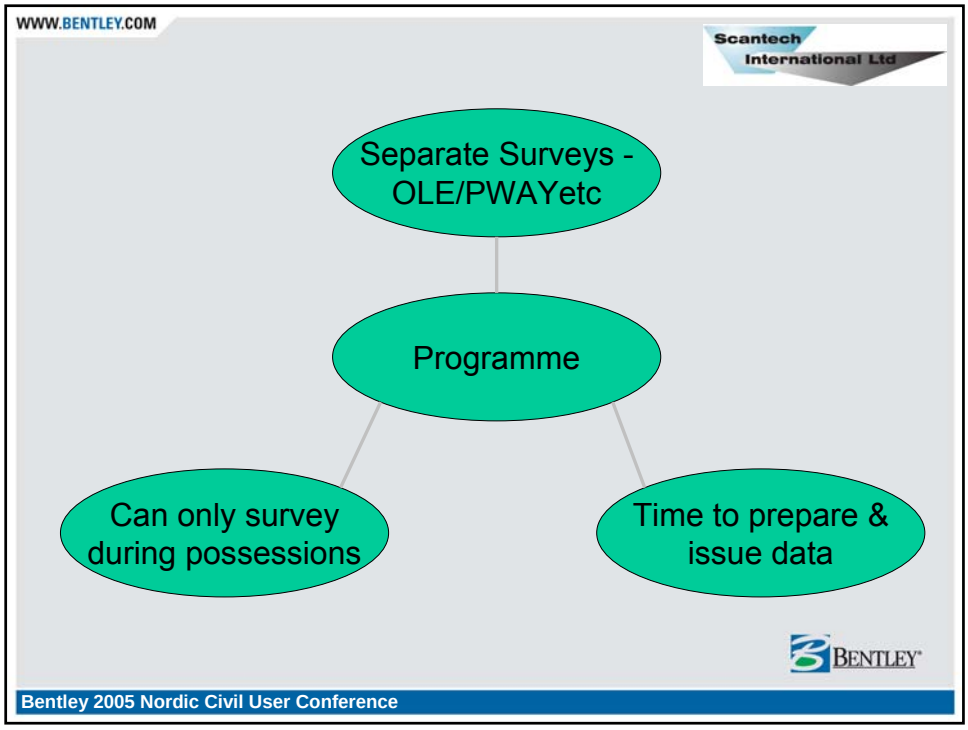

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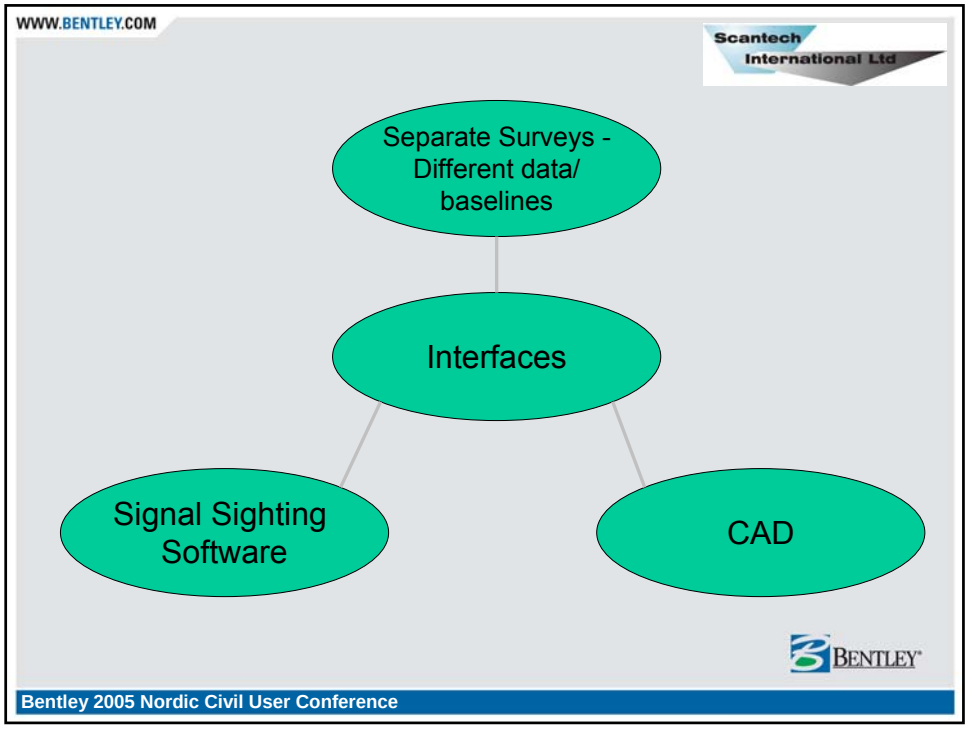

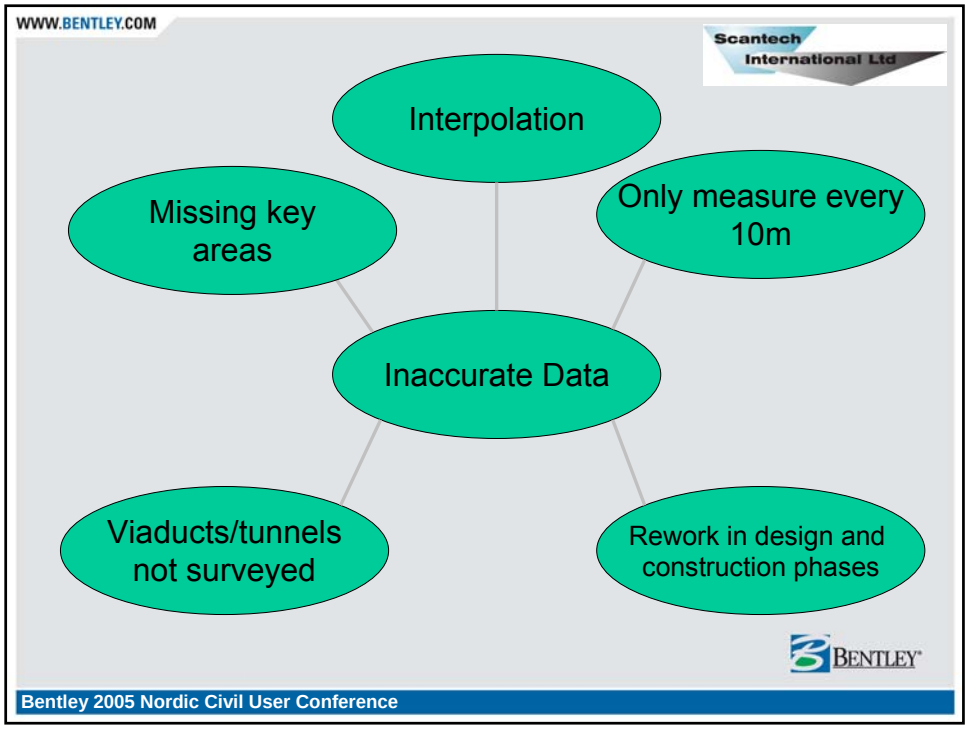

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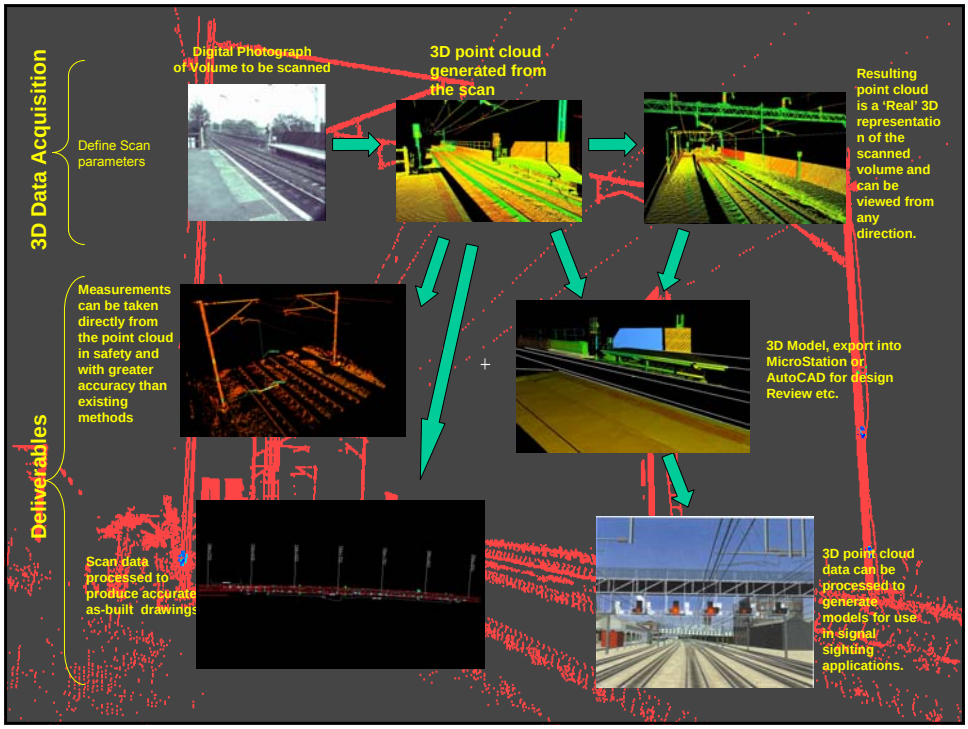

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Scantech International Ltd

Business Benefits

- **Safety** - Work in Green zone or off the road in safe location
- **Programme** - Captures all the information in one visit
- **Innovation** - It is new technology
- **Interface** - Common interface so everyone working to same data
- **Inaccurate surveys & out of date information** - Information accurate to 5mm

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Project Example 1
Macclesfield Tunnel

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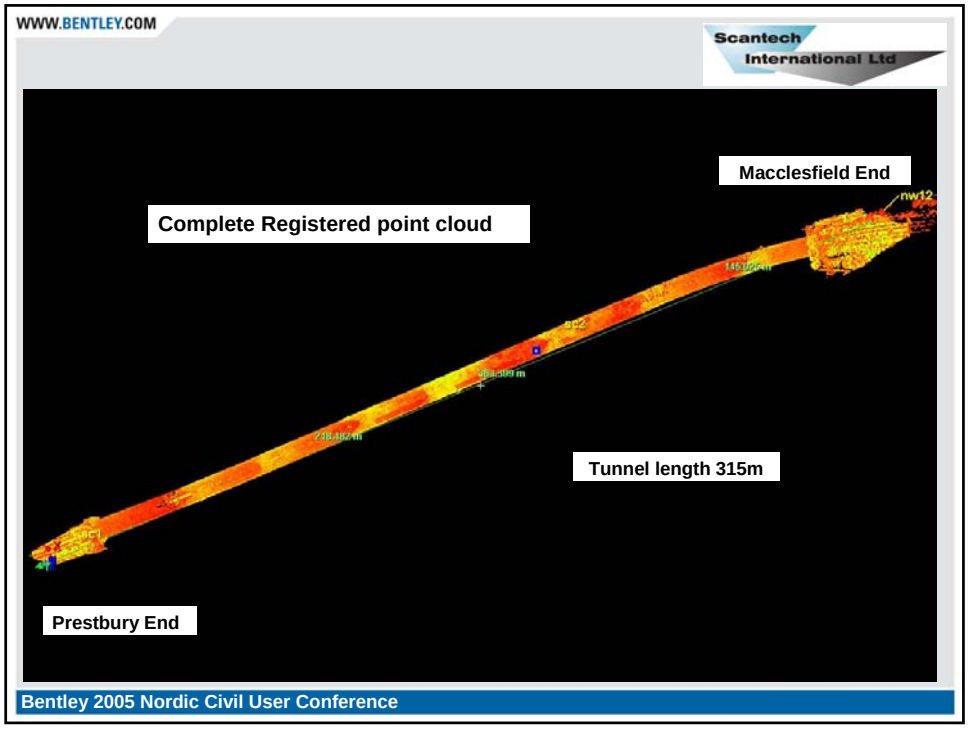

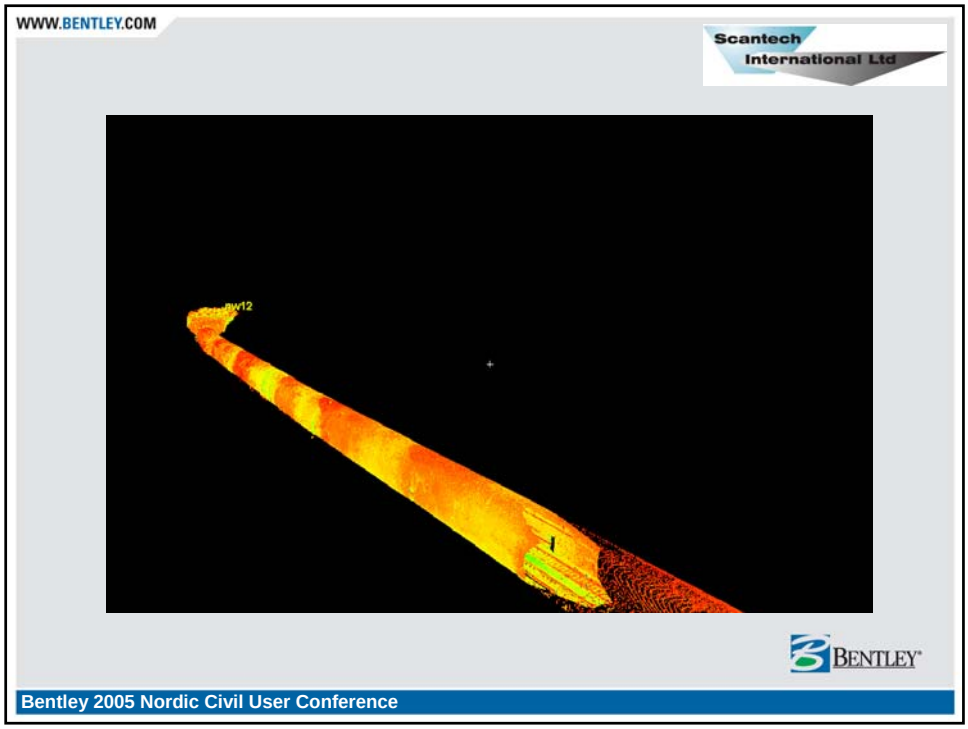

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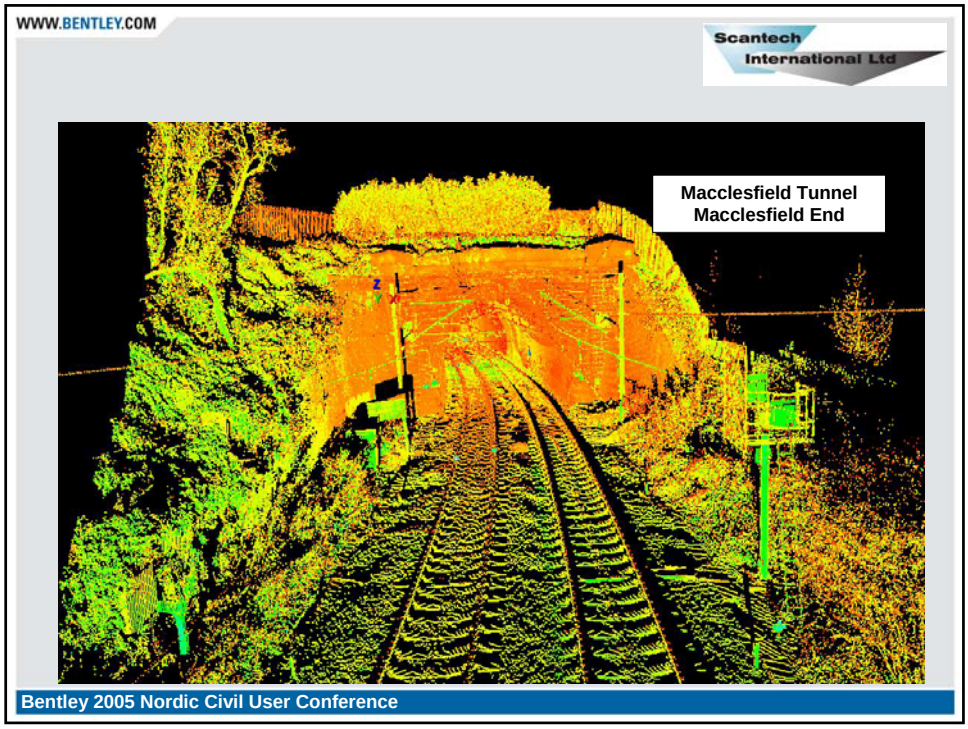

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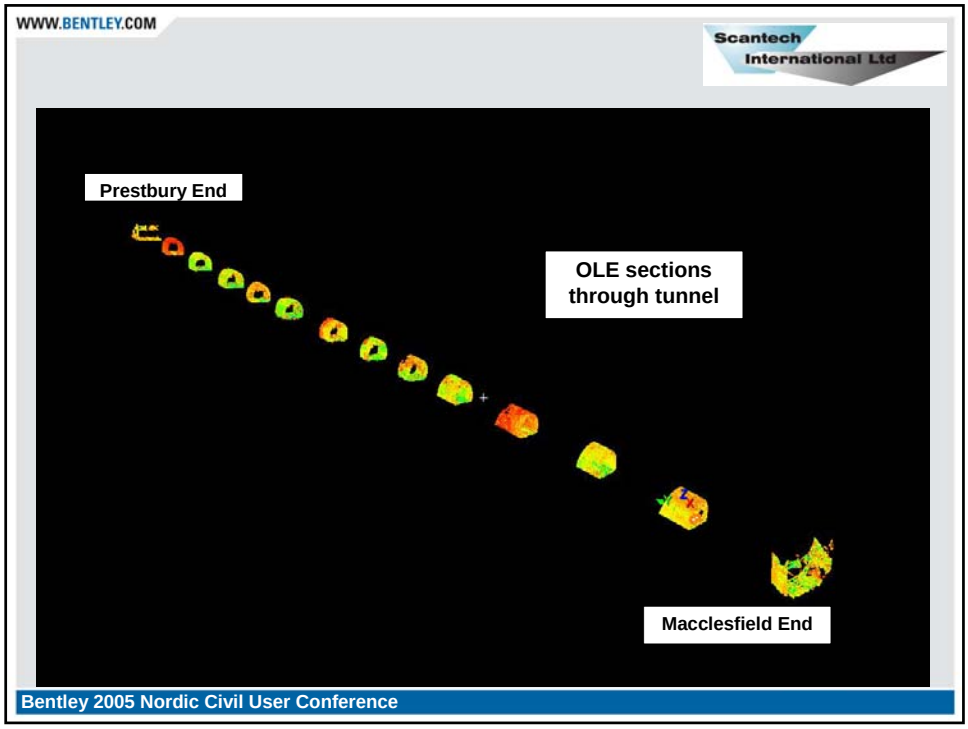

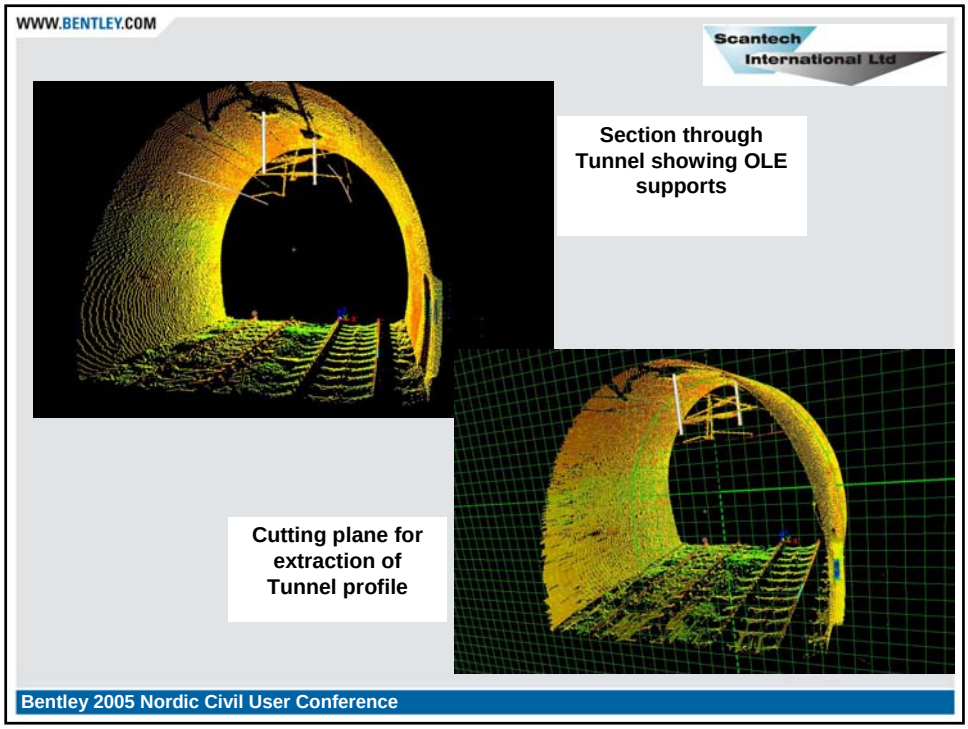

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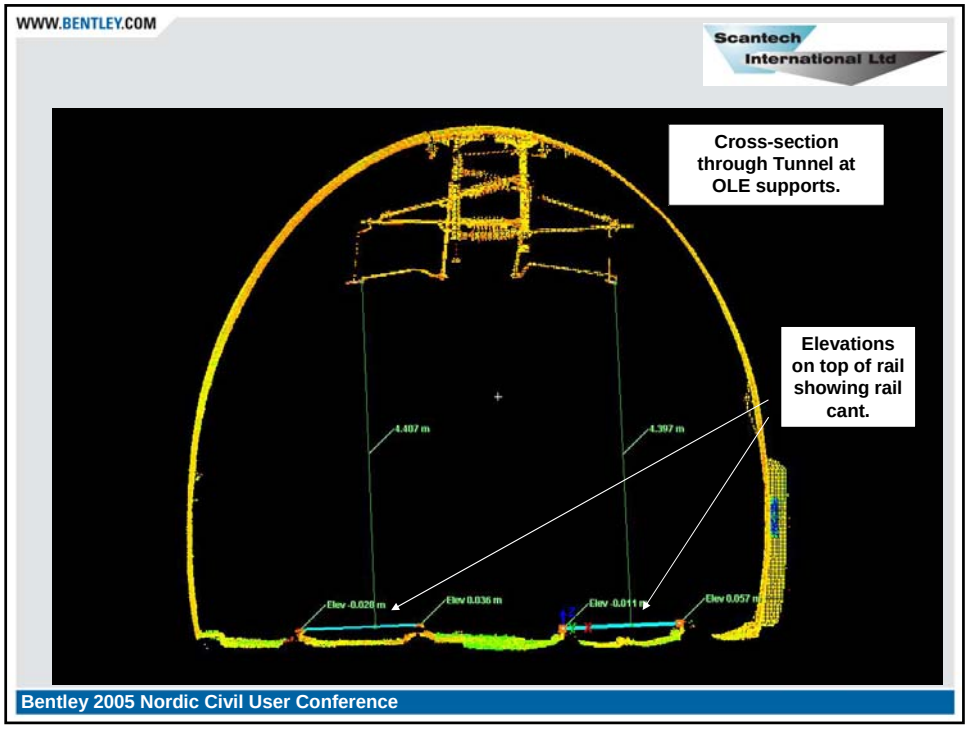

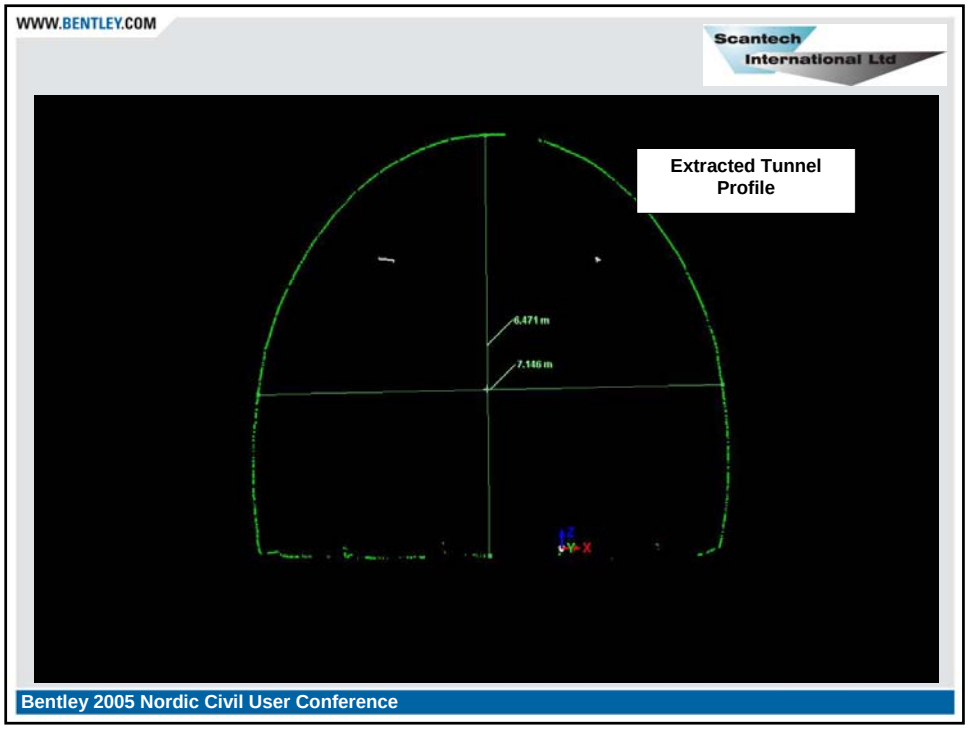

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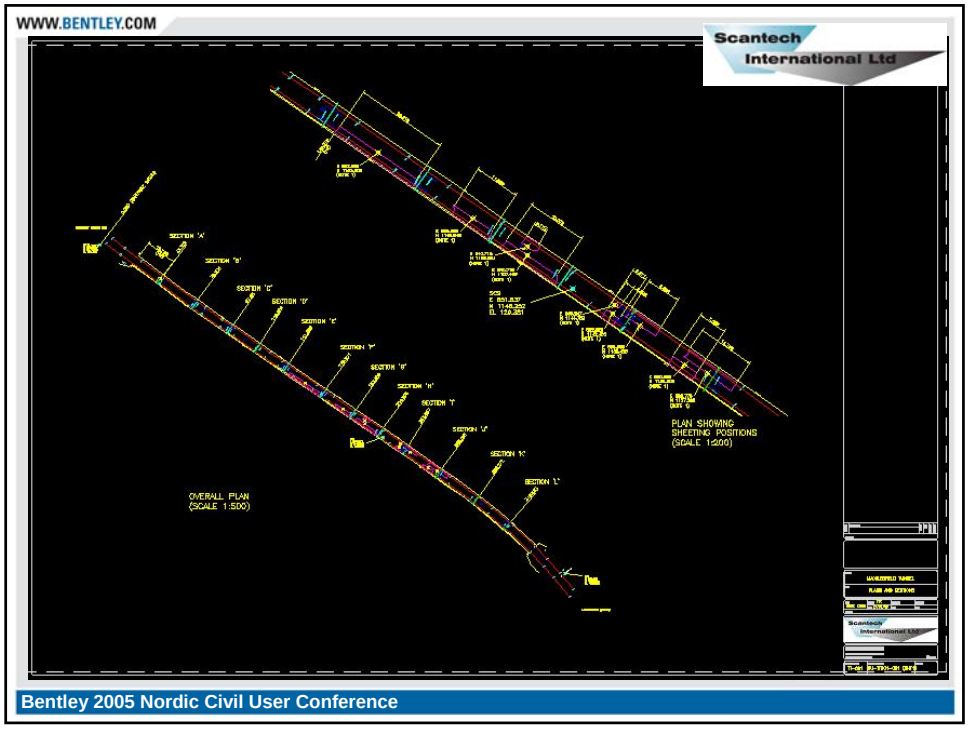

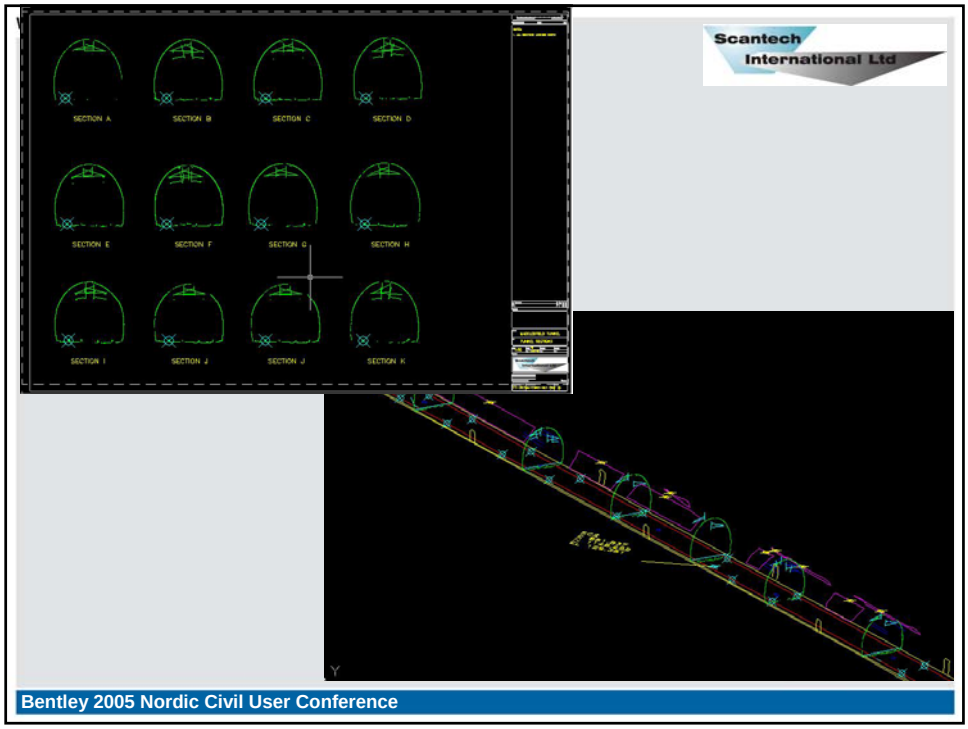

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Project Example 2
S & C at Kidsgrove Station

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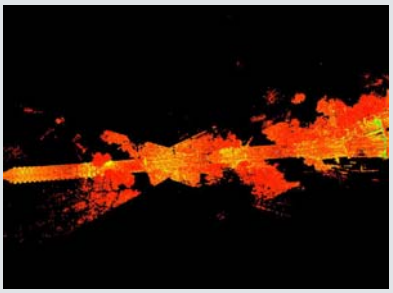
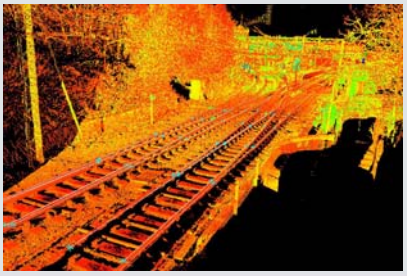
Scantech International Ltd

Digital photograph





Complete point cloud

Kidsgrove station

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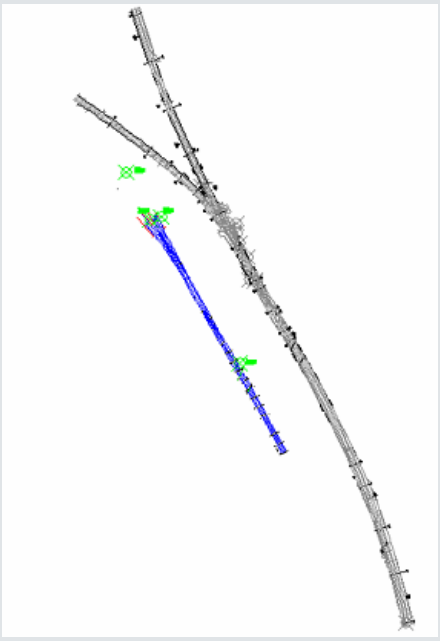

Kidsgrove station

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ABA Surveying

Project Example 3
Preston Brook Tunnel

The requirement:

- *To survey the track, the OLE including structural steelwork and the tunnel profile in order to provide a positional database of all the assets within the tunnel.*

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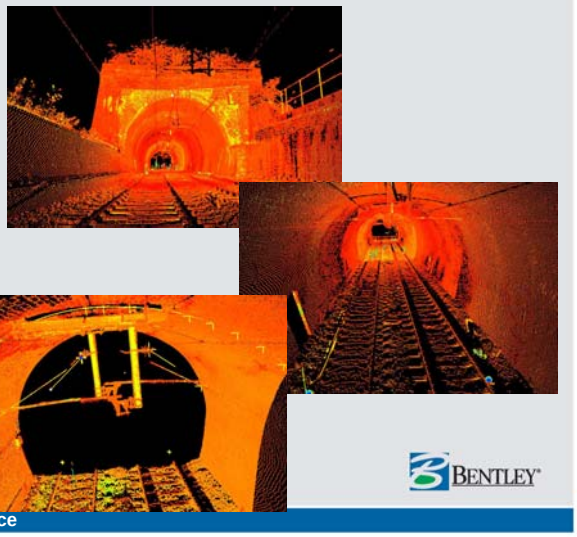
ABA Surveying

Sequential scanning of the tunnel

- *Multiple scans are registered together to form a Scanworld.*
- *The Scanworld is registered to the real world coordinate system through fixed control point targets.*
- *The 3d model can be viewed from any position and spatial data taken off to millimetre accuracy.*



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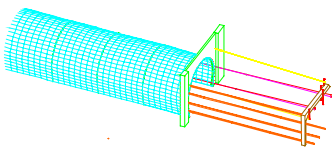
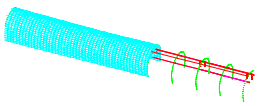
ABA Surveying

Geometric data is abstracted

•Slices of the 3d point cloud can be taken at will to build into a fully detailed geometric framework.





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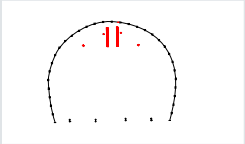
Geospatial data is abstracted

- *or spatial data can be extracted directly into a database format without manual transcription and to millimetre accuracy*



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CO,DESC:3-A-02
CO,SURV,GL
=SDR,G-283-OB48-3,OVERBRIDGE
=ELR,CGJ2
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=PR3       ,107509.845,307491.177,  30.782,    3
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=PR5       ,107509.727,307491.132,  31.774,    5
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=PR8       ,107509.901,307491.198,  33.245,    8
```

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ABA Surveying

Sometimes we find the unexpected

When we do - we have the ability to interrogate the dataset in as much detail as we wish without having to revisit the site.

Watch the waist of the tunnel as we sequence through the dataset and you will see the tunnel lean from the left through to the right as we progress through.

You will see that the roof has also compressed in places by as much as 250mm

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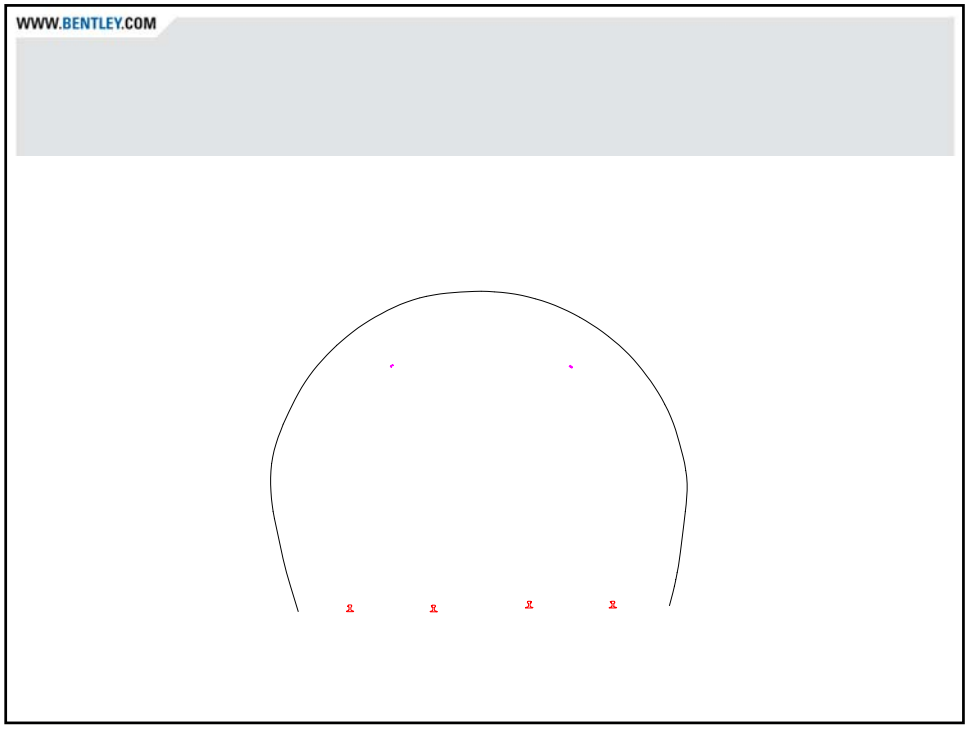

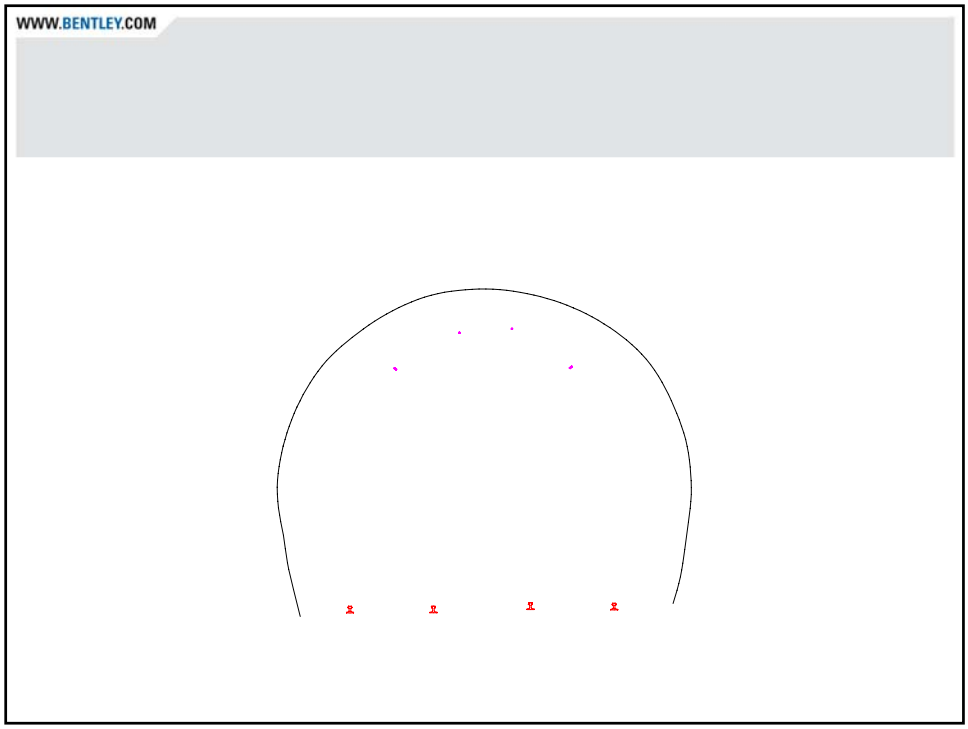

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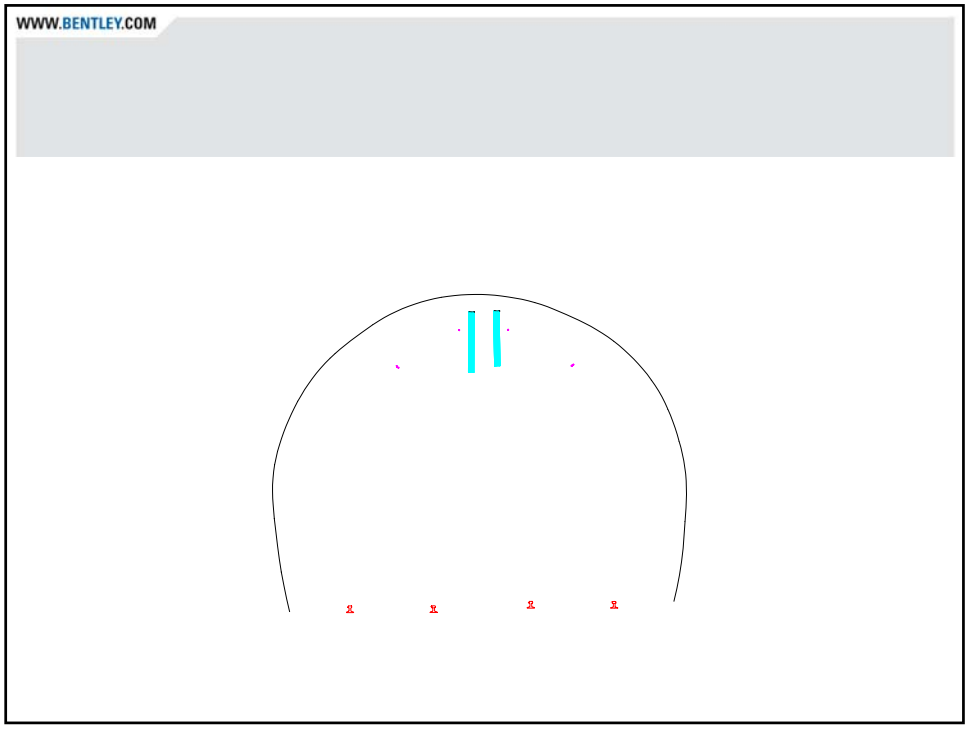

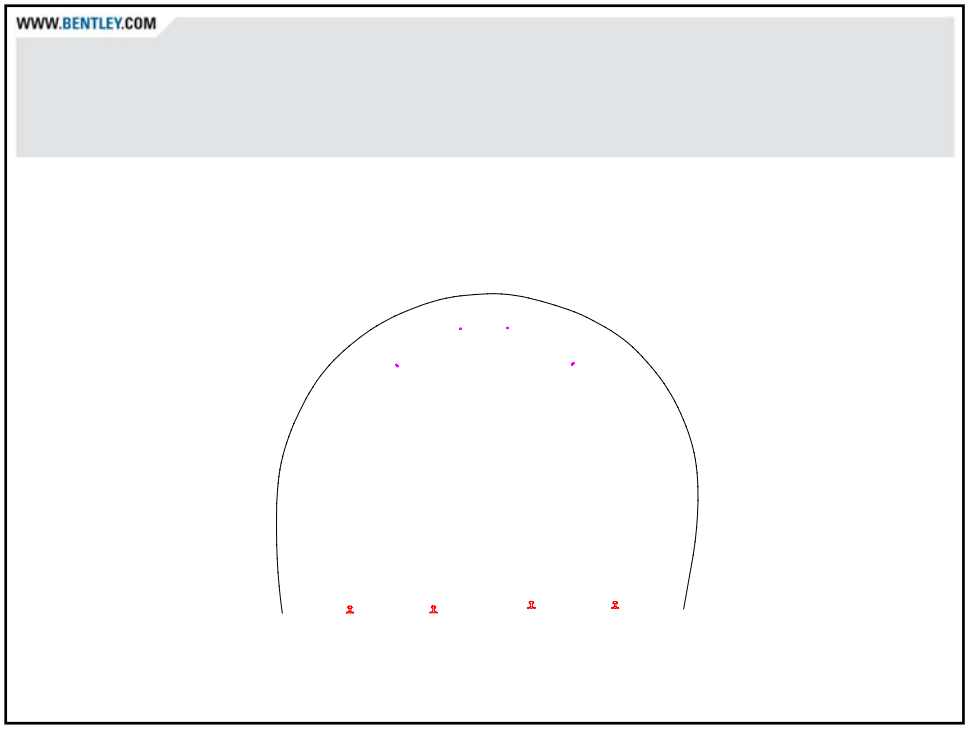

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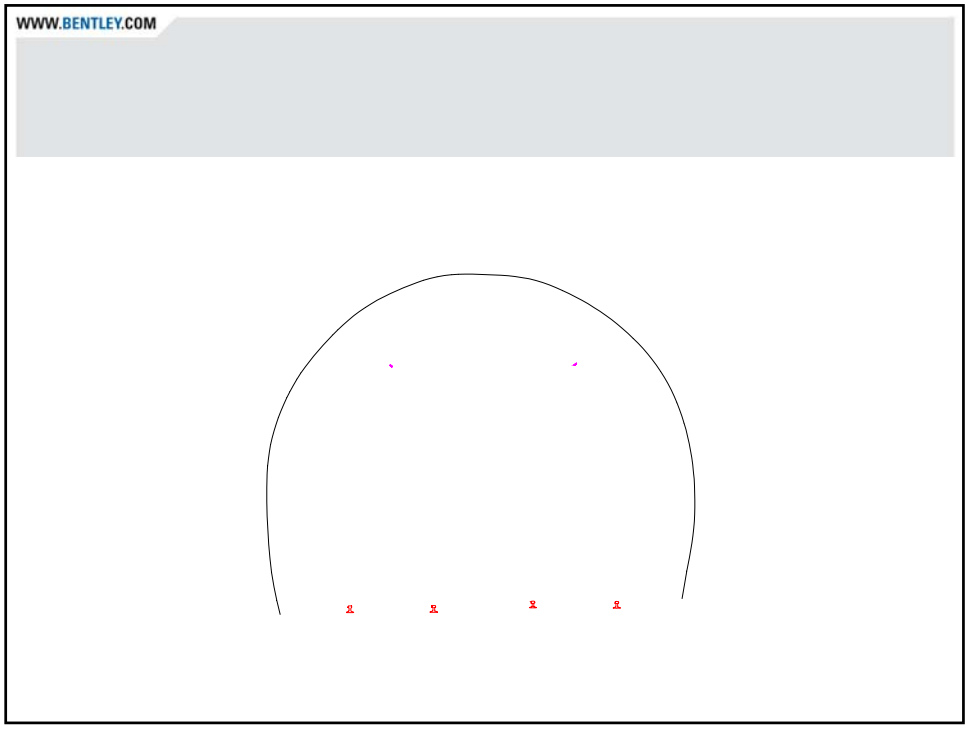
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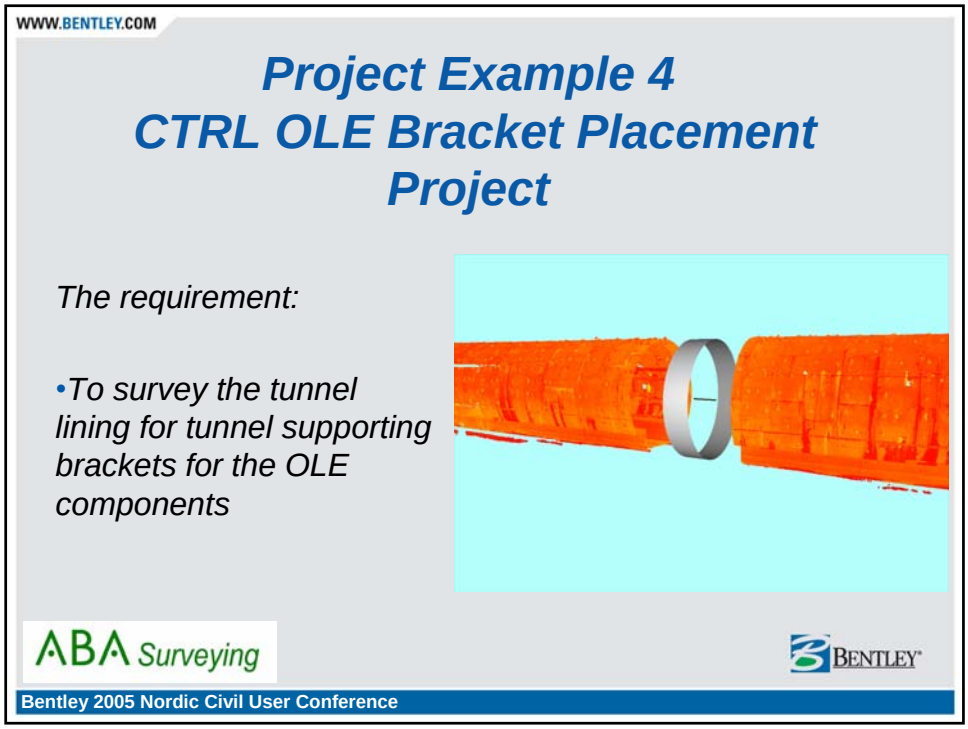
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Project Example 4
CTRL OLE Bracket Placement Project
The requirement:
•To survey the tunnel lining for tunnel supporting brackets for the OLE components
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360 Scan using HDS 4500

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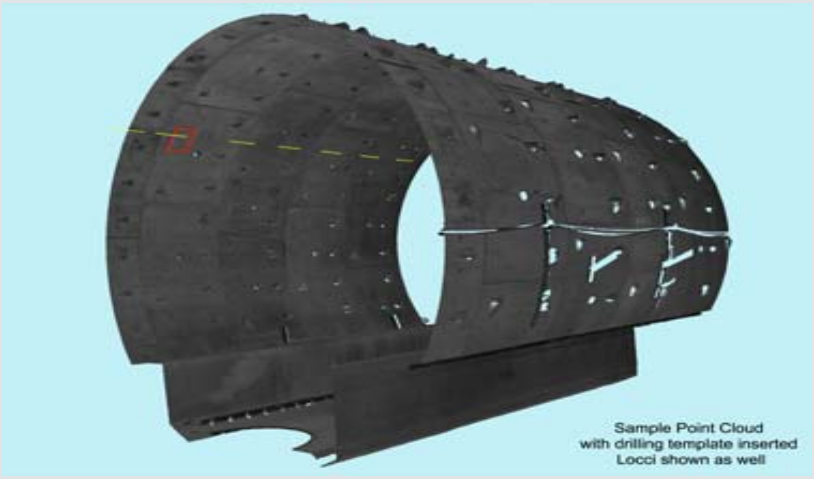
CTRL OCS Bracket location



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Drilling Template

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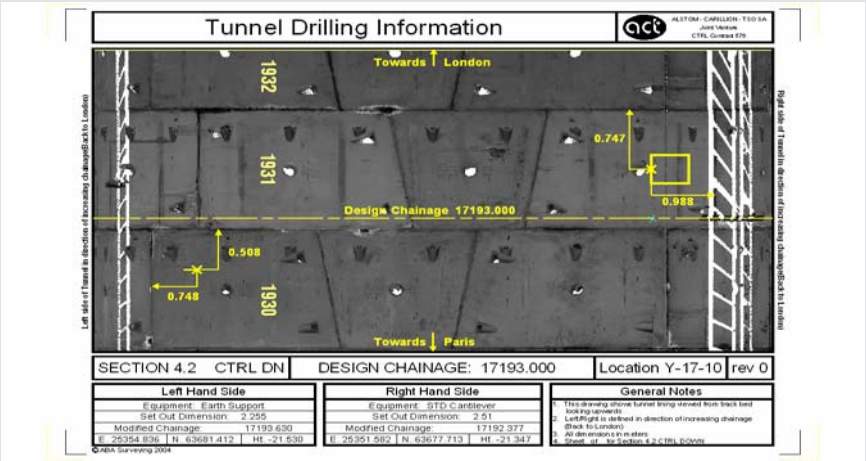
CTRL OCS Bracket location



ABA Surveying

Final Deliverable

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Project Example 5
Piccadilly Circus - BCV

PCA

Plowman Craven & Associates

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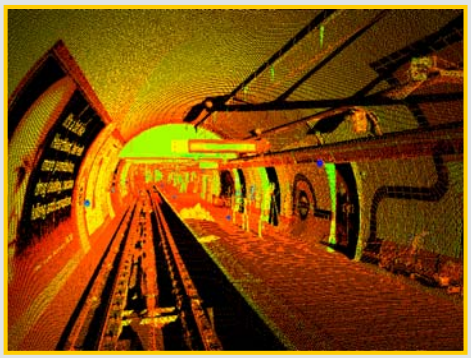
Piccadilly Circus - BCV



- 15 Scans
- 14.6 million points
- 74 Control points
- 4 nights on site

PCA

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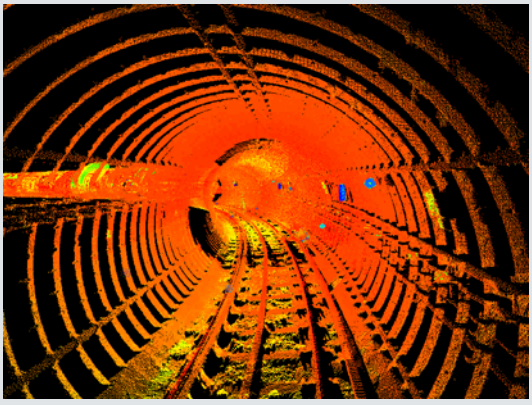
Animations and ‘Flythroughs’

Piccadilly Circus
BCV



PCA

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Project Example 6
Mile End Station - BCV

PCA

Plowman Craven & Associates

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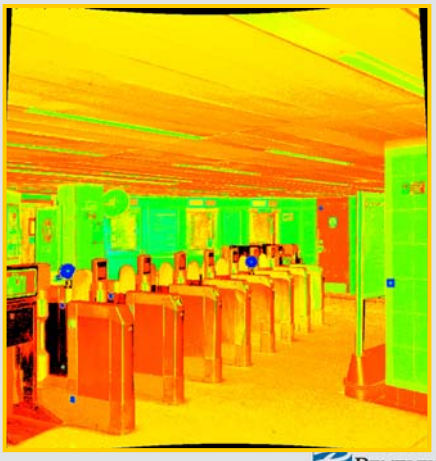
Point Clouds from Scanners

Mile End Station
BCV



PCA

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We measure……. so you can manage

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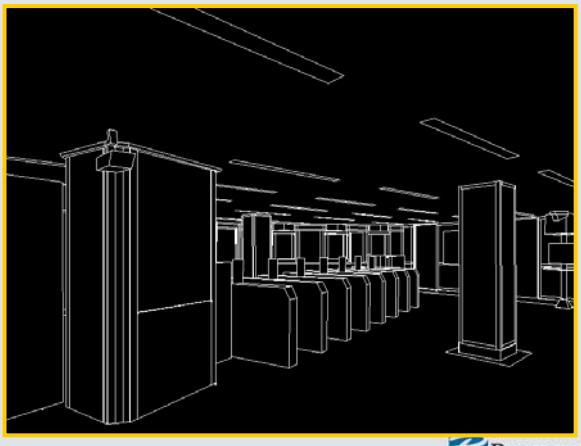
3D Wireframe, surfaced & rendered models

Mile End Station
BCV



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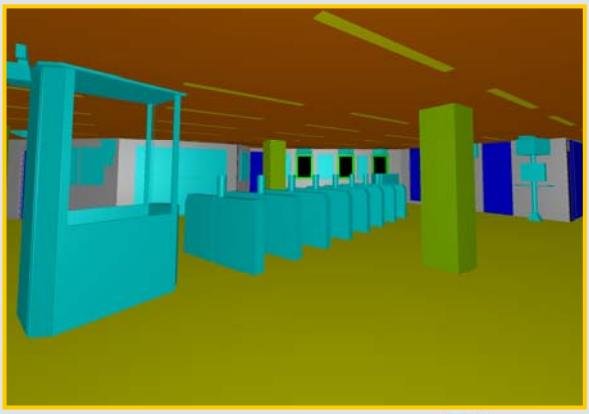
3D Wireframe, surfaced & rendered models

Mile End Station
BCV



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3D Wireframe, surfaced & rendered models

Mile End Station
BCV

PCA

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3D Wireframe, surfaced & rendered models

Mile End Station
BCV

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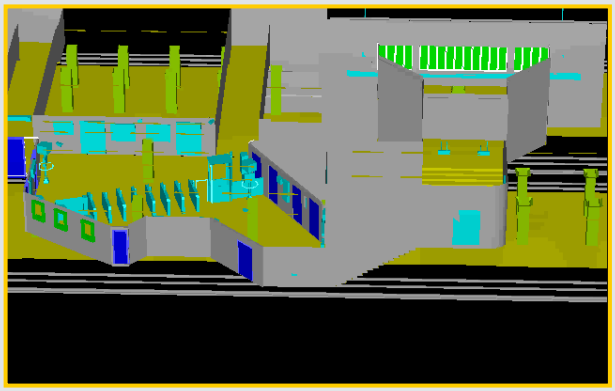
Animations and 'Flythroughs'

Mile End Station
BCV



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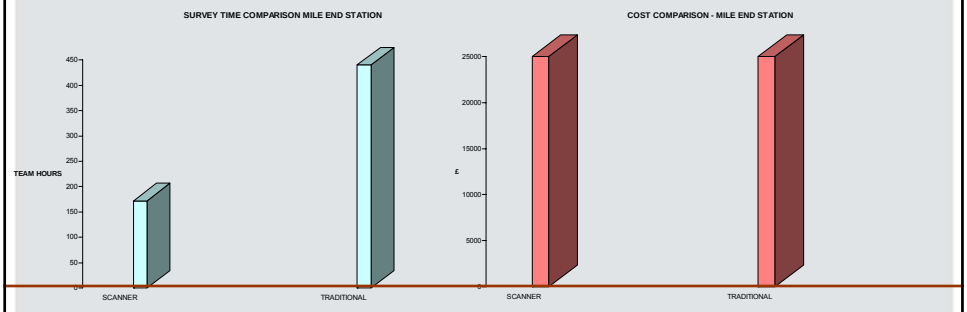
Benefits of scanning – Mile End Station



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Project Example 7
Oxford Circus - BCV

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Plowman Craven & Associates

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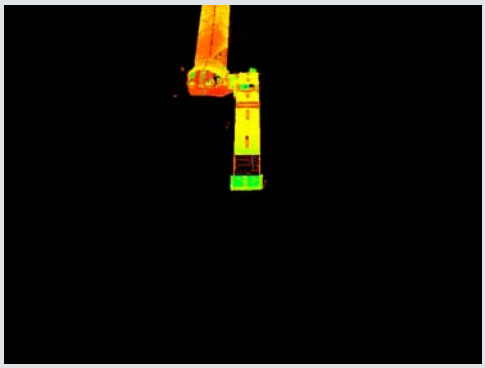
Point Clouds from Laser Scanners

Oxford Circus
BCV



- 11 Scans
- 8,810,802 points
- 53 Control points
- 6 hours (2 nights) on site

PCA

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Track Geometry and Clearance Measurement Systems

Leica Geosystems

In cooperation with Amberg Measuring Technique

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Track geometry and clearance data

- Full track geometry in absolute 3D co-ordinates
- Automatic gauge measurement
- Automatic cant measurement
- Automatic 360° clearance cross-section measurements
- Real-time comparison of project axis to as-built track axis
- Data export to track tamper leveller-liner (Matisa / Plasser)

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Open system architecture for flexible system configuration

- Relative mode

- Absolute positioning with TPS

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Track trolley: on the move including gauge and cant values

- Rugged, compact high precision aluminium frame track trolley
- delivered with calibration certificate
- integrated sensor for gauge, cant and stationing
- back-lit LCD display for system parameter control and visual sensor readings
- hosts radio link, battery pack and other accessories

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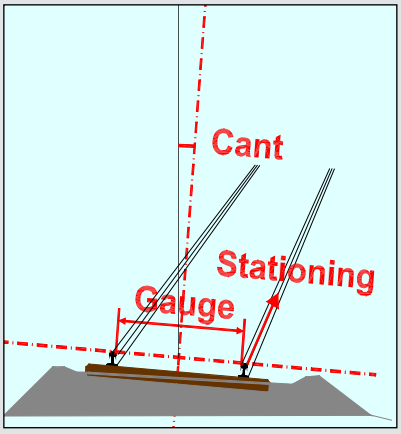
Integrated sensors for gauge, cant and stationing measurement



- The trolley integrated sensors measure continuously the cant, gauge and stationing
- Values are recorded automatically in control software GRPwin
- Gauge measuring accuracy 0.3mm
- Cant measuring accuracy 0.5mm (on 1435mm base)
- Stationing resolution 2cm

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PROFILER 100: precise measurement of obstacles

- ideal for tunnels, platform edges, overhead wire position
- fully motorized, 360° cross-section survey system
- automatic or manual control
- distance range 0.5m to 50m
- distance accuracy 1.5mm
- angular accuracy 66'cc
- measurement speed: up to 50pts./min.
- pre-selectable scanning modes
  - start and end angle
  - spacing

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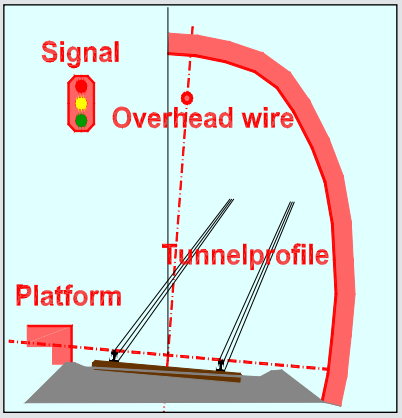
Integrated measurement of clearance profile



- Measurement of any obstacles with the integrated PROFILER 100
  - Automatic measurement of a profile
  - Manual measurement of individual points
- Direct measurement to thin objects (overhead wire) without the use of a target
- Online-Graphic on GRPwin software

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New high speed or existing old lines for LEICA GRP3000

New high speed railway lines
- high precision track positioning
- Offset tables for track tamper guidance
- track axis, gauge, cant and clearance control
- quality control / final acceptance

Existing railway lines
- assessment of existing track geometry and clearance
- data for track axis optimisation
- track alignment control according to optimised project axis

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GRP3000: Production performance

Production rate:

• typical system setup time -	15 min.
• track survey / hour -	1500m track / 200 axis points
• clearance cross-sections / hour	45 cross-sections with 50 pts.ea.
• typical battery power endurance	5 hours (with one set)
• manpower required	1 surveyor, 1 survey assistant
• accuracy of track geometry	< 2mm at 300m distance with TPS

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GRP 5000: Laser Scanner LEICA HDS4500

- Highest scanning speed with up to 33 cross-section per second
- Each cross-section up to 20‘000 points
- Maximum distance frequency 625‘000 points per second
- Accuracy in cross-section 10mm
- Range 0.8m to 25.3m

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GRP5000: track gauging trolley

- Integrated sensors for stationing and gauge measurement
  - Stationing accuracy 2cm
  - Gauge measurement accuracy 0.3mm
- Integrated power supply from rechargeable batteries
  - Approx 5 hrs of continuous operation
  - Exchangeable
- Adaptable to different nominal gauges from 1.000m to 1.670m

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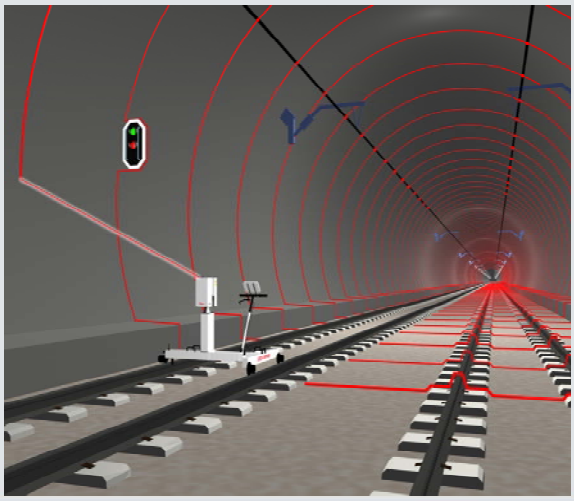
GRP5000: Measuring principle

- While the instrument is scanning the cross-sections the operator pushes the trolley with a speed of between 1-4 km/hour
- Scan-lines at a very dense distance are measured



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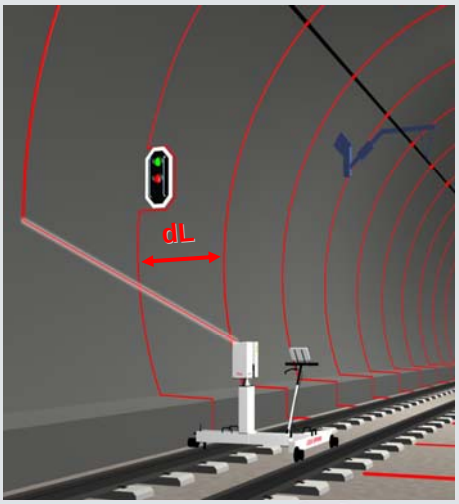
GRP5000: Density of measurement

Rotation frequency 33Hz

Travelling speed	Distance dL between profiles
0.25 m/sec (0.9 km/h)	7mm
0.5 m/sec (1.8km/h)	15mm
1.0m/sec (3.6 km/h)	30mm



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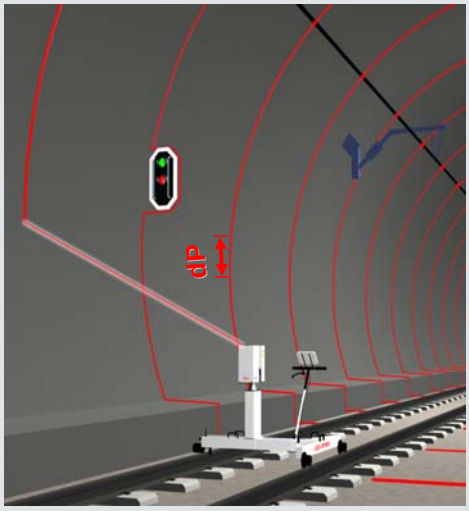
GRP5000: Density of measurement

Rotation frequency 33Hz

Measured distance	Distance dP between two profile points (with 10'000 points per profile)
5 m	3 mm
10 m	6mm
15m	9mm



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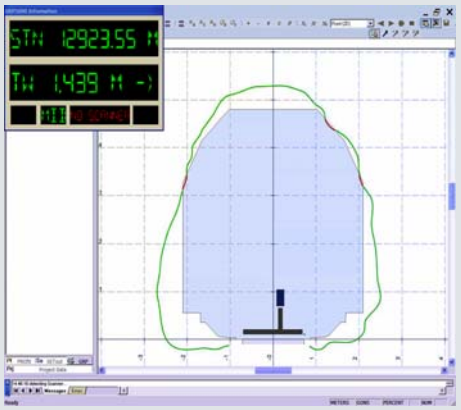
LEICA GRP5000: Measurement control

- Preparation
- The user can define the clearance profile to be used
- The user specifies the reference stationing
- The user sets the measurement parameters
- Measurement
- The graphic shows the actual cross-section measurement
- A comparison is made in real-time with the clearance profile
- The measured data is stored to file according to storage mode



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LEICA GRP5000: 3 different storage modes

- Three different storage modes:
- Continuous storage of all measurements (continuous operation)
  - All the measured points are stored continuously to the file with greyscale and geometrical information
- Interval storage (continuous operation)
  - The user sets the storage interval (e.g. 5 meters) and the integration specifications (e.g. ±2.5 meters)
  - One cross-section is stored in the specified storage interval as minimum and maximum profile (only geometrical information)
- Snap-shot storage
  - The user “searches” the interesting points / narrow spots with the help of the on-line graphic
  - Whenever the cross-section is required to measure, he stores that measurement to file (only geometrical information)

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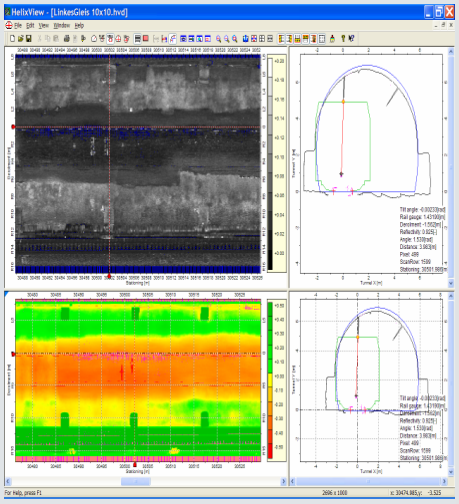
LEICA GRP5000: Processing procedure

- Data is normalized to
  - projection system (cylinder, tunnel profile, plan-view, others)
  - Correct stationing
- Reflectivity information is used for greyscale / false colour image
- User selects viewing window
- User select specific location (stationing for cross-section)



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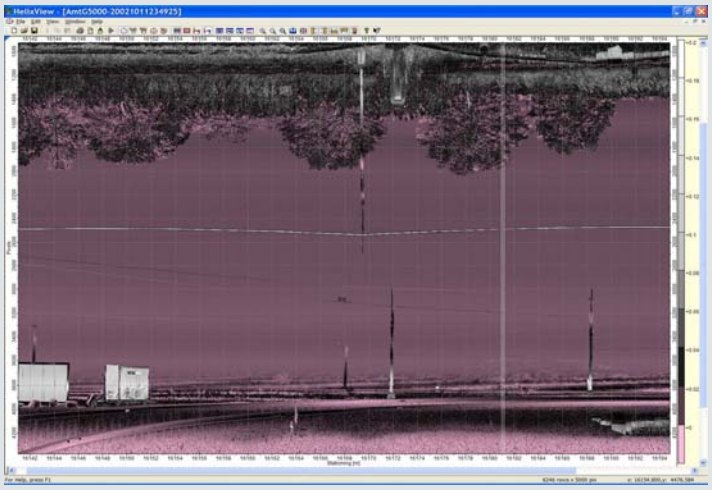
GRP5000: Processing example “Open Track”



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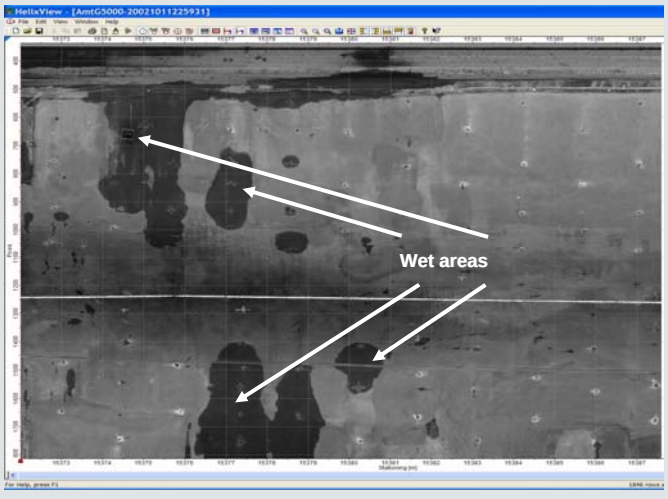
GRP5000: Processing example “Tunnel”



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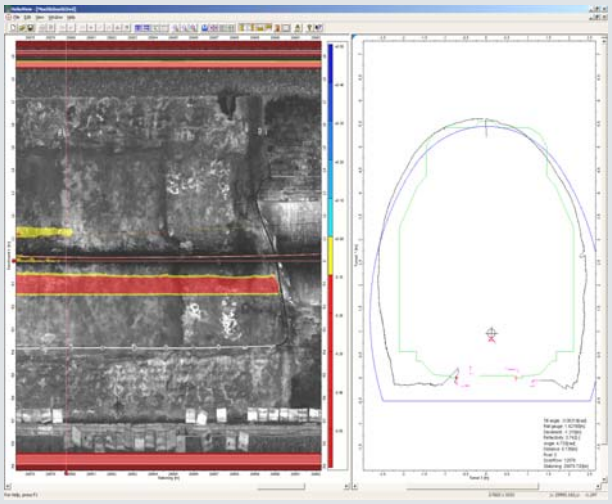
GRP5000: Processing example “Clearance map”

- Colour encoded visualization of underprofile

- Overlay with reflectivity information



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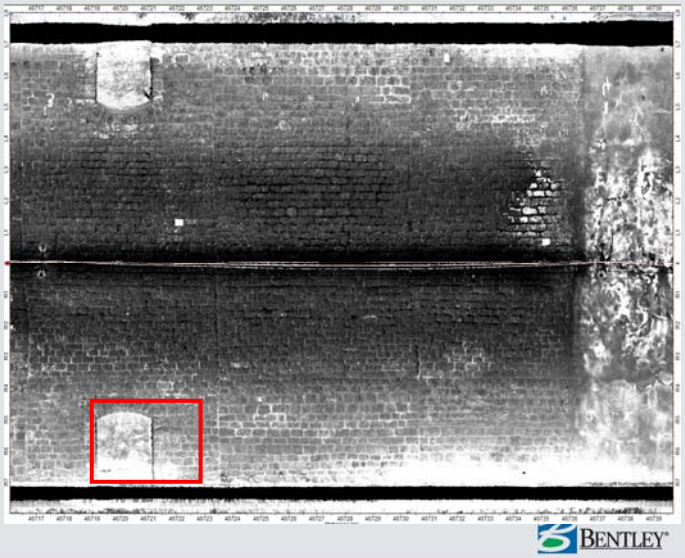
GRP5000: Processing example “Visual image”

High resolution reflectivity image

(Overview)



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GRP5000: Processing example “Visual image”

High resolution reflectivity image

(Zoom)

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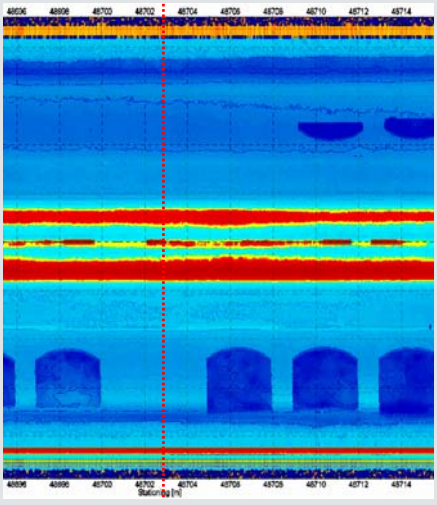
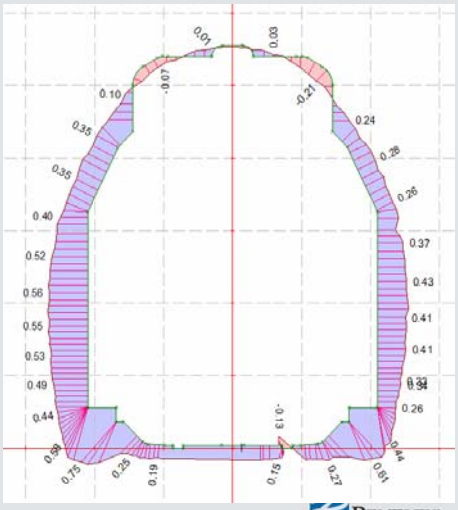
GRP5000: Processing example “Cross-section”

Clearance map



Extracted cross-section



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LEICA GRP5000: Summary

- Productivity 1-4km / hr
- Point density 5mm to 10mm
- Greyscale information
- Geometric information
- Portable and light weight
- Fully battery operated
- Tailored measurement and processing software
- Simple handling

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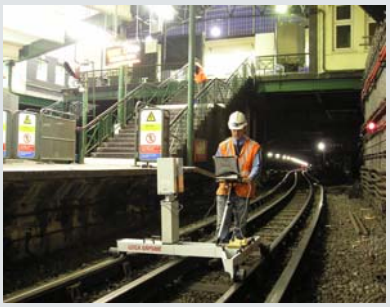
ABA SURVEYING

INNOVATION IN GEOMATICS AND 3D LASER SCANNING

SURVEYING HAS INDEED MOVED ON
- Lets take a look ?



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ABA SURVEYING

2001

ABA develops scanning for Railway Surveying

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2003
ABA
mounts
high speed
3d scanner
on rail trolley

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2004 HIGH-DEFINITION SURVEYING SYSTEMS

The value added to deliverable products has encouraged investment in a new generation of 3D Scanners.

HDS3000

HDS4500

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IN 2004 ABA SURVEYING DEVELOPED KINEMATIC 3D SCANNING

The system GRP5000 combines the HDS4500 and Leica's GRP Rail Trolley.

- The Scanner is mounted on the Trolley and fixed perpendicular to the Track.
- The Beam rotates at up to 33 Scans per second and records up to 20 000 Points per revolution.

- Pushing the Trolley along the Track at circa 1km/hr results in a progression along the track of 8mm between each scan ensuring all detail is picked up.
- The System also records the track chainage and cant, gauge and a time stamp at very close intervals.

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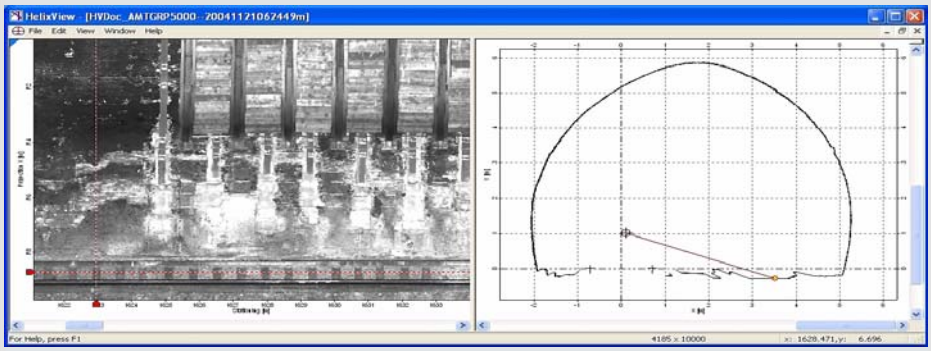
Even unlit tunnels can hide no secrets



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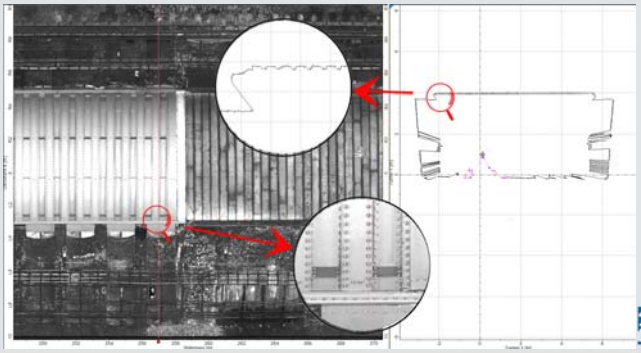
KINEMATIC 3D SCANNING

Massive amounts of Storage Capacity are required. At 1.5 MB of Data is recorded every second, approximately 500 MB of raw Data per 100m is stored.

Software allows the Scan to be viewed with a de-rolled Projection at almost Photo resolution and Profiles can be extracted at any Chainage.



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Railway Specific Developments

The Rail Trolley

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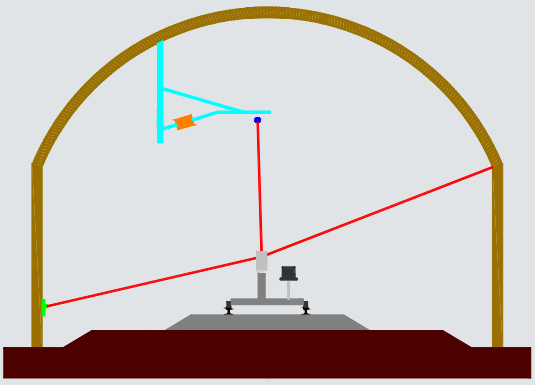
Railway Specific Developments



The ability to develop 3d coordinates

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Getting it Right

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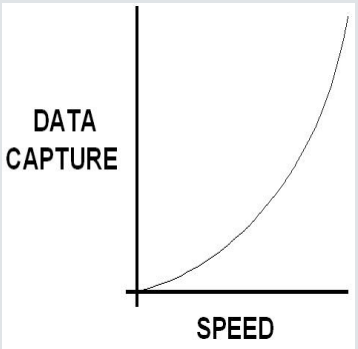
ABA SURVEYING

Onwards and Upwards
EXPONENTIAL PROGRESS

- 30 years ago it took a Surveyor plus an Assistant and a Draughtsman to produce 150 Points per day.
- 15 years ago it took a Surveyor plus an Assistant to produce 1000 Points per day.
- 5 years ago it took a Surveyor on their own to produce 15 million Points per day.
- **Today a Surveyor on their own can produce 10 Billion Points per day!**



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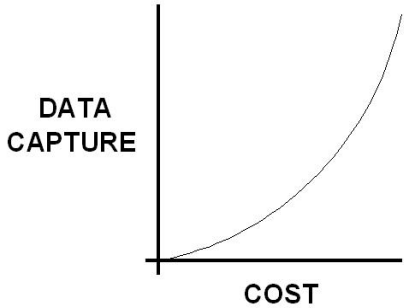
Onwards and Upwards
THE CLIENT'S PERCEPTION

- The Cost stays the same or reduces.
- Why pay more for the Supplier to use state of the art equipment?
- Doesn't this just make the work much more expensive?



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Onwards and Upwards
THE SURVEYORS ROLE HAS CHANGED

The role of the Surveyor has shifted from a Survey and Setting-Out Engineer to an Information Technology Provider.

- The key now is to provide Solutions not just Data.
- A survey is no longer just a mapping dataset.
- A survey is an Asset Data Base – presenting Data in a meaningful way.
- Information Rich Data Set.
- Multi-discipline - the ability to blanket topic with dimensional information

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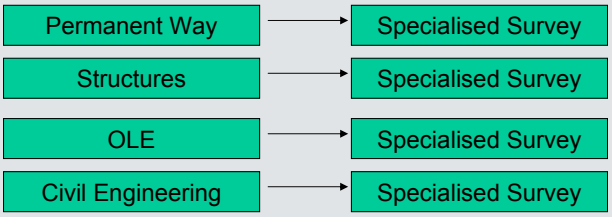
CLIENT-SPECIFIC SURVEYS

- Traditional survey datasets are based on Discreet Point surveying.
- Discreet Point Datasets must be fully specified by the Client and thoroughly understood by the Field Surveyor.
- Any missing or faulty Data or a change in scope of work by the Client requires another site visit by the Surveyor.
- During the life time of a Project some areas will often be re-surveyed many times to suit the particular needs of different Specialists.



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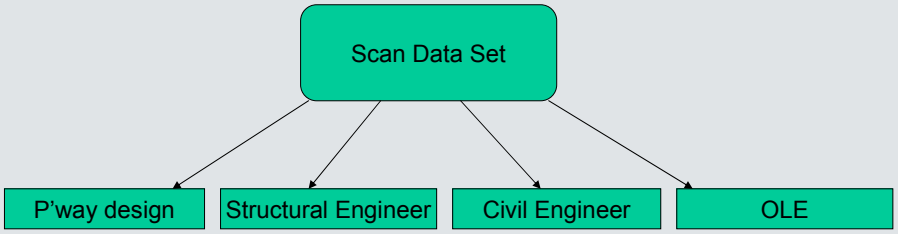
CENTRAL DISSEMINATOR OF SPATIAL INFORMATION

- Scan Data is multi-discipline – this information rich Data Set can be manipulated to meet the needs of many Specialists.
- New information can be extracted from the Data Set at any time during the entire life of a Project.
- If managed properly, it becomes a central disseminator of information.



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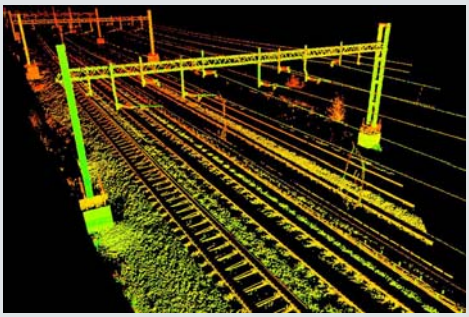

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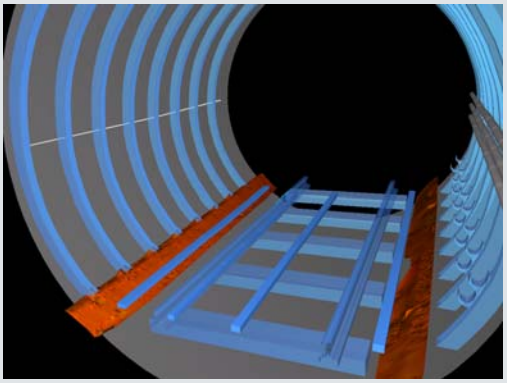

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A Final Movie

Thank You and any Questions

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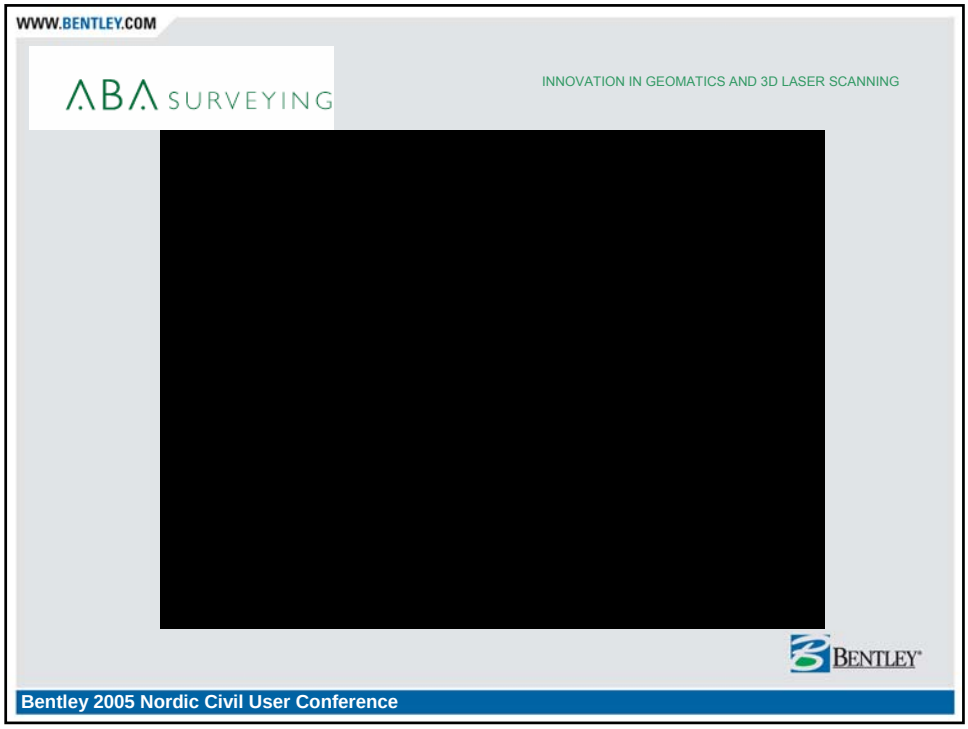

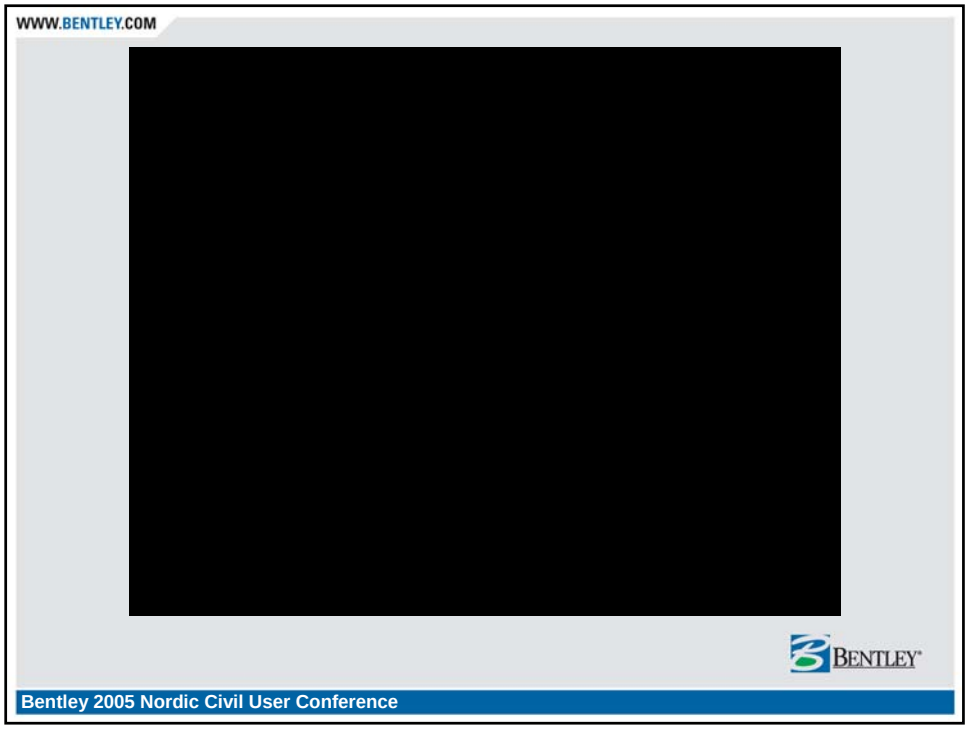

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