Cintoo

Cintoo: Next Generation Reality Capture Data

The next generation of Cloud and BIM-compatible Reality Data from terrestrial laser scanners will revolutionize the way the BIM, Architecture, Engineering and Construction sectors manage, collaborate and share their data.

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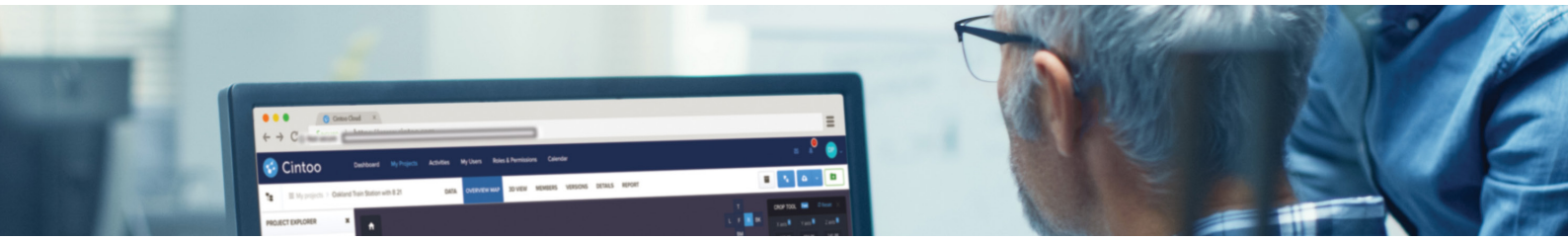
EXECUTIVE SUMMARY



'Reality Data' is the data captured from various reality capture devices, including terrestrial laser scanners, also commonly called '3D point cloud'. Reality Data is already largely used in various industries as the trusted source of information related to "as-built' or existing conditions of a site, a building, an infrastructure, etc. Most CAD software now support viewing and editing of such Reality Data or point clouds.

However, the massive size of the Reality Data captured by terrestrial laser scanners limits its use in the cloud because of the time required to upload and download this type of data via the Internet. Modern terrestrial laser scanners can now acquire up to a hundred million points in a single capture. Managing or viewing the acquired raw data is extremely desktop-centric and it is one of the last data types in the industry that is not yet cloud compatible.

Enabling the use of Reality Data in the cloud is critical to unlock the digital transformation of various industries, such as BIM in the Architecture, Engineering, Construction (AEC) and infrastructure sectors.

Cintoo proposes a revolutionary new model to handle the gigantic point clouds generated from terrestrial laser scans. Developed with a focus on BIM workflows in the AEC industries, Cintoo Cloud™ offers a unique point cloud- to-surface technology, enabling users to access high precision terrestrial laser scans on demand. With Cintoo Cloud™, even high-resolution data (billions of points) from large projects (thousands of scans) can be manipulated in 3D from any desktop or laptop using a standard web browser, without quality reduction or data simplification.

Cintoo Reality Data is a new generation Reality Data that is cloud-compatible, making it collaborative, distributable and shareable. Users can convert point cloud data to 3D surfaces within Cintoo Cloud™ then reconvert it when required. The solution offers powerful visualization features, with display modes in RGB, x-ray, height or 3D Surface, that reveals a granular level of scan detail never seen before. Cintoo Cloud™ enables Scan-to-BIM and Scan-vs-BIM workflows, allowing laser scanning to be fully integrated in collaborative BIM processes.

From a workflow perspective, the user can organize a project into Work Zones (rooms/floors), assigning specific scans to each zone and then exporting only the necessary data for a Scan-to-BIM job. Crops of project sections and elevations can also be easily exported, while new measurements can be performed, and annotations be created to inform other project users.

This white paper provides an analysis of the increasing market requirement for collaborative Reality Data, and how Cintoo's solution answers this need. The paper then details the technology behind the solution, and the comprehensive benefits end users will gain from moving their terrestrial laser data to Cintoo Cloud™. The paper also offers a benchmark for selected laser scanners and file formats, and how they perform with Cintoo Cloud™.

The conclusion is clear: Cintoo Reality Data divides the size of the data to upload by 10 to 20 times (depending on the data complexity) while preserving the accuracy of the source point cloud. The difference between the source point cloud and the reconstructed point cloud from Cintoo Reality Data is hardly noticeable (sub-millimeter in most cases) and much below the intrinsic accuracy of the device. Cintoo Cloud™ offers a trusted solution to distribute and share your laser scans with whoever, anywhere and anytime.

Reality Capture And AEC/BIM

Background

The AEC (Architecture, Engineering and Construction) industry started a worldwide initiative in the early 1990s, to standardize the exchange of information between the various stakeholders that make up the industry. This initiative is now commonly known as BIM ('Building Information Modeling'). BIM relates to the different digital technologies that manage the various phases of the lifecycle of a building: design, construction and exploitation.

Reality Capture is one of these digital technologies and is being quickly adopted in the AEC industry. Reality Capture allows the digitization of the real world and is the result of technology breakthroughs in laser scanning and the commercial drone sector. 3D scanning using active sensors such as laser scanners began more than 30 years ago to meet the increasing demand for digitization from the energy sector (nuclear power plants, oil and petrol refineries). These solutions were at the time extremely expensive, but today are benefitting from both technology and pricing disruptions.

Use Cases For Reality Data

Data from terrestrial Laser scanners, generating 3D point clouds, is already largely used in the AEC industry for various use cases:

- Digital capture of topographic terrain
- Capture of the as-built conditions for renovation projects
- Update to indoor and outdoor plans
- 3D BIM modeling post-construction to assess variance between the current state compared to as-built
- Monitoring of construction progress and quality
- Analysis of the differences between the as-built and design intent
- Management of building assets
- Content creation for use in Virtual Reality experiences for owners or future buyers

While Reality Data has become prevalent in many industries and can now be viewed and edited in most CAD software (leading suppliers include Autodesk, Bentley, Intergaph, Siemens, ESRI), the massive size of terrestrial laser scan data means that physical storage media such as hard disks or USB drives or memory cards are required for its distribution. Reality Data is massive and its use in the cloud for collaboration is almost inexistent today because of the time required to upload and download this type of data via the Internet. Managing or viewing the acquired raw data is extremely desktop-centric and it is one of the last data types in the industry that is not yet cloud compatible.

Enabling the use of Reality Data in the Cloud is the key to unlocking the digital transformation of BIM in the AEC and infrastructure industries.

Cintoo Technology

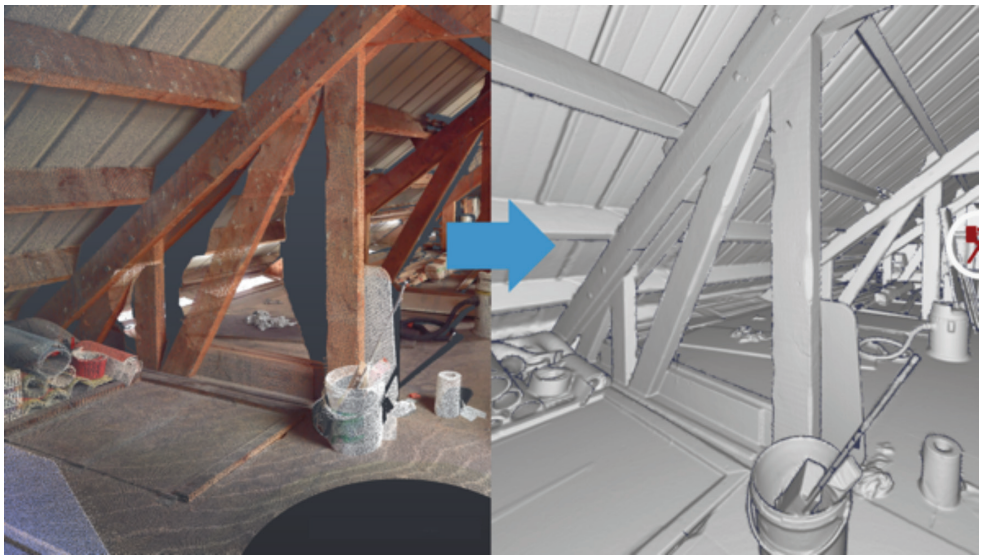
Modern terrestrial laser scanners can now acquire up to a hundred million points in a single capture. Scanners employ line-of-sight technology, so several vantage points are needed to capture a large-scale scene to avoid occlusions. As a result, scanning just the interior of a small building generates gigantic point clouds that are composed of billions of 3D points. The Benchmark Section of this white paper explains more about the size of raw data.

To upload point clouds to the cloud, some existing solutions reduce the number of points by drastically subsampling the point cloud, which leads to a loss of topological information.

In a completely new approach, Cintoo proposes a revolutionary new model to handle the gigantic point clouds generated from terrestrial laser scans. Based on years of academic research and rapidly evolving progress in cloud, streaming and 3D technologies, Cintoo has developed a unique point cloud-to-surface technology. It enables users to access high precision terrestrial laser scans on demand, retains the project structure (scan locations, panoramic images) without imposing size limits or compromising accuracy in any way - and can be used in a standard web browser.

3D point clouds lack structure and are made up of disconnected dots in space. To address this problem and to preserve the topology of the scan project (i.e. the vantage points), Cintoo handles the topology of the underlying surface directly from the depth maps generated during the capture process. Processing the depth maps sequentially provides a seamless solution to the problem of memory usage when processing such huge data.

Point Cloud-To-Surface Transformation



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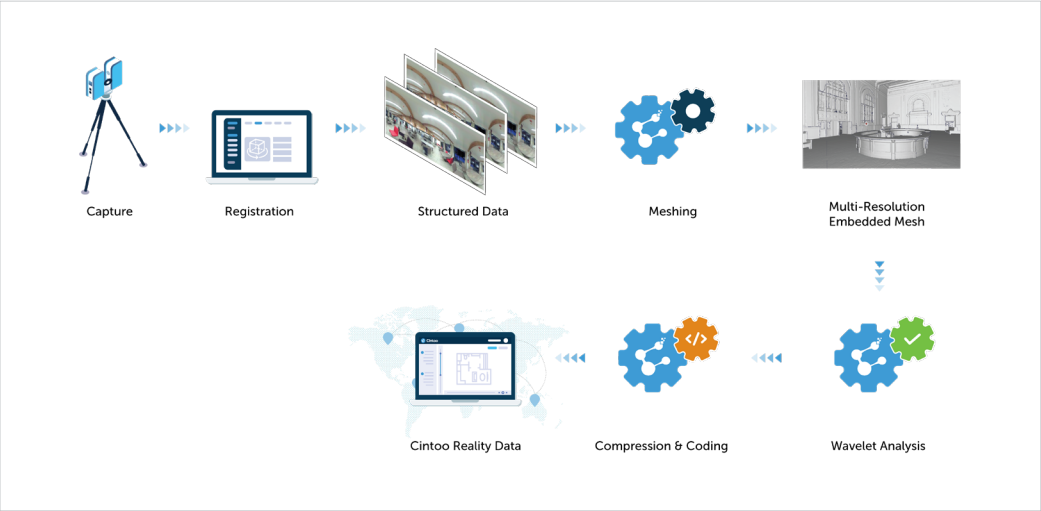
Cintoo has also developed a range of proprietary algorithms to enable the streaming and manipulation of gigantic mesh-based surfaces on different types of devices. The solution is based on data compression algorithms and a LoD (level of detail) system, which adapts the quantity of information to transmit and/or display based upon the performance of the viewing device and the bandwidth limitation.

Cintoo's Technology Is Based On:

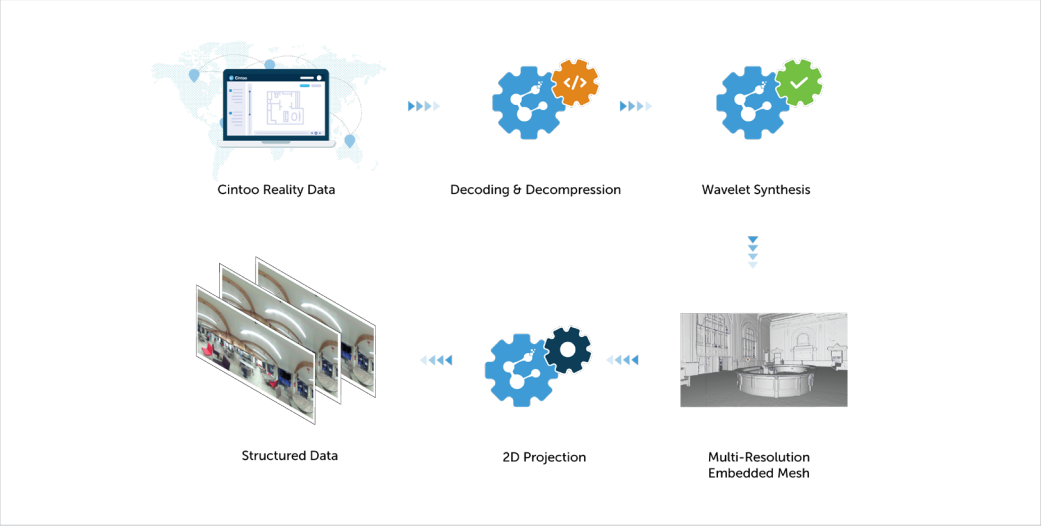
- **Optimized resampling of depth maps**, which preserves the entire 3D surface topology and survey points.
- Generation of a **multi-resolution embedded 3D mesh** that matches the underlying 3D data surface and that can handle extremely high resolutions.
- **Wavelet analysis**, efficient compression and mesh coding developed using **vector quantization**, **bit allocation** and **entropy coding**.
- **The generation of a Cintoo 3D Surface mesh structure** which enables the switch at decoding from the mesh structure to the point cloud and inversely from the point cloud to the mesh.
- The ability to **return to a depth map structure from the Cintoo format after decoding**.

Cintoo's technology includes several algorithmic steps that are summarized in the two following diagrams.

From a structured point cloud to Cintoo 3D format (surfaces):

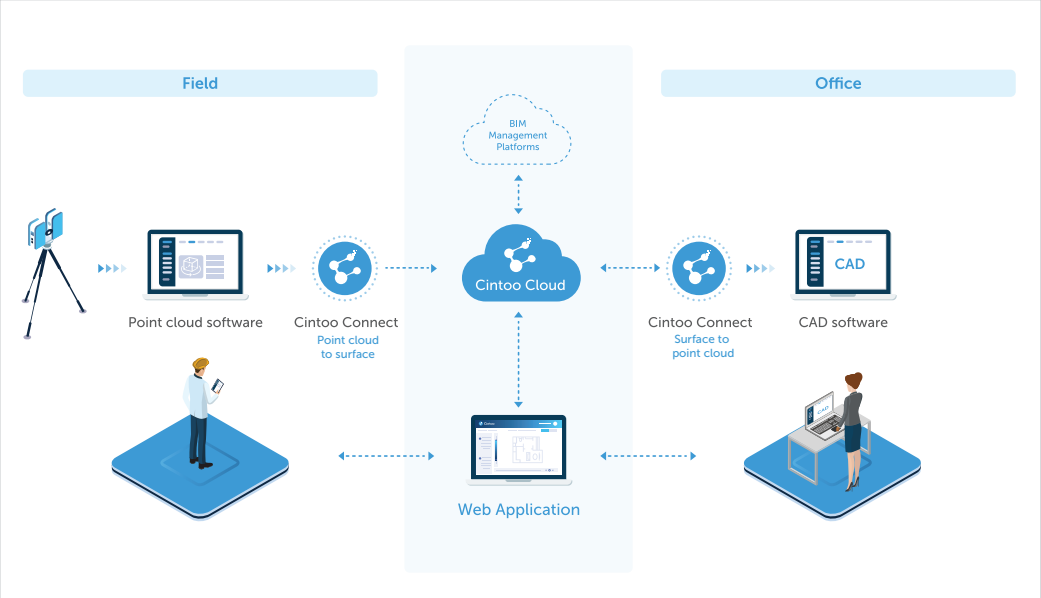


From Cintoo 3D format (surfaces) to a structured point cloud:



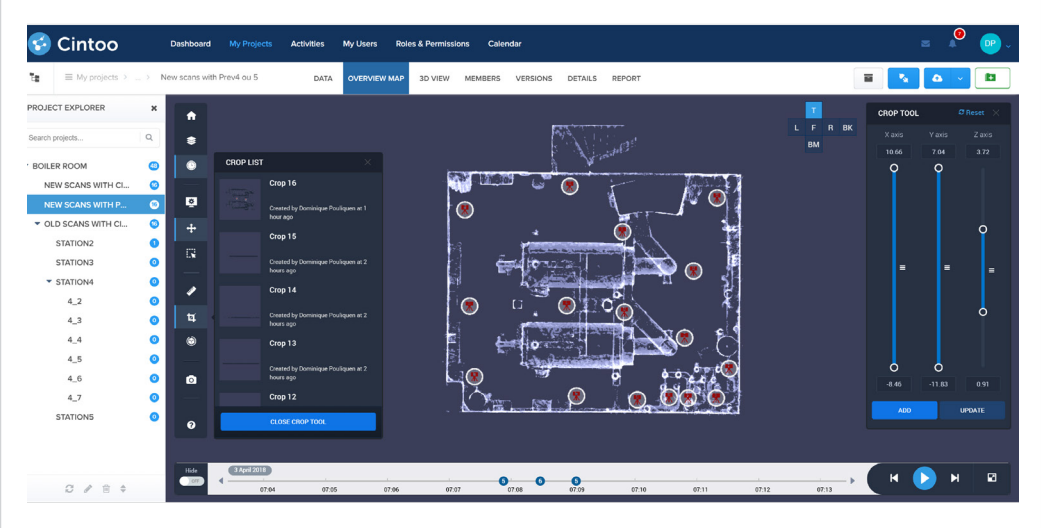
Cintoo Technology In Cintoo Cloud™

Cintoo's core technology is embedded in two key products: Cintoo Cloud™ and Cintoo Connect.



Cintoo Cloud™

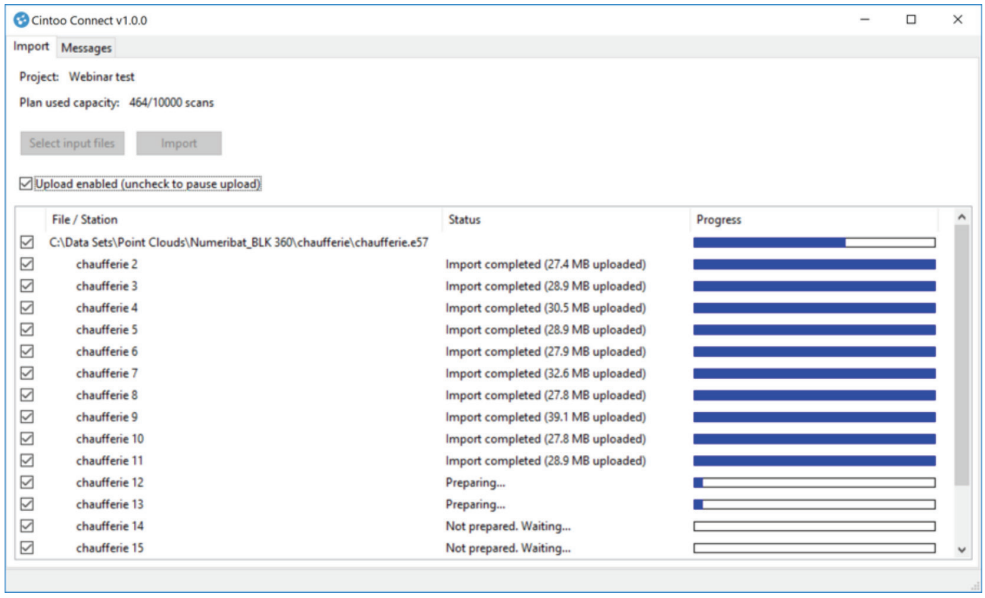
Cintoo Cloud™ is a cloud-based Reality Data management and collaboration platform accessible from any location via a web application. Cintoo Cloud™ is available on Microsoft Azure or Amazon Web Services and can also be deployed in an organization's private data center behind a secure firewall.



Cintoo Connect

Cintoo Connect is a Microsoft Windows client that connects desktops to Cintoo Cloud™.

- **From desktop to cloud**, it is used to perform the translation of laser scan projects into Cintoo Reality Data and manage its fast upload to Cintoo Cloud™.
- **From cloud to desktop**, Cintoo Connect will download Cintoo Reality Data and reverse-translate it back into point cloud data that is compatible with most CAD software.



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Cintoo Cloud™ enables every stakeholder in a project (owners, architects, BIM managers, designers, field technicians and contractors), to access and collaborate on the same laser scan-based Reality Data all over the world. With Cintoo Cloud™, service providers and General Contractors can continuously manage their captured data over time. BIM Managers and surveyors can exchange Reality Data and collaborate with engineers, designers or stakeholders working at different locations regionally, nationally or internationally.

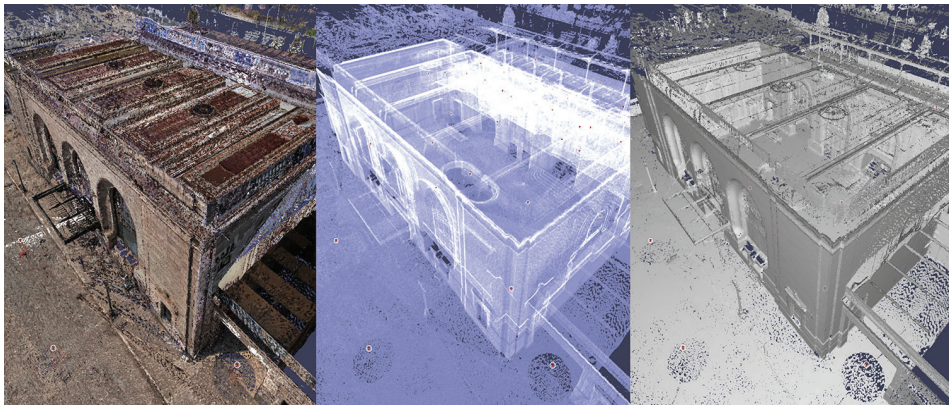
Cintoo also leverages the power of Cloud computing to perform the in-depth geometric analyses and powerful 3D visualization that BIM and surveying professionals require. The Cintoo Cloud™ solution reads any registered 3D scans in e57 format or Autodesk RCP format and is agnostic to both 3D laser scanner and point cloud software.

Cintoo Cloud™ also includes all necessary data management and team management features. By connecting to BIM Management platforms and by streaming Reality Data in desktop-based modeling software such as Autodesk Revit, Cintoo Cloud™ also enables Scan-versus-BIM and Scan-to-BIM workflows, making it the solution to turn terrestrial laser scans into BIM-compatible Reality Data.

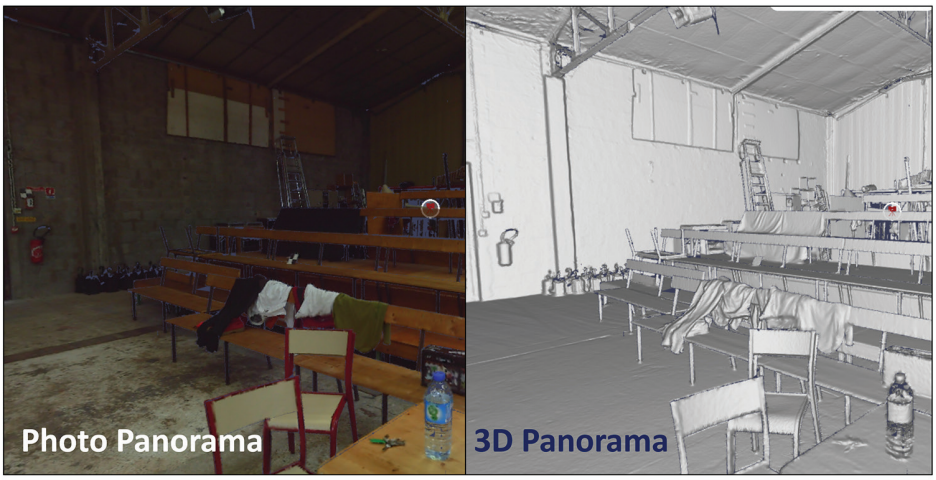
Key User Benefits Of Cintoo Technology

Cintoo's core innovation is disruptive. It is integrated into a suite of algorithms and provides numerous benefits for the end user:

- Enhanced visualization
  The user can handle high-resolution Reality Data made from billions of points from large projects that use thousands of scans without any quality reduction or data simplification. This massive data is accessible on any desktop, laptop or mobile device via a web browser. Turning massive point clouds in surfaces greatly enhances visualization and makes it much easier to navigate Reality Data. Back face culling and occlusion management are used to see through the walls, floors or ceilings without the need to clip the point cloud.



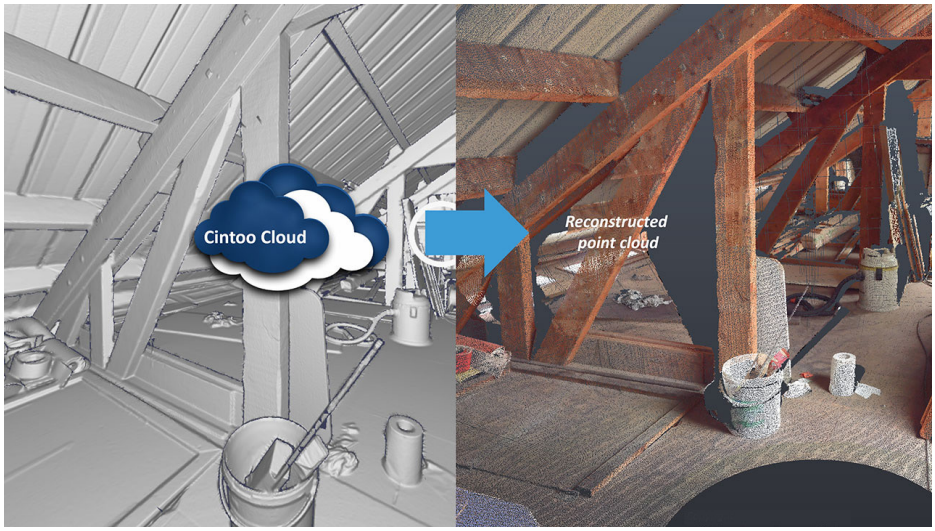
- Photo, 3D and Virtual Panoramic views management
  Panoramic views are key outputs from terrestrial laser scanners because they are used to navigate the Reality Data, extract measurements, tag and annotate, or simply as a visual reference for modeling in the Scan-to-BIM process. Cintoo's Reality Data keeps the project structure, including scanning positions and panoramic views. In addition, by translating to surfaces, laser scan panoramas are not only viewed as images with depth, but as 3D models as well. The visualization of mesh-based surfaces will reveal details in the laser scans that are hardly seen in typical point clouds. The user can also create as many additional virtual panoramic viewpoints as necessary making the Scan-to-BIM process easier (coming soon).



- **Fast upload and reduced storage**
  Cintoo's innovative and powerful compression algorithms make Cintoo Reality Data much faster to upload or download, and greatly reduce the need for storage space. Ratios comparing raw point clouds to Cintoo Reality Data can be viewed in the Benchmark Section of this white paper.

- **High speed streaming**
  High speed streaming ensures that only the most useful data is sent to the web browser for viewing, providing fast access to the most detailed areas, and limiting use of both computer resources and bandwidth.

- **Inverse translation (Surface to Point Cloud)**
  Cintoo's translation from a structured point cloud to a 3D surface can be inverted, so the user can retrieve the original source files as a structured e57 point cloud or a unified RCS point cloud. The impact on accuracy through this inverse translation is extremely minimal, and much lower than a laser scanner's default accuracy (ratios are provided in the Benchmark Section of this white paper).



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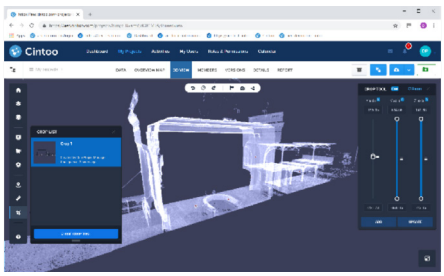
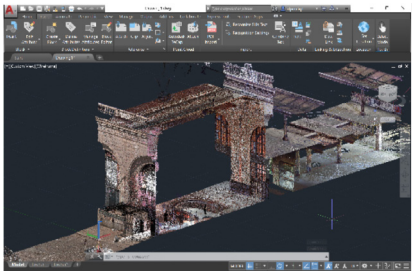
- **Cropping and export to Recap format**
  Cintoo Reality Data can be easily cropped in various sections or elevations along the X, Y or Z axis in the Web viewer. These crops can then be exported and turned back into unified RCS point clouds and used as 3D references to get 2D floor plans or 3D BIM models in Autodesk AutoCAD or Revit.





- **VR ready**
  Translating laser scan data to surfaces and streaming those surfaces in real time based on the user's point of view, makes this laser scan data ready to be displayed using Virtual Reality devices (coming next).

- **Analytics and AI ready**
  Creating continuous surfaces from discrete points also makes Reality Data compatible for machine learning and feature extraction (coming next).

Benchmarking

The following benchmark aims to provide metrics related to Cintoo's core technology, i.e. the point cloud-to-surface and the surface-to-point cloud engines. We have selected various scanning devices from Faro and Leica and we have completed extensive measurements on various data sets. What is being measured are the following metrics, per scan:

- The compression ratio from the source raw data in e57 to Cintoo Reality Data;
- The time required for the point cloud-to-surface and surface-to-point cloud translations on a conventional PC equipped with an intel i7 processor with 32 Gb. of RAM;
- The time needed to upload and download Cintoo Reality Data using a 100 Mbps optical fiber network;
- The accuracy of the reconstructed point cloud as e57 file compared to the source e57 point cloud. These measurements have been made using the Cloud Compare software (http://cloudcompare. org/).

All data per scan Reference datasets									
Scan Size	10 Million Points	40 Million Points	10 Million Points	40 Million Points	10 Million Points	40 Million Points	15 Million Points	60 Million Points	40 Million Points
Scanner Model	Faro S120	Faro S120	Faro X130	Faro X130	Faro X330	Faro X33	Leica BLK	Leica BLK	Leica P20
Accuracy	±2mm at 10m	±2mm at 10m	±2mm at 10m	±2mm at 10m	±2mm at 10m	±2mm at 10m	±8mm at 20m	±8mm at 20m	±3mm at 50m
Ranging Noise at 10m	1.2mm at 10% refl	1.2mm at 10% refl.	0.4mm at 10% refl.	0.4mm at 10% refl.	0.4mm at 10% refl.	0.4mm at 10% refl.	-	-	0.8mm at 10% refl.
Resolution (height*width)	2134*5168	4267*10316	2135*5062	4267*10132	2134*5072	4267*10148	2700*5508	5138*12264	4050*10120
Attributes									
Position	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colour	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Reflectance	No	No	No	No	No	No	Yes	Yes	Yes
Impact On Reality Data Size									
Registered Scan File Size (Mbytes) Per Scan	55	181	38	182	68	175	377	2145	-
Registered Scan File Format	FLS	FLS	FLS	FLS	FLS	FLS	RCP	RCP	-
Registered scan files size using E57 format	254 Mbytes	1001 Mbytes	215 Mbytes	947 Mbytes	251 Mbytes	1000 Mbytes	341 Mbytes	1450 Mbytes	802 Mbytes
Registered scan files (Cintoo format)	12.7 Mbytes	38 Mbytes	7.6 Mbytes	41 Mbytes	8.4 Mbytes	27 Mbytes	15.8 Mbytes	110 Mbytes	75 Mbytes
Compression Ratio (compared to E57)	**20**	**26**	**28**	**22**	**30**	**37**	**22**	**13**	**11**
Impact On Processing Time									
Cintoo Connect Prepare (Translation from point cloud to Cintoo format) Time per scan intel i7, 32 Gb. RAM	49 seconds	37 seconds	3 minutes 2 seconds	3 minutes 12 seconds	39 seconds	2 minutes 52 seconds	58 seconds	6 minutes 13 seconds	3 minutes
Network (Upload Time) 100 Mbps optical fiber network	4 seconds	8 seconds	3 seconds	7 seconds	3 seconds	6 seconds	4 seconds	18 seconds	12 seconds
Cintoo connect Export (Inverse Translation from Cintoo format to point cloud) intel i7, 32 Gb. RAM	29 seconds	2 minutes 11 seconds	36 seconds	1 minutes 53 seconds	22 seconds	2 minutes 12 seconds	52 seconds	5 minutes 21 seconds	1 minute 29 seconds
Network (Download Time) 100 Mbps optical fiber network	3 seconds	8 seconds	3 seconds	7 seconds	3 seconds	6 seconds	4 seconds	16 seconds	11 seconds
Impact On Accuracy The following table shows the different distances calculated between original laser scans compared to compressed ones. We can easily see that the noise produced by the Cintoo process is very small and mostly of the same order of magnitude as the scanner's ranging error.									
Cloud to cloud distance at 10m (nearest neighbor distance) in mm	0.37	0.30	0.25	0.48	0.25	0.18	1.62	1.71	0.74
Cloud to cloud distance at 25m (nearest neighbor distance) in mm	0.40	0.35	0.25	0.48	0.26	0.22	1.68	1.71	1.05
Cloud to cloud distance (Local surface modeling using least Square plane) in mm	0.17	0.20	0.14	0.25	0.16	0.11	0.45	0.74	0.56

Conclusion

The conclusion is clear: Cintoo Reality Data reduces the size of the data to upload by 10 to more than 20 times (depending on the data complexity) while preserving the accuracy of the source point cloud. The difference between the source point cloud and the reconstructed point cloud from Cintoo Reality Data is hardly noticeable (sub-millimeter in most cases) and much below the intrinsic accuracy of the device. Cintoo Cloud™ is then a trustful solution to distribute and share your laser scans with whoever, anywhere and anytime.

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