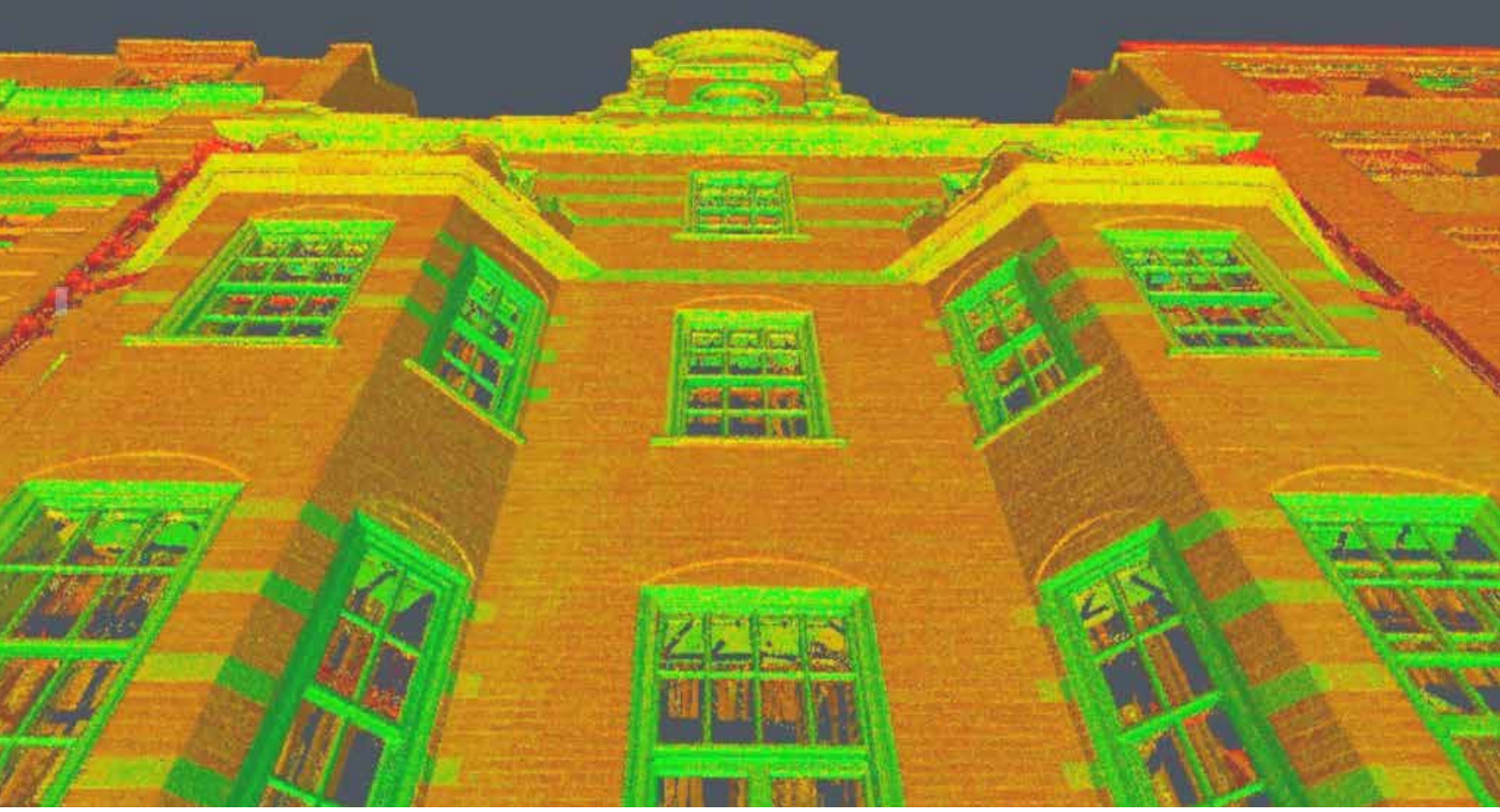


THE SURVEY ASSOCIATION

CLIENT GUIDE TO **TERRESTRIAL LASER SCANNING**

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The Survey Association's Client Guides are primarily aimed at other professionals such as engineers, architects, planners and clients in general. They are not intended to go 'in depth' into practical issues but to act as a basic guide on a particular topic and in particular, on procedures and regulations which may govern how a particular aspect of the survey is carried out.

1 Introduction

Three-Dimensional Laser Scanning (3DLS) – often referred to as Terrestrial Laser Scanning (TLS), High Definition Surveying (HDS) or 3D Reality Capture – is used to measure surfaces and objects within a space, resulting in a rich, geospatial dataset. This sector of the industry has seen significant development in the last twenty years, with major improvements in hardware functionality, data acquisition speed and software processing algorithms.

The data captured by a laser scanner is referred to as a point cloud. After processing, this data can be analysed to derive large quantities of geospatial information which can then be exported in a range of formats, for a variety of uses. Laser scanning is ideal whenever highly accurate, detailed geospatial information is required, or the object of interest is simply out of physical reach.



Figure 1:
A laser scanner is the perfect tool for those awkward shaped buildings

3D laser scanners can also capture high-resolution digital photography in conjunction with the measured point cloud data. The images can then be overlaid onto the point cloud to show a true representation of the physical world in digital form.

Laser scanning collects detailed geospatial data rapidly, facilitating health and safety advantages. Less time is required on site and personnel are physically separated from hazards as data is captured from a safe distance. Laser scanners can also be mounted onto unmanned moving vehicles.

2 How does a laser scanner work?

Laser scanning systems rapidly measure millions of points by emitting an array of timed laser pulses and calculating the elapsed time/phase shift and intensity of the return pulse, reflected from any surface. A common approach is to have a fixed laser source which is deflected by a rotating or oscillating mirror to generate a scanning action.

Laser scanners vary in their features and capabilities. Specifications including speed, size and data accuracy will determine the best value scanner. Modern laser scanners often include additional sensors such as GNSS, inertial/visual motion units (IMUs), barometers and compasses to facilitate 'on the fly' registration. When selecting a scanner for a particular project the following should be considered:

- **Range**
- **Angular accuracy**
- **Level accuracy Precision**
- **Speed**
- **Colour capture (intensity, RGB)**



Figure 2:
A laser scanner can obtain a high level of detail

Depending on the task additional survey control work may need to be done to ensure the required accuracy of the point cloud is achieved. Care should be taken to ensure point clouds from different set-ups are accurate and correctly georeferenced, especially when considering level and orientation.

All laser scanning hardware is 'line of sight' – the scanner can only measure what it can 'see.' It cannot measure through, behind, around or underneath objects. Complete point clouds, without shadows, are captured by taking individual scans from multiple locations. These are then joined together in a process called registration. Modern laser scanning systems may include a field registration procedure, often run from a tablet connected wirelessly to the scanner. It is also good practice to carry out a post-site checking and tightening of the registration process.

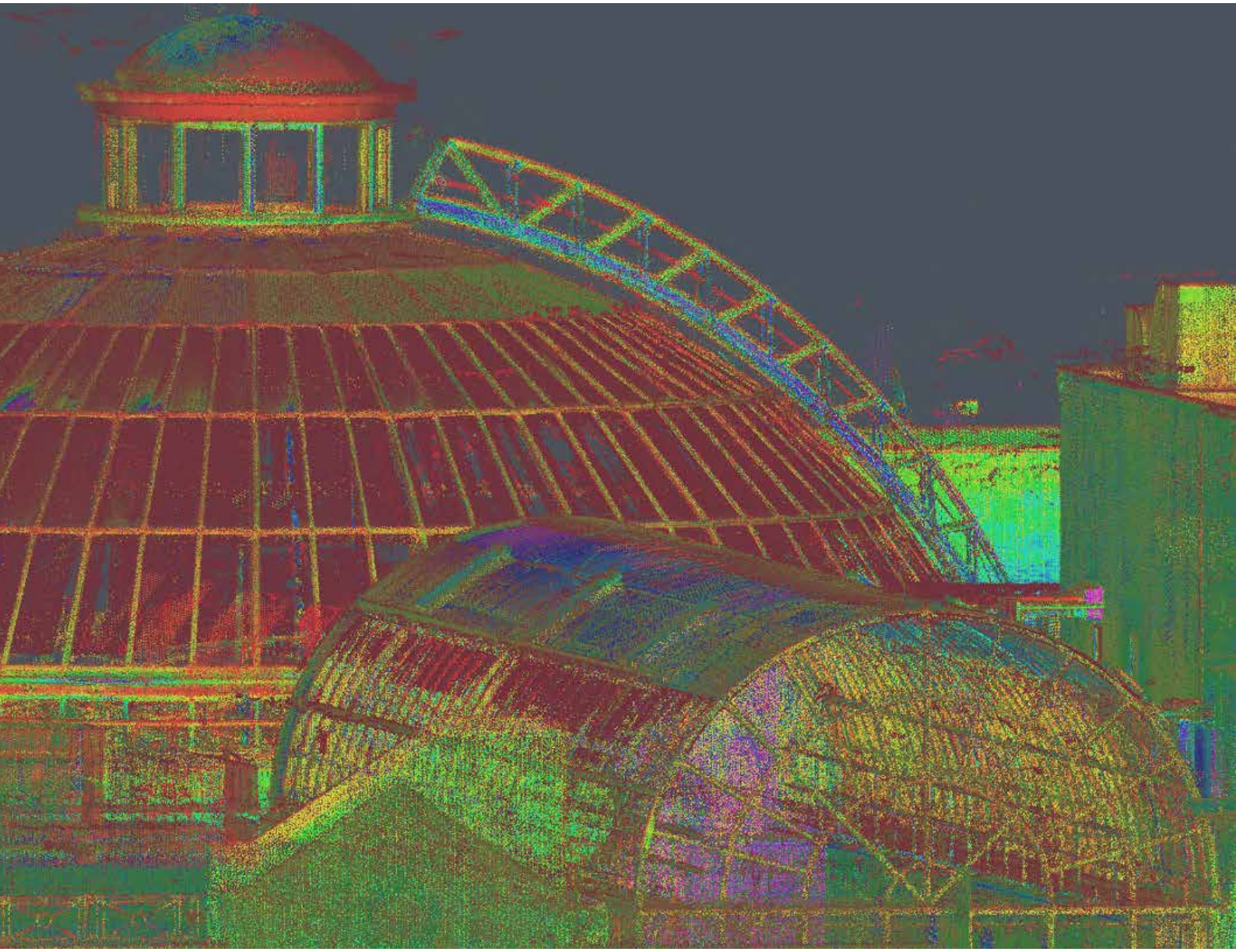
3 What is a point cloud?

A point cloud is a map of points in space consisting of individual 3D coordinates (X, Y and Z), creating a visual digital reality of an environment. Laser scanning is one of several ways in which point clouds can be collected. Other methods include mobile mapping, photogrammetry and sonar scanning.

Raw point cloud data can include a colour or greyscale value based on the intensity of the signal received. In many cases red, green and blue (RGB) values are recorded directly or extracted from photographs aligned to the scan data.

The number of XYZ coordinates collected in the point cloud within a specified area is defined as point density. The point density selected should be sufficiently rich to allow extraction of detail at the scale specified for the project.

Figure 3:
A point cloud showing intensity values



4 What is point cloud data used for?

Point clouds can be used for any task that requires accurate measurement of a spatial environment. The following list provides examples where point cloud data is particularly useful:

- **Primitive fitting**
- **Meshing/Surfacing/DTMs**
- **2D/3D line drawings**
- **3D solid models**
- **Ortho-images**

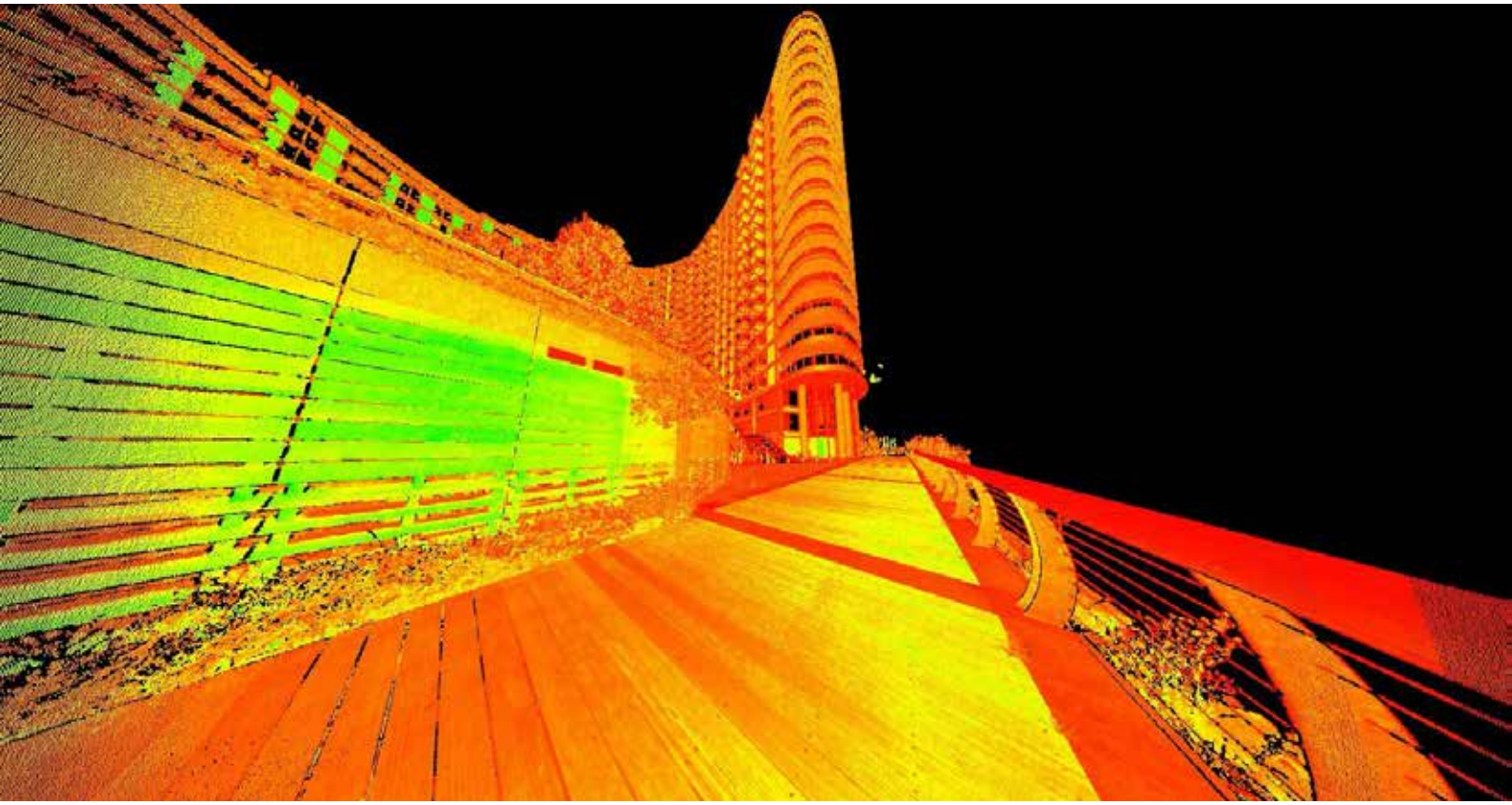


Figure 4 – above:
Intensity value point cloud for a highly detailed public realm



Figure 5 – right:
Floor flatness deliverable

- **Cross section/Profile generation**
- **Animation**
- **Simple measurements**
- **Web-based data sharing such as TruView & WebShare.**

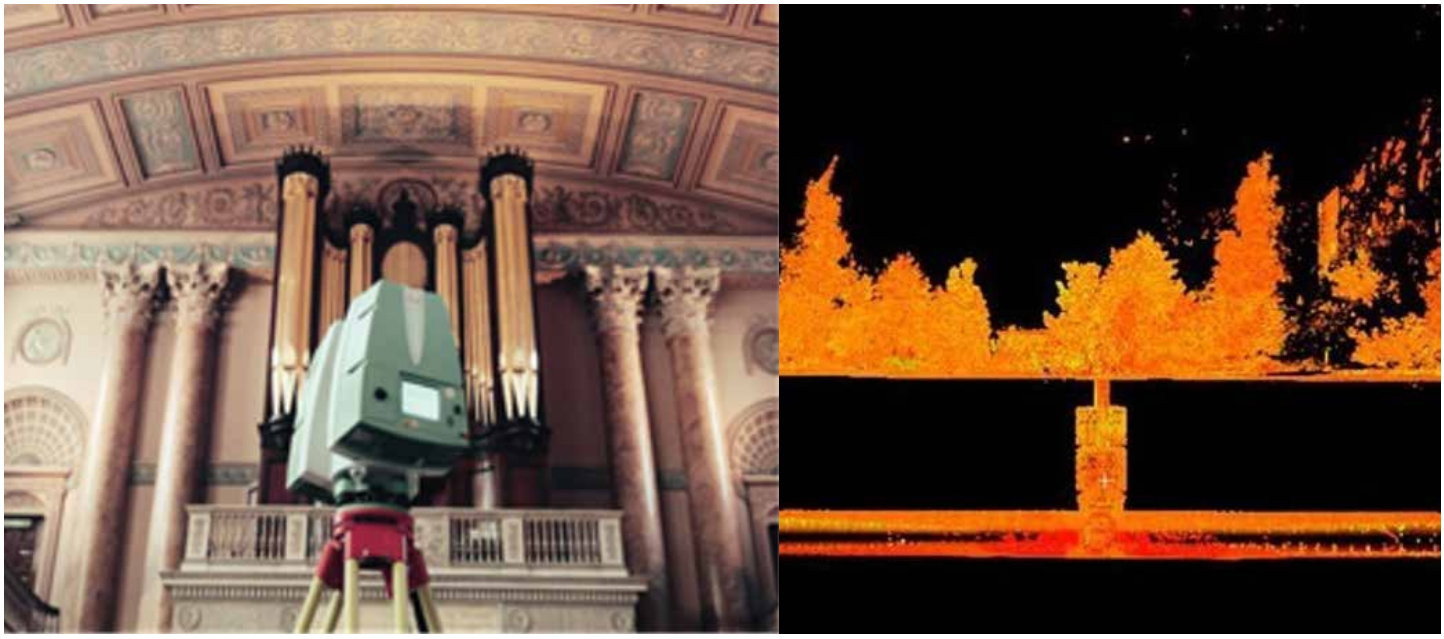


Figure 6:
A survey grade laser scanner being used to survey high up areas and below ground voids

5 When is 3D laser scanning used?

3D laser scanning has a wide variety of applications and continues to grow with the development of new and emerging technologies. Scanning technology is regularly used in architecture, heritage and historical archiving, civil and engineering, mining, process plant and pipe modelling, forensics, aviation, BIM, monitoring, volumetric projects, pre-construction and as-built surveys, visual effects within the TV and film industry and archaeological documentation.

Laser scanning has transformed the way surveyors approach many types of projects. Deciding whether laser scanning technology is appropriate for the job, the following questions and examples should be considered:

- **What level of accuracy is required for the project? (measuring the size of a flange to millimetre accuracy or citywide mapping to +/- 250mm).**
- **Is a high amount of detail required? (measuring dense and complex pipe work in an industrial environment to facilitate the design of new piping and detect potential clashes or conflicts).**
- **Is access limited to the area of interest? (confined spaces or contaminated areas).**
- **Is there a time restriction to undertake the field work? (plant, railway or runway downtime).**
- **Is the site location within a hazardous environment? (busy highways).**
- **Is a complete archive required for data preservation? (heritage objects and buildings).**

Although laser scanning technology can be ideal for certain applications, it is not always the best tool for every project. Sometimes traditional surveying technologies may be more suitable, although laser scanning may provide a more cost-effective option.

6 Factors affecting accuracy

The accuracy specified for each project will determine how the point cloud is configured in the field. Distance, angle of incidence and surface finish all contribute to the final accuracy of the point cloud. Every laser scanner is designed to achieve accuracy to an optimum distance. The greater the distance the laser must travel beyond its design capabilities, so the accuracy of the measured points will decrease. The more oblique the angle of the laser beam is to the object, the greater the size of the laser footprint on the surface. The nature of the reflecting surface will also affect the returning information. For example, wet and dark surfaces are not ideal due to the disbursement and weak reflection of the laser on contact.

Modern laser scanners and traditional survey methods are generally used to calculate the control coordinates of reference points or targets and relate the point cloud to the real world. The resultant accuracy of the targets will decide the overall accuracy of the project. Cloud to cloud registration of individual scans can also be used to join and rectify the data into a single point cloud. Cloud to cloud registration works by picking common points or planes that occur in multiple scans, aligning all the scan data. Some sophisticated software programs can automatically identify common planes and features, thus reducing post-processing registration time.

As with all electronic measuring devices, extreme temperature has a direct effect on the accuracy of the collected information. All manufacturers of laser scanners specify operational temperature ranges that should be respected to ensure quality data. Other environmental factors such as rain, snow, dust and fog in the atmosphere can also affect the data and create unwanted points or 'noise'. The laser scanner requires line of sight to the desired subject and therefore the view must be unobstructed. When scanning from an elevated position, consideration should be given to the security and stability of the equipment. Any movement or excessive vibration will result in erroneous data.

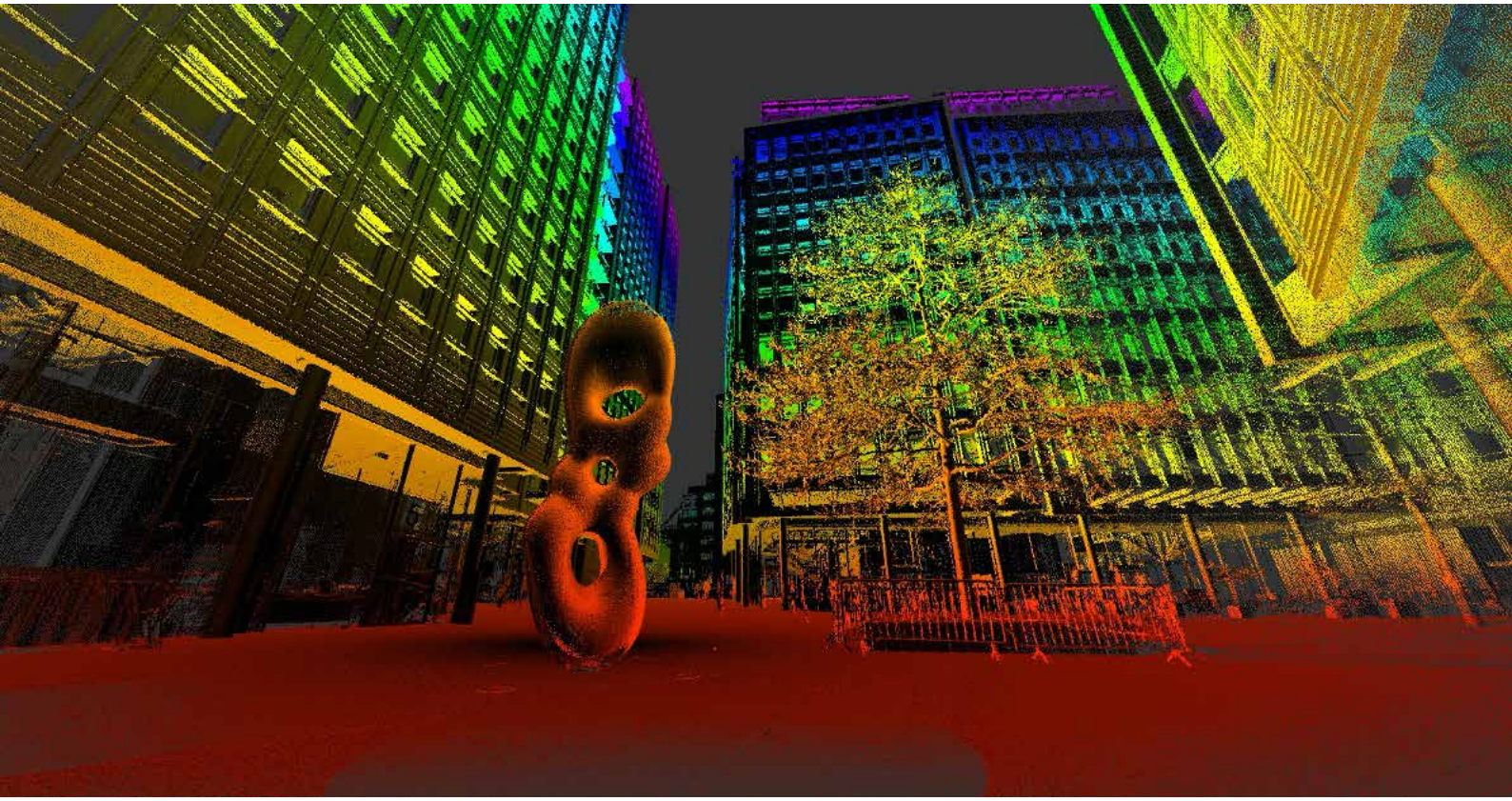


Figure 7:
Laser scanning can be particularly valuable in urban environments

7 Processing and deliverables

Submitting the final deliverable of any project generally starts with data collection in the field. While industries such as engineering and architecture are increasingly familiar with the use of laser scanning, many are still not accustomed to working with point clouds and large datasets. They rely on drafting or modelling of the data to extract features in a more familiar format. Understanding how the data will be used is a key part of creating deliverables from point cloud datasets.

Once point cloud data has been collected, the information can be processed and extracted as required by the project. With so much data available, determining the features that need to be extracted and created can be challenging, so modelling/drafting only those features that are necessary helps to reduce costs. A laser scan captures a near complete snapshot of a site at that point in time, keeping costs associated with revisits to a minimum or even eliminating them altogether. Common deliverables of point cloud data can be simple to complex models or CAD drawings, through to outputs of many different third-party analysis applications.

Figure 8 – top:
Colourised point cloud showing realistic RGB colours

Figure 9 – bottom:
Post processing of scan data to produce contouring



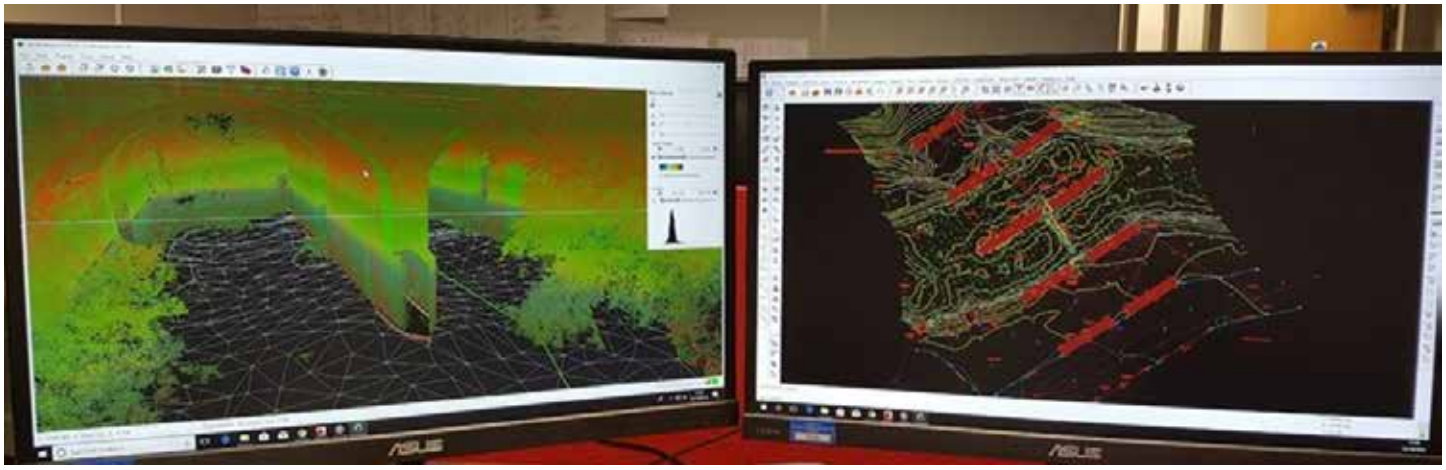




Figure 10:
Point cloud coloured based on point elevation

8 Summary

The ability to collect a comprehensive and immersive dataset in a matter of minutes has changed how surveyors capture data and what they are able to do with it.

The number of industries now utilising point cloud technology is vast. 3D laser scanning is so versatile, surveyors now work in a wide variety of sectors and industries. In particular, the wealth of the data captured is of significant importance in digital documentation and heritage preservation.

Remote data collection techniques, using 3D laser scanners, have improved safety in many situations. For example, data can be captured quickly by the side of a busy highway from a position of safety, and processed in an office environment.

3D laser scanning is one of the most significant developments in the history of surveying. The technology has developed over a relatively short period of time and continues to do so at a significant pace.

9 Further information

Measured Surveys of Land, Buildings and Utilities
Third Edition, 2014, published by RICS

3D Laser Scanning for Heritage
Third edition, 2018, published by English Heritage

Metric Survey Specifications for Cultural Heritage
Third Edition, 2015, published by English Heritage

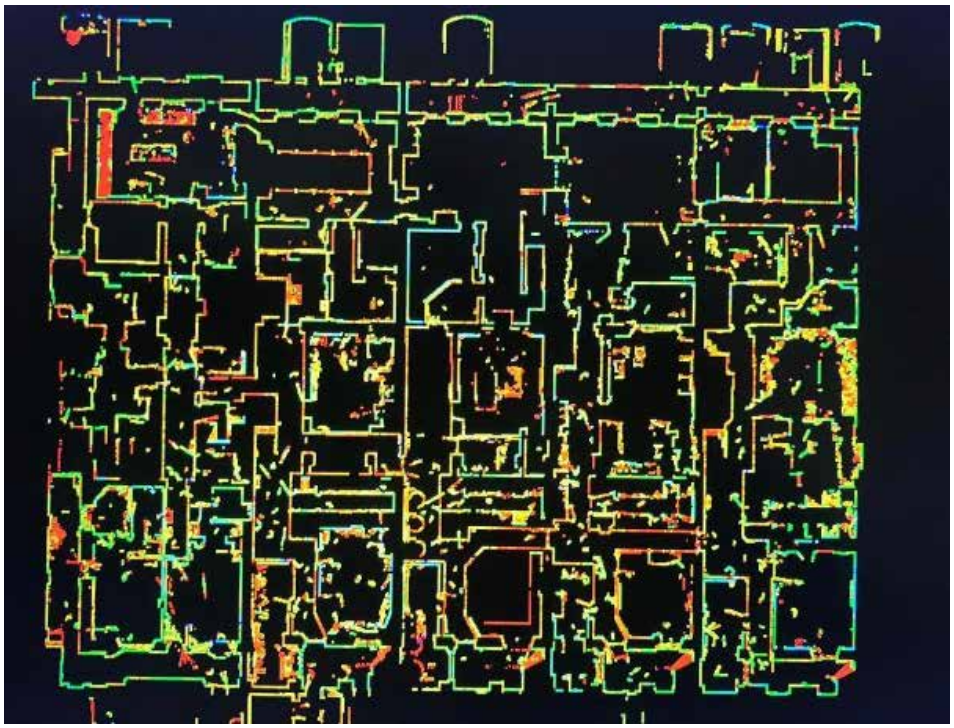


Figure 11:
A horizontal slice through a point cloud to show an internal layout

The Survey Association

Formed in 1979 as The UK Land and Hydrographic Association, TSA is now established as the representative organisation for UK private surveying firms. The Association's aims are:

> **To provide a vehicle for members to act effectively together on agreed courses of action**

> **To promote the interests of the profession to all those who determine the economic and social conditions in which the industry operates**

> **To identify and represent the views of the industry.**

Using a TSA member

By using a TSA member you can be assured that your project will get off to the best possible start. Whatever the size of project, you can be certain that TSA member companies are expert in the provision and management of spatially related data on which to base your concept, design and construction.

Professional attention from a TSA surveyor will reduce risk, repetition, possibly save you money and will ensure that your project receives the best possible attention.

TSA Contact Details

If you would like any more information about the TSA or its members or about other Information leaflets then please contact TSA at:

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