

# Implementation of 3D Scanning in Presentation and Preservation of Cultural Heritage Case Study: Dungeons of the National Museum in Pančevo

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Zgradba Magistrata in zapora predstavlja pomemben del kulturne dediščine mesta Pančevo. Stene celice propadajo zaradi vlage. Zaradi vlage in odpadanja ometa izgubljam o vrezana sporočila zapornikov. Za dokumentiranje trenutne situacije so bili uporabljeni 3D skenerji. Poleg visoke natančnosti laserskega skeniranja skener omogoča tudi ustvarjanje visokokakovostnih tekstur na 3D modelih. Na ta način smo zagotovili varno predstavitev zaporniških celic obiskovalcem muzeja.

*Ključne besede:* laserski skener, 3D skeniranje, kulturna dediščina, predstavitev, zaščita

The Magistrate building and the dungeons in it represent a significant part of the cultural heritage of the city of Pančevo. Dungeons walls are deteriorating due to moisture and engraved messages of the prisoners are disappearing, 3D scanners were applied to the record current situation. In addition to the high precision of laser scanning, this scanner also enables the creation of high-quality textures on 3D models. In this way, we provided a safe presentation of dungeons for the visitors of the museum.

*Keywords:* Laser scanner, 3D scanning, Cultural heritage, Presentation, Preservation

The historic buildings are important because they are social and cultural evidence of the past, which is why their reuse needs to be carefully thought out. In their lifetime, many historic buildings, government or not, may lose their function. Some buildings become functionally obsolete, or they are too small due to modern needs. For this reason, many of these historical buildings have been abandoned by the previous users, so their purpose has changed. Reasons why buildings become redundant usually represent changing of economic and industrial practices, demographic changes, increasing the cost of maintenance and primarily because they are no longer suited for the function they were being used.<sup>1</sup> Adaptation and re-

use of these buildings, through changes of its purpose, and the ways of use, is not a rarity.

Buildings usually change their use through their lifetime; this is a case with the “Magistrate” building in Pančevo that this paper will discuss. The structure was built between 1833 and 1838, as an administrative building. Throughout the history, this type of buildings was built in order to show the power of the state and to represent its culture and economic wealth. The building has a dominant position in the main city square, with an emphasized main facade. The city administration left the building when a new building was built in 1964 and space changed its purpose and became the National Museum.

The International Council for Monuments and Locations (ICOMOS), define cultural heritage as the expression of lifestyle improved by the community and moved from the past to fu-

<sup>1</sup> Kağan, Günçe, and Damla Misırlısoy. “Adaptive reuse of military establishments as museums: conservation vs. museography.” *WIT Transactions on The Built Environment*, (September, 2014): 126, doi: 10.2495/DSEHF140111.

ture generations.<sup>2</sup> Documentation represents the main ways of protecting, understanding and recognition of the values of the cultural heritage. To achieve that goal, heritage monuments need to be well recorded. During the process of documenting cultural monument, it's necessary to capture and record all relevant data and information, everything needs to be saved both in visual and written format<sup>3</sup>. The cultural heritage is worldwide endangered by a different kind of threatening, such as human negligence, weather changes, vandalism, terrorism, population growing and natural disasters. Considering all mentioned, the growing requirement for document and conserve the heritage in the fast and precise way is justified. That is why a process of 3D documenting, having a great potential, and represent important technique on the international level. Therefore, 3D data is important component for permanent records of the important cultural heritage objects so that they might be saved for future generations.<sup>4</sup>



Figure 1. The building of the former Magistrate ([http://www.muzejpancevo.rs/pages/o\\_muzeju/?page=o\\_muzeju](http://www.muzejpancevo.rs/pages/o_muzeju/?page=o_muzeju))

- 2 Mohns, M. Shanoer and Fanar M. Abed. "Evaluate 3D laser point clouds registration for cultural heritage documentation" *The Egyptian Journal of Remote Sensing and Space Sciences*, In Press, Corrected Proof (2017). doi.org/10.1016/j.ejrs.2017.11.007
- 3 Naif Adel, Haddad. "From ground surveying to 3D laser scanner: A review of techniques used for spatial documentation of historic sites" *Journal of King Saud University - Engineering Sciences* Vol. 23, Issue 2, (June, 2011): 109-118. doi.org/10.1016/j.jksues.2011.03.001
- 4 Fabio, Remondino and Rizzi Alessandro. "Reality-based 3D documentation of natural and cultural heritage sites-techniques, problems, and examples" *Appl Geomat*, Vol. 2, no. 3 (September 2010): 85. doi.org/10.1007/s12518-010-0025-x

## The condition

During the period when the building was an administrative and judicial centre, prison cells were located in the basement of the building. Over the eighty years dungeons have been used, many people were in them, usually during the trial. Preserved inscriptions on the cell walls testify about this (Figure 3). Due to inadequate maintenance of basement, and strong moisture impact, the basement area is in a bad condition. In the basement, conservation works have never been done. The space of the dungeon has never been renovated, and the original messages of the prisoners still stand, like their statements about innocence, fears, hopes, and desires, many of which can still be read on the walls. Graffiti originate from various periods and speaks about social and political changes, indicating what happened in this territory over the time (Figure 3). These messages represent a very important part of the cultural heritage of the city, as well as the entire area of South Banat. As the whole cellar is endangered by moisture, there is a real danger that this data will be lost. The wall mortar on which these inscriptions are located is in a very bad condition and the question is whether there is a way to preserve it.



Figure 2. The building of the former Magistrate ([http://www.muzejpancevo.rs/pages/o\\_muzeju/?page=o\\_muzeju](http://www.muzejpancevo.rs/pages/o_muzeju/?page=o_muzeju))

## The idea

Since this area is in a bad state, it is not possible to organize visits for museum visitors without endangering heritage and people. Therefore, the application of new technologies has been imposed as the best solution. The basic idea, in this case, is the protection and presentation of cultural heritage through digitization and the application of new technologies has been imposed as a solution.

The digitization of cultural heritage is accepted as one of the best and most effective processes for the protection of cultural heritage worldwide. Thanks to the strong and dynamic development of modern technology and science, the process of converting analogue to binary code has been defined as an important way of protecting cultural heritage. Digitalization enables the protection of cultural heritage, eas-

ier presentation for the professional and general public. Thanks to modern technology, there is a growing possibility of popularizing cultural heritage through digitization. The main goal is to digitize in order to protect the endangered cultural heritage. One of the specific solutions is to create a 3D model by scanning the endangered space with the latest models of the laser scanner, which in addition to high precision features, brings a high-quality camera too. This procedure will record the current state of the dungeons, and should simultaneously provide a precise three-dimensional model including excellent texture, meaning more precise details on the walls. 3D laser scanning technology can be used to map the plan of the ceiling, floor, wall surfaces, and masonry facades. This technique can be used to provide evidence of possible structural shifts or deterioration not appar-



Figure 3. Inscriptions made by prisoners (foto by Nenad Jončić)

ent through traditional visual inspection and measurement methods<sup>5</sup>. Laser scanning greatly shortens the period of surveying with traditional technical equipment, in relation to work with

labour force on the site. In some cases, it is hard to reach every part of the building, wall, ceiling, or the monument when using conventional methods or scaffolds are required. The important question is the extent and how detailed the object or surface will be drawn. The scale of the

<sup>5</sup> John, Smits. "Application of 3D Terrestrial Laser Scanning to Map Building Surfaces." *Journal of Architectural Conservation*, 17, no. 1, (November, 2011) 81, doi: 10.1080/13556207.2011.10785083.

detail and precision of the 3D scans is directly related to the density ratio of the laser beams<sup>6</sup>.

## Laser scanning technologies

### Phase-Shift (PS)

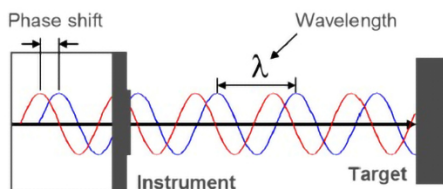


Figure 4. Schematic illustration of the phase shift

Phase-Shift technology work by sending out a continuous laser beam with a modulated signal embedded in the laser. The scanner compares the phase of the signal at the source with the phase of the laser light once it has travelled to the object and reflected back to the scanner. Recorded changes of phase in laser light are measured and allows the scanner to calculate the distances.<sup>7</sup> In comparison to Time-of-flight scanners, PS scanners have a lower operational range (80 meters, with some systems reaching up to 120 meters), but can capture more points per second with a higher precision. Generally, PS scanner operates similarly to TOF scanner. The main difference is that PS scanner calculates the time of flight by measuring the difference in the phase of the laser as it returns to the scanner.<sup>8</sup> Phase-based scan-

ners are typically used in industrial applications such as plants and refineries, or interior architectural spaces.

### Time-of-Flight (TOF)

The time-of-flight method works by sending a laser pulse of light and then measuring the time it takes to travel from the scanner to the object and back, with collected data scanner calculate the distance.<sup>9</sup> The detector of the scanner will generate a time-tagged trigger pulse depending on set up criteria. Some of the detection methods take characteristic points of the pulse path as the decisive factor<sup>10</sup>. Based on the speed of light, we knew the time that laser need to reach the destination and get back to the sensor, thanks to that the location of the object can be determined. A fundamental property of the light wave is its propagation velocity. In a given medium, light waves travel with a constant but finite velocity. The measurement itself is represented by time delays (referred to as the 'time-of-flight') created by light travelling in a medium from the source to the reflective target surface, and back to the source.<sup>11</sup> The advantage of this technology is the significant increase the data capturing speed, up to several million points per second. TOF is typically used for exterior civil/survey applications such as topographic surveys of roadways and buildings, since the key benefit of this type of laser scanning technology is its capability of capturing data from a greater distance (from several hundred up to several thousand meters), while maintaining the accuracy in the order of centimetres or smaller units.<sup>12</sup>

6 Benli, Gulhan, and Ozer Derya Gulec. "USE OF LASER SCANNING FOR CULTURAL HERITAGE DOCUMENTATION". *International Journal of Electronics, Mechanical and Mechatronics Engineering (IJEMME)* 3/1 (June 2013): 447

7 Julia, Armesto-González, Belén Riveiro-Rodríguez, Diego González-Aguilera, and M. Teresa Rivas-Brea. "Terrestrial laser scanning intensity data applied to damage detection for historical." *Journal of Archaeological Science* 37, no. 12 (December, 2010): 3037-3047, doi: 10.1016/j.jas.2010.06.031.; Alonso J.I., San José, Jose Martinez Rubio, José Fernández Martin Juan, and Jorge García Fernández. "Comparing Time-Of and Phase-Shift the Survey of the Royal Pantheon in the Basilica of San Isidoro (LEÓN)" *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXVIII-5/W16*, (September, 2011): 377-385, doi: 10.5194/isprsarchives-KSKSKSVIII-5-V16-377-2011.

8 Julia, Armesto-González, Belén Riveiro-Rodríguez, Diego González-Aguilera, and M. Teresa Rivas-Brea. "Terrestrial laser scanning intensity data applied to damage detection for historical."

*Journal of Archaeological Science* 37, no. 12 (December, 2010): 3037-3047, doi:10.1016/j.jas.2010.06.031.

9 Julia, Armesto-González, Belén Riveiro-Rodríguez, Diego González-Aguilera, and M. Teresa Rivas-Brea. "Terrestrial laser scanning intensity data applied to damage detection for historical." *Journal of Archaeological Science* 37, no. 12 (December, 2010): 3037-3047, doi: 10.1016/j.jas.2010.06.031.

10 George, Vosselman and Hans-Gerd Maas. *Airborne and Terrestrial Laser Scanning*. (Dunbeath: Whittles Publishing, 2010), 5

11 George, Vosselman and Hans-Gerd Maas. *Airborne and Terrestrial Laser Scanning*. (Dunbeath: Whittles Publishing, 2010), 3

12 Massimiliano, Pieraccini, Gabriele Guidi and Carlo Atzeni. "3D digitizing of cultural heritage." *Journal of Cultural Heritage* 2 (1), (March, 2001): 63-70, doi: 10.1016/S1296-2074(01)01108-6.; Naci,

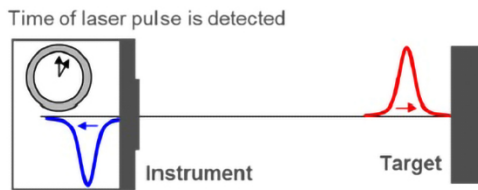


Figure 5. Schematic illustration of the time of flight EDM method

### Wave Form Digitizer (WFD)

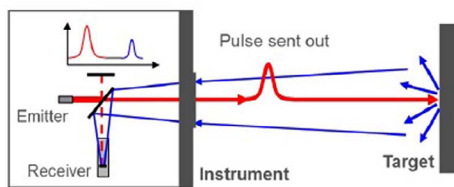


Figure 6. Schematic illustration of the WFD EDM method

The Wave Form Digitizer represents a fast and accurate distance measurements, it is a successful combination of laser scanning and total station in one instrument.<sup>13</sup> The WFD is a technology system that combines advantages of the phase shift and the time-of-flight method in a unified system. Digitized waveform data have two basic characteristics, the amplitude quantization, and the time sampling resolution. The amplitude resolution describes the extent of samples that can be used to digitally represent the amplitude of the waveform, expressed in bits. The resolution represents a quantity of how often are the measurements amplitude collected.

Yastikli. "Documentation of cultural heritage using digital photogrammetry and laser scanning." *Journal of cultural heritage*, 8, Issue 4, (September, 2007): 423-427. doi: 10.1016/j.culher.2007.06.003.; Alonso J.I., San José, José Martínez Rubio, José Fernández Martín Juan, and Jorge García Fernández. "Comparing Time-Of and Phase-Shift the Survey of the Royal Pantheon in the Basilica of San Isidoro (LEÓN)" *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXVIII-5/W16*, (September, 2011): 377-385. doi: 10.5194 / isprsarchives-KSKSKS-VIII-5-V16-377-2011

13 Hannes, Maar, and Hans-Martin Zogg. *WFD – Wave Form Digitizer Technology, White Paper*. Heerbrugg, Switzerland, September 2014. 3

With this technology, the distance is calculated on the time between the received start and a stop pulse signals.<sup>14</sup> Leica BLK 360 scanner is using this technology.

### Solution

Faced by the problems outlined above, we decide to use a laser scanner for documenting, the existing situation in the dungeons. The use of 3D laser scanning in the preservation of cultural heritage is very common nowadays. There have been many studies that illustrate how 3D scanning, implemented in the protection of cultural heritage, produces excellent results, both in terms of speed and precision. 3D laser scanning is a non-destructive, non-contact method of capturing data that provide accurate and rapid creation of three-dimensional models, for archiving and digital manipulation. A 3D laser scanner emits a laser beam that hits a target object, measuring millions of closely spaced measurements in a matter of minutes. The scanned measurements are grouped into compressed point cloud databases, which are further generated into a 3D representation of the object.<sup>15</sup> The main task of 3D scanning is to produce models that can be used for presentation and preservation. A technology of 3D scanning is aimed at collecting information on the shape and texture of the scanned object. The acquired data build a digital three-dimensional mode useful for a wide variety of interpretative and analytical purposes.

The 3D scanner used for scanning dungeons in the building of the National Museum of Pančevo is Leica BLK 360 (Figure 4). It turned out that that 3D laser scanning technology has many advantages in this situation. For example, scanning is possible under poor visibili-

14 Hannes, Maar and Hans-Martin Zogg. *WFD – Wave Form Digitizer Technology, White Paper*. Heerbrugg, Switzerland, September 2014. 4

15 Pedro Arias-Sánchez, Herraéz Jose, Lorenzo Henrique, and Ordóñez Celestino. "Control of structural problems in cultural heritage monuments using close-range photogrammetry and computer methods" *Computers and Structures*, (August 2005): 1754-1766. doi: 10.1016/j.compstruc.2005.02.018; Naci, Yastikli. "Documentation of cultural heritage using digital photogrammetry and laser scanning." *Journal of cultural heritage*, 8, Issue 4, (September, 2007): 423-427. doi: 10.1016/j.culher.2007.06.003.

ty and low illumination gained 3D models can be rotated and measured in the virtual space and can be used for different purpose.



Figure 7. Leica BLK 360 (foto by Nenad Jončić)

The Leica BLK360 represent a compact professional 3D scanner, utilizes the high-speed time of light enhanced by Waveform Digitizing technology. Scanner emits an invisible laser beam sent by rotating mirror at a rate of up to 360,000 points per second. The working distance range of the scanner is from 0.6m up to 60m and the accuracy range of the scanner is from 4mm (at 10m) to 7mm (at 20m). Leica BLK 360 have three available scanning modes; low, medium and high resolution, with scanning times ranging from approximately 2 minutes for low, and up to 7 minutes in high resolution and full HDR colour.

In most cases, the camera built in the scanner does not provide images with sufficient quality and resolution. Therefore, in order to create correctly colored textures, we have to take photographs with high-quality photographic camera and lens placed in the position that match-

es exactly the position of the scanner. But Leica BLK360 scanner has three HDR cameras with 15 mp, with LED flashlights, together resulting with full dome capture a 150-mp, providing a 360-degree horizontally and 300 degrees vertically coverage.<sup>16</sup> A BLK360, has a blind spot directly underneath, that spot is replete with points from the second scan made from another point. Gained 3D model can aid further analysis, as it provides us with vertical and horizontal cross-sections of the space, as well as precise measurements of the building, which are significant for calculating and reconstruction the architectural plans.



Figure 8. 3D model of dungeons (foto by Nenad Jončić)

The BLK360 also has a thermal imaging camera placed on the back of the device, that provides a 3D model with thermal data (Figure 9).<sup>17</sup> One of the results is a 3D model with thermal areas that can indicate the level of moisture in the walls (Figure 5), indicating the current state and damage degree of wall mortar. More specifically, it indicates the level of moisture responsible for the degradation of the plaster on which the messages are located. Moisture caus-

16 *Leica Geosystems AG*. 2018. [https://lasers.leica-geosystems.com/global/sites/lasers.leica-geosystems.com/global/files/leica\\_media/product\\_documents/blk/17-lei-030\\_blk360\\_spec\\_sheet\\_r2\\_v2.pdf](https://lasers.leica-geosystems.com/global/sites/lasers.leica-geosystems.com/global/files/leica_media/product_documents/blk/17-lei-030_blk360_spec_sheet_r2_v2.pdf) (accessed june 15, 2018)

17 *Leica Geosystems AG*. 2018. [https://lasers.leica-geosystems.com/global/sites/lasers.leica-geosystems.com/global/files/leica\\_media/product\\_documents/blk/17-lei-030\\_blk360\\_spec\\_sheet\\_r2\\_v2.pdf](https://lasers.leica-geosystems.com/global/sites/lasers.leica-geosystems.com/global/files/leica_media/product_documents/blk/17-lei-030_blk360_spec_sheet_r2_v2.pdf) (accessed june 15, 2018)

ing mould, unwanted parasites, and the decanting of salts, and represent one of the main factors in the deterioration of heritage buildings. The existence of moisture is evidence of bad conservation conditions, affects the building aesthetic. Because of all mentioned, it is very important to verify and assess the extent of the moisture, in order to create a moisture protection plan<sup>18</sup>. In other words, it is quite justified fear that prisoners inscriptions will not survive on the walls for a long time, considering that the lower parts of the walls are almost completely free of mortar that was once there.

The Leica BLK360 has been developed in close collaboration with Autodesk, the CAD software editor. The 3D scanner is delivered with the Autodesk ReCap 360 Pro Mobile software, compatible with the Apple iPad Pro. The latest version of Autodesk's software registers the BLK360 scans in real-time, wherever you are. Autodesk's cloud services enable sharing or easy transfer of data into any Autodesk CAD software for further use.

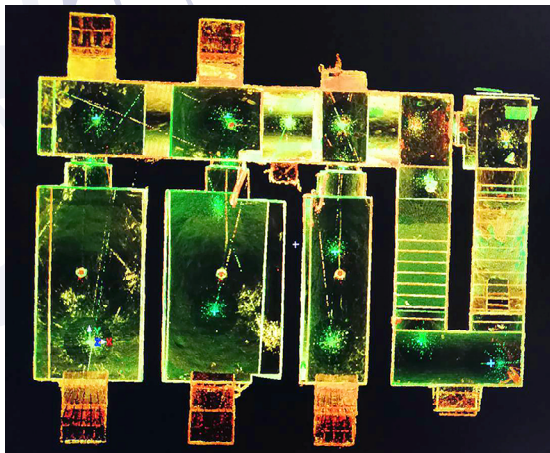


Figure 9. Thermal model of dungeons (foto by Nenad Jončić)

The scanner has built-in, internal memory capacity of 32GB. The BLK360 is created for

18 Pedro Martín, Leronés, Vélez David Olmedo, Rojo Fernando Gayubo, Jaime Gómez-García-Bermejo and Casanova Eduardo Zalama. Moisture detection in heritage buildings by 3D laser scanning. *Studies in Conservation*, 61:sup1, 46. (April 2016): 46-54. doi:10.1179/2047058415Y.0000000017

use both indoors and outdoors, with operating temperature range from +5 to +40 degrees centigrade.<sup>19</sup> During the scanning of the basement of museum in Pančevo, a temperature was slightly above +5 degrees centigrade, and we experienced some trouble with scanning. From time to time the scanner would stop scanning and show a red light indicator. We solved the problem, by taking the scanner off from the tripod and heating it under our jackets. After the scanner was warmed up, it continued to work normally. That excluded, we needed about 30 minutes to complete the complete scanning of three dungeons cells, guards' rooms, hallway, and stairs.

## Conclusion

The Magistrate building in Pančevo is under the protection as a cultural monument of great importance. The dungeons in the basement, with wall inscriptions representing an important part of the cultural heritage, which is slowly disappearing due to moisture and dereliction.

Implementation of laser 3D scanning impose like the best solution. During this process was used Leica BLK360 scanner, that represents an extremely versatile piece of technology that can be applied to a number of applications and fields across the cultural heritage industry. One of the biggest advantages is a possibility which allows the user to move through a 3D model using a tablet. This represents a great opportunity for presentation, without fear of damaging the inscriptions or possibility that someone can be hurt during a visit. Obtained 3D models, as well as thermal images, represent a significant fund for professional research.

Through this case study like an example, this paper illustrates how 3D laser scanning technology can be used for recording the plan of the building, with the aim of protection of cultural heritage. Except for documentation of the current state of the cultural monument, as part of the process of its protection, this technology

19 *Leica Geosystems AG*. 2018. [https://lasers.leica-geosystems.com/global/sites/lasers.leica-geosystems.com/global/files/leica\\_media/product\\_documents/blk/17-lei-030\\_blk360\\_spec\\_sheet\\_r2\\_v2.pdf](https://lasers.leica-geosystems.com/global/sites/lasers.leica-geosystems.com/global/files/leica_media/product_documents/blk/17-lei-030_blk360_spec_sheet_r2_v2.pdf) (accessed june 15, 2018)

provides possibilities for the digital presentation of the cultural monument. Furthermore, that involves a lot of possibility for displaying cultural monument that been scanned. Like it is already mentioned results of 3D scanning can be presented in real time directly on iPad pro. Also, a presentation of a 3D model of dungeons can be adapted for any touchscreens, the gained 3D model also can be presented with Virtual Reality headsets and allows visitors to walk through the dungeons without any risk for them or cultural heritage.

### Povzetek

Zgradba Magistrata, kot tudi zapora v kleti te stavbe, predstavlja pomemben del kulturne dediščine mesta Pančevo in območja Južnega Banata. Stene zapora se slabšajo zaradi vlage. Z minerali, ki odpadajo iz obzidja, izgublamo gravirana sporočila zapornikov. Ta situacija je privedla do zamisli o uporabi 3D skenerjev v trenutni situaciji. Uporabljen je bil Leica BLK365 3D skener, ki deluje na principu tehnologije Waveform Digitizer (WFD). Poleg visoke natančnosti laserskega skeniranja ta skener omogoča tudi ustvarjanje visoko kakovostnih tekstur na 3D modelih. To se doseže z uporabo treh kamer z visoko ločljivostjo, ki ima vgrajeno tudi optično senzorsko kamero z dolgimi valovi. V tem primeru uporaba toplotne kamere kaže na prisotnost vlage v stenah. Leica BLK360 3D skener vsebuje programsko opremo Autodesk ReCap 360 Pro Mobile, za Apple iPad Pro. To omogoča enostaven prenos skeniranih podatkov v katero koli programsko opremo Autodesk CAD za nadaljnjo uporabo. Zagotavlja tudi možnost predstavitve v realnem času ali kasneje, ne glede na lokacijo. Na ta način lahko zagotovimo varno predstavitev za obiskovalce muzeja.

### Summary

The Magistrate building, as well as the dungeons situated in the basement of this building, represents a significant part of the cultural heritage of the city of Pančevo and the area of South Banat. The walls of the dungeons are deteriorating due to moisture. With mortar falling from the walls we are losing engraved messages of the prisoners. This situation led to the idea of applying 3D scanners to the record current situation. The Leica

BLK365 3D scanner was used, the scanner works on the principle of Wave Form Digitizer (WFD) technology. In addition to the high precision of laser scanning, this scanner also enables the creation of high-quality textures on 3D models. This is accomplished by using three high-resolution cameras built in, the scanner also has a longwave thermal imaging camera in its encasing. In this case usage of thermal camera, indicate the presence of moisture in the walls. The Leica BLK360 3D scanner is delivered with the Autodesk ReCap 360 Pro Mobile software, for the Apple iPad Pro. This provides easy transfer of scanned data into any Autodesk CAD software for further use. Also providing the possibility for presentation in real-time or later, no matter where you are. In this way, we provide a safe presentation of dungeons for visitors to the museum.

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