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|  | AIM Addendum to tender - Terrestrial Laser Scanning (TLS) |  |

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| Version | Date | Author | Description |
| 01 | 27-11-2019 | KAKI | First version |
| 02 | 9-03-2020 | KAKI | Number of points added / truview update |
| 03 | 27-11-2020 | KAKI | Translation from Polish V03 to English |
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# Introduction

Laser Scanning is the process of capturing digital information about the shape of an object with an equipment that uses a **laser**. This equipment is called laser scanner and is a contact-free measuring device which can collect dense point clouds of objects. After registration and processing of point clouds from multiple positions, each point is assigned with X, Y, Z coordinates, colour value and reflectance value. The collected data can then be used to create digital 2D drawings or 3D models that are usable inside a range of other applications.

Laser scanning divides into three main branches:

* **Airborne Laser Scanning** (a point cloud is created by the application of a laser scanner and an airplane, a helicopter or a drone)
* **Mobile Laser Scanning** (a point cloud is created from a mobile platform, eg. a car, a backpack)
* **Terrestrial Laser Scanning** (a point cloud is created from terrestrial laser scanners placed in multiple locations where a tripod and the scanning device can be placed).

This document relates mainly to **Terrestrial Laser Scanning (TLS)**.

Laser scanners measure approx. 1 million points per second. The specification of the most advanced devices includes information on the accuracy of the measurement of approx. 3 mm, however, the actual measurement accuracy of these devices after the use of an appropriate EPGS system is approx. 2 cm (due to the accuracy of obtaining coordinates from GNSS satellite positioning systems). What is more, laser trackers are very precise devices for metrology that also use a laser to measure the coordinates of points on a fragment of space. Laser trackers measure on average about 1000 points per second, and the measurement accuracy is determined even at about 100 μm. Laser trackers are used for precise measurements performed at a specified time on the basis of which various types of geometry analyzes and calculations are performed.

Table 1 summarizes the specifications for laser scanning (TLS) and metrology.

Table 1 Comparison of specifications for metrology and TLS.

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|  | **Specification for TLS[[1]](#footnote-1)** | **Specification for metrology[[2]](#footnote-2)** |
| **Accuracy of the study** | over 2cm | 0,1mm – 20mm |
| **Coordinate system** | EPGS | local, usually without EPGS |
| **Duration of one single scan** | 1-5 min | 5-20 min |
| **Field of view of 3D scanning** | Full 360-degree field of view | Limited field of view |
| **Aim of 3D scanning** | 3D scanning of whole buildings, halls, depots. | Reverse engineering, precise examination of the shape of the object; geometry study; quality control; verification with a 3D model, 2D and 3D deformation analysis. |
| **Colours of point clouds** | RGB | Grey scale / RGB |
| **Frequency of 3d scanning** | Usually one-time measurement | The measurement is usually several times |
| **Number of positions of 3d scanner** | The measurement is usually multi-station | Usually one-station measurement |
| **Distance between a position of 3D scanner and the object** | Up to approx. 250m | Usually short: e.g. 10-40m |

# 2. Abbreviations

In this document following abbreviations will be used:

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| AMP | ArcelorMittal Poland |
| AIM | Automation, Industrial IT and Models (in AMP) |
| EPSG | European Petroleum Survey Group – Geodetic parameter dataset |
| TLS | Terrestrial Laser Scanning |

# PROJECT REQUIREMENTS DEFINITION

## Project requirements towards buyer

* Describe the **objective** of the desired TLS.
* Define the **area** to be scanned: boundary on the basis of GIS / layout plan or orthophotomap.
* Define a **number of levels** to be scanned and provide information about different levels (e.g. level 0,0 m can use a shortcut - 00; level 18,5m can use a shortcut - 01 etc.; information about used shortcuts must be included in text file).
* Prepare **a map** with notes and descriptions of areas to be scanned with shortcuts used in AMP (see 5.1., e.g. DWD, SSG).
* Describe which locations are important from the point of view of **safety** and the **completeness** of the laser scanning and define:
  + which installations/objects must be visible and to which extent;
  + which installations/objects are not visible from multiple positions and where extra positions of laser scanning need to be added;
  + which installations/objects cannot be recorded by TLS.
* Check whether there are **standstills** required for certain installations or zones.
* Check which areas must be tensioned against **free passage**.
* Explore and identify potential difficulties related to the **movement** of machines, vehicles and people etc.
* Prepare a **plan to stop** moving machines, vehicles and people for the time of conducting laser scanning (approx. 1-5min for every scan position).
* Provide a **local visit** with the contractor in quotation phase:
  + Arcelormittal’s guide is necessary during TLS (with mobile radio connections with operators, control rooms etc.);
  + Discuss a potential scan positions and heights for positioning of a laser scanner on a tripod;
  + Since a laser scanner is often mounted on a fixed tripod, it has to be discussed with the contractor whether it is necessary to do laser scanning at different levels, and whether a worker with climbing permission has to be provided.
* Provide information to the vendor about **local coordinate system**.
* Provide information to the vendor about **existing control points** measured by land surveyors in the past.
* Provide the vendor **plans/layouts** of areas to be scanned in electronic format; the layout of the area should have information/descriptions that are necessary for the creation of Autocad files.
* Prepare images of objects/columns/construction elements that are used for **reference** purposes for any measurements and present them on a map.

## Project requirements towards vendor

* **Registration of point clouds**:
  + **Time-of-flight laser scanner** must be used and must be equipped with an integrated external calibrated camera.
  + **Registration** must be done using two indirect approaches (**target-to-target** constrains or **cloud-to-cloud** constraints). For target-to-target method it is important to place targets in positions visible from multiple locations, whereas in the case of cloud-to-cloud constrains it is important to make sure that laser scans have 30% overlap. The chosen method must be described in a final report.
  + **Targets** must have unique visible numbers and must be easy to find in the future; targets cannot be removed after the registration process unless they do not distract the work of machines.
  + Once the 3D laser scanning is completed on the site, all data has to be registered by **software** for processing point clouds developed by the producer of a laser scanner and information about this process has to be included in a final report.
* **Georeference:**
  + Control points located **outside** must be measured using GPS device.
  + Control points located **inside** must be measured using total station.
  + There must be a structured order for control points **naming** (e.g. P01, P02).
  + All measured control points has to me positioned on **a map**.
* **Coverage:**
* It is required that the entire hall surface (all rooms) are scanned in accordance with the **scope** of the study.
* For each particular project there must be a dedicated agreement regarding accepted amount of **shades** (shades may only be created in special cases - a report of inaccessible places is required).
* In an agreement with a buyer and AIM department, other **data acquisition technologies** may be used rather than laser scanning in places inaccessible in order to fully scan the shape of the site.
* **Training**
* It is required to provide a training about the usage of point cloud and basic operations on the generated point clouds to the buyer (3-4 employees) (6-8 hours) in AMP.

**All details must be agreed and approved by AIM.**

**Any deviations from the standard must be approved by AIM.**

# MINIMAL DESIRED PARAMETERS for the TLS

* **General**
* The laser scanning device must be a **class 1** laser classification according to **EN 60825-1** and **IEC 60825-1** and use impulse method for measurement.
* The permitted deviation from the accuracy of the laser scanner may not exceed **± 3mm for a range of 70m**.
* To ensure the accuracy of the laser scan, the range of the laser scanner is adjusted according to the size of the area to be scanned; eg. **2 - 70m** for smaller internal spaces**, 2 - 350m** for sites and (outdoor) installations.
* Each individual static scanning position contains a 360° image with a resolution of at least **40 million pixels.**
* **The scan orientation and origin in the national reference system:**
  + X, Y, Z coordinates in **EPSG2178** (coordinate system 2000, zone 7, PL-EVRF2007-NH) for Krakow
  + X, Y, Z coordinates in **EPSG2177** (coordinate system 2000, zone 6, PL-EVRF2007-NH) for DG & Slask
  + Relative X, Y, Z coordinates has to be indicated when AMP provides information about the local coordinate system. A known, fixed position is specified within the scanned zone as "scan origin" (relative coordinates).
  + Model of quasi-geoid **PL-EVRF2007-NH** is required height system.
* **Accuracy of georeferencing:**
* The **error of fitting** the resulting point cloud into the measured reference points cannot be larger than 20 mm.
* The error of fitting must result from the attached **report**.
* The **control points** must be evenly distributed over the whole object.
* The **accuracy of determining the control points** cannot be worse than 20 mm in terms of location and 20 mm in height.
* **Raw, structured and unified scan projects**
* Point clouds must be provided in **raw format**, as directly copied from laser scanner.
* Point clouds from individual laser scanner positions must be saved as **structured projects**.
* Point clouds from multiple laser scanner positions must be saved as **unified projects** with an error of no more than **20 mm**.
* The **error value** must result directly from the report generated from the program in which the project was submitted.
* **Geometric detail:**
* **Geometric resolution** (cloud density) must be selected in such a way as to correctly identify objects with dimensions of **20x20mm** (up to a height of 5m).
* On every position of a scanner, **20-90 million points** should be registered in order to perform 3D modelling in the future (number of points should be included in the report).
* **Information detail:**
* The entire cloud must have **3 XYZ coordinates**, **reflection intensity** (8bit) **RGB colour** (8bit) and normals.
* **Scan noise**:
* the deviations between the point cloud and the actual surface with various possible causes must be minimal and cannot exceed the **3x accuracy** of the laser scanning.
* It is not allowed to do laser scanning in **temperatures** more than 50°C and where vibrations occur.
* **Processing point clouds:**
  + For each point cloud, **filtration** must be performed in order to remove "noise" (i.e. points reflected from people, vehicles, windows, mirrors, etc.) and points beyond the scope of the study.

**All details must be agreed and approved by AIM.**

**Any deviations from the standard must be approved by AIM.**

# DELIVERY of TLS

## Data set

* **First delivery:**
  + After completing the first object/a part of an area to be scanned, the processed data should be **delivered to AIM** in order to be checked whether they fulfil this specification for TLS.
  + The first delivery must be provided via FTP.
* **List of files:**
  + The **folder structure** is defined in 5.4.
  + The following files must be provided on a hard drive:
    - **raw scan data** (as copied directly from laser scanner);
    - point clouds in **formats**:
      * LAS/LAZ,
      * Structured[[3]](#footnote-3) RCS, E57.
      * Unified[[4]](#footnote-4) RCP, E57;
    - reports and sketches in PDF files (see 5.3);
    - images and 360-degree images;
    - orthoimages in GeoTIFF format;
    - visualisations of levels and descriptions in JPG format;
    - **TGV/LGS files** (source files for TruView) or other source files for panoramic viewing of point clouds;
    - DWG files.
* **Additional files**
  + A map of the distribution of fragments of structured files has to be created for every level and saved in PDF format.
  + The finished project must include **georeferenced orthoimages** for every level (ready to be opened in QGIS software; saved as **GeoTIFF**).
  + The finished project must include photo documentation of control points (Fig. 1) and a map of locations of these points (Fig. 2); file name of images must include number of a control point.
  + Source files of creating projects for panoramic and bird’s eye view must be included in final delivery (see 5.2. for explanation of two types of views).

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Fig. 1. Photo documentation of control points.

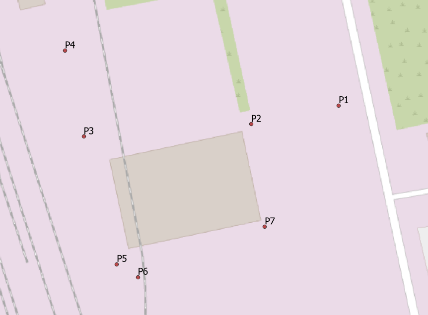


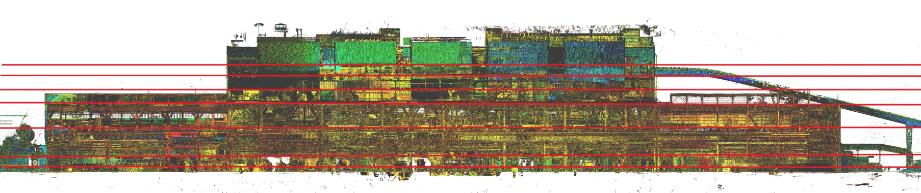
Fig. 2. Location of control points in relation to the scanned object.

* **Final delivery**
  + Transfer data to an **external hard drive** (2.5 "or 3.5" USB 3.0); hard drive will not be returned by AIM.
  + Transfer TLS data via FTP is not acceptable.
* **File names**
  + File names must include the date and time of laser scanning and a **unique identifier** that is specific for the particular laser scanner position and georeferenced system used.
  + The identifier for point cloud data must include the following sequence of digits and letters:

**YYMMDD\_AAA\_BBB\_CC\_EE\_LL\_XXXX**

where:  
**YY** – year (e.g. 19)  
**MM** – month (e.g. 10)  
**DD** – day (e.g. 09)  
**AAA** – plant (e.g. DWD)  
**BBB** – area (e.g. SCS)  
**CC** – stands for EPSG coordinate system (e.g. 77 (for EPSG2177) or 78 (for EPSG2178) or LO (for local coordinate system))  
**EE** – height reference system (e.g. 86 (for Kronsztad86), 07 (for EVRF2007), LO (for local height reference system))  
**LL** – level of a hall (for ground floor use 00)  
**XXXX** – unique number of a laser scanner location in a project (e.g. 0001)

* + For projects with small number of laser scan positions, 4 digits in laser scan location number can be reduced (e.g. XXX – 3 digits, XX – 2 digits); a number of digits in XXXX should also include potential future number of scans.
  + For levels use two digits (LL) and prepare visualisation and descriptions in a form of an image in PDF or JPG file (Fig. 3).



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Fig. 3. Image with visualisation of multiple levels.

* + The identifier for 360-degree images must include the following sequence of digits:

**YYMMDD\_LL\_XXXX**

where:  
**YY** – year (e.g. 19)  
**MM** – month (e.g. 10)  
**DD** – day (e.g. 09)  
**XXXX** – unique number of a panorama created on a laser scanner location (4 digits) (e.g. 0001)

* + The identifier for other images must include the following sequence of digits and letters:

**YYMMDD\_LL\_ZZZZZ\_####**where:  
**YYYY** – year (e.g. 2019)  
**MM** – month (e.g. 10)  
**DD** – day (e.g. 09)  
**ZZZZZ** – unique number of an image (5 digits) (e.g. 00001)

**#### -** number of control point (if presented on image)

## Publishing TLS

* **Two types of viewing point clouds**
  + Two types of viewing point clouds are required: **panoramic view** (Fig. 4) and **bird’s eye view** (Fig. 5).

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Fig. 4. Panoramic view of a point cloud created by TLS.

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Fig. 5. Bird’s eye view of a point cloud created by TLS.

* **Preparing TLS for AMP**
  + The prepared project must be made available for **free** on **the intranet site on AMP’s server** in order to perform interactive measurements based on a point cloud and 360-degree panoramas using computers in the resources of the majority of AMP employees.
* **External servers**
  + Publishing TLS data on **servers** outside AMP is not permitted.
* **Viewing TLS data**
  + The finished project must be able to perform **basic operations on the point cloud and panoramic images** (including distance measurement, setting markers and mark-up notes, creating profiles, saving as **PDF and** **DWG/DXF** files) **without installing additional software or plug-ins.**
  + Tools for viewing point clouds must run in **a browser** and allow intuitive navigation even through complex environments.
  + Recommended application for bird’s eye view is open-source PoTree. Additional navigation (a map and interface) must be created for PoTree projects.
  + A tool for viewing point clouds using panoramic view must allow choosing laser scan position; **a unique number of laser scan location** (XXXX) must be displayed on an overview map (Fig. 6).
* A tool for viewing point clouds using bird’s eye view must allow viewing **global and local** (if available) **coordinates**;
* A tool for viewing point clouds using panoramic view must allow loading **RGB panoramic images** from laser scanner positions; Fig. 7 presents one of 360-degree images created at the specific laser scanner position.
* Installation of extra **plug-ins** for a browser for viewing point clouds from bird’s eye and panoramic views is not allowed.

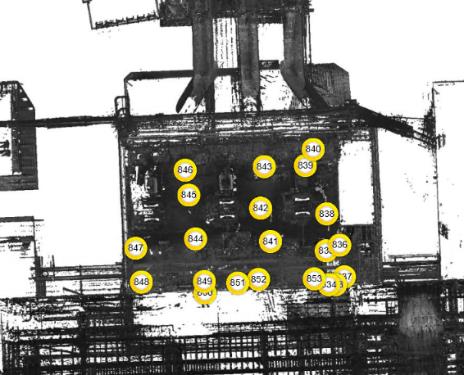


Fig. 6. Locations of positions of a laser scanner include numbers that consists 3 digits (XXX).



Fig. 7. 360-degree image created by the application of a laser scanner equipped with a digital camera.

* **DWG files:**
  + The finished project must include basic **DWG file** with specific layers agreed with the buyer in **global and local coordinate system** (Fig. 8).

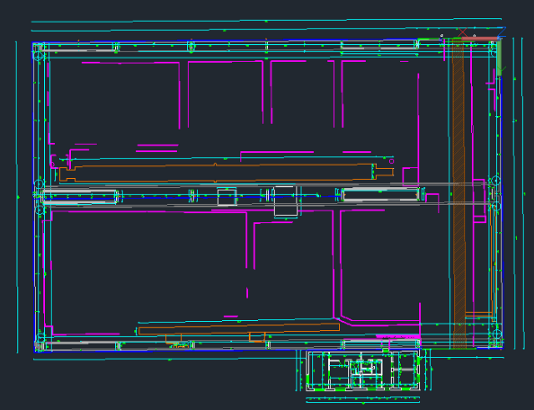


Fig. 8. A basic Autocad file (DWG format) presenting layout of the scanned area in local coordinate system.

## Reports

* **Final report**
  + **Technical report** on the work carried out with the description of measurement methods and the preparation of results and photo documentation.
  + This report must include:
    - Dates of conducting laser scanner on site.
    - Dates of editing point clouds.
    - Reference system used.
    - Description of land surveying/GNSS measurements.
    - Used TLS equipment with a serial number.
    - Summary of alignment of land surveying measurements.
    - Description of laser scanning process with images.
    - A list of control points (with their coordinates and photos presenting their location) used to provide a georeference to the whole project.
    - Report on combining individual laser scan positions into one project.
    - Report with a description of inaccessible places.

## Delivery of laser scanning data

Registering scan sites using ReCap is not allowed.

Folder structure transferred from an external hard drive to a server must be in this order:

+++Laser scans (project name starting from data in format: YYYYMMDD\_)

++ 01 Raw data

++ 02 Structured scan projects

+ 02\_01 RCS

+ 02\_02 E57

++ 03 Unified scan projects

+ 03\_01 RCP

+ 03\_02 E57

+ 03\_03 LAS

++ 04 Intranet data

+ 04\_01 Top[[5]](#footnote-5)

+ 04\_02 Panoramic

+ 04\_03 Source data

++ 05 Georeference data

05\_01 GeoTIFF files

++ 06 Reports

++ 07 Photo documentation

++ 08 CAD files

01 Raw data

Original data from the scanner

02 Structured scan projects

Data that include individual laser scans, panoramic images and registration transforms

03 Unified scan projects

Data that include unified (merged) laser scans into one project. Large point cloud can be divided into parts, where a description of parts created can be found in PDF file included in this folder.

04 Intranet data

Here are the georeferenced intranet data prepared to be viewed for free from a browser using two types of viewers: panoramic and bird’s eye view.

05 Georeference data

All data related to adding georeferenced to the projects (list of coordinates, information about coordinate systems, zero points, sketches and images of survey points etc.)

06 Reports

All reports created during TLS (See point 5.3)

07 Photo documentation

All photos taken during the process of TLS.

08 CAD files

DWG or DXF files with specific layers and with vectorised lines presenting the scanned objects

1. AIM Addendum to tender - TLS LG VXX.docx (LG means language version, XX means version number) [↑](#footnote-ref-1)
2. AIM Addendum to tender - metrology LG VXX.docx (LG means language version, XX means version number) [↑](#footnote-ref-2)
3. **Structured scans** – the structured data contains each scan location, each panoramic image, depth map and the 3d point cloud, as the result from the registration process; file size is big. [↑](#footnote-ref-3)
4. **Unified scans** – the unified scans lose the structure of the project; digital images are lost; file size is smaller making the 3d point cloud easier to consume in desktop modelling applications. [↑](#footnote-ref-4)
5. For bird’s eye view. [↑](#footnote-ref-5)