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SOME STUDIES AND SOLUTIONS BASED ON PERFORMED GEODETIC MEASUREMENTS (USING GNSS TECHNOLOGY AND 3D TERRESTRIAL LASER SCANNING) FOR POWER-SUPPLY OBJECTS

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SUMMARY

Nowadays there are several surveying technologies, which could be used for measurements of an object with specific industrial function. This paper studies the case in which a substation was subject of geodetic measurements, using independently two different surveying technologies – GNSS and 3D terrestrial laser scanning. The choice of the relevant instrument depends on various factors, like: terrain conditions, type and specifics of the building, weather conditions, etc.

The study is focused on the processes of: performing geodetic measurements using independently (in different days) GNSS and 3D terrestrial laser scanning, quality analysis of the measurements and comparison of the final results – the coordinates of the terrain points, respectively the created contour of the object.

The paper gives example for another possible application of GNSS technology in RTK mode for measurements of an energy object and studies the possible technical issues, which might happen in the field.

The advantages and disadvantages of the applied both technologies were studied for this specific case. Analytical and graphical examples of the final results are given in the paper. The differences in the results from the performed geodetic measurements of the object were studied.

The necessary conclusions and recommendations for future work are given in the paper.

KEYWORDS: **LASER SCANNING, GNSS, GEODETIC MEASUREMENTS, ACCURACY, POWER-SUPPLY**

1. INTRODUCTION

In geodetic practice there are a number of ways to determine the coordinates of contour of industrial object. The choice of the technology to be applied depends on various conditions, e.g. the density of urbanization, terrain conditions, etc.

The applied technologies in this paper - 3D terrestrial laser scanning and GNSS positioning are accurate and productive. They deliver 3D coordinates of terrain points from the performed geodetic measurements. A number of publications exists and here could be mentioned some of them: [Milev, 2012], [Minchev et al., 2005], etc.

This paper deals with the application of these two technologies for measurements of industrial power-supply object and the problems, which encountered in the field work.

It might happen that active and/or passive disturber influence and deteriorate the measured data. Because of this occasion and also the results from GNSS measurements it was necessary to perform independent, another way for determination of the coordinates of certain terrain points.

Due to the circumstance, that scanner performs the measurements in its own coordinate system, the coordinates of each measured point should be transformed into the relevant coordinate system. Both the coordinates delivered from GNSS measurements and the data from 3D terrestrial laser scanning were transformed into the official coordinate system.

In this paper GNSS equipment was applied as a possibility to obtain:
- unsurpassed productivity in open field;
- high accuracy of the coordinates in certain conditions.

Necessity for application of LIDAR in this specific case:
- contactless measurements for specific cadastral objects;
- field control of already performed geodetic measurements.

The study focuses the attention on the issues, which might happen in the process of measurements of power-supply object and the relevant solution to be taken. The analysis of the achieved accuracy of the measured points was also done.

2. SOME EXAMPLES FOR THE APPLICATION OF GNSS TECHNOLOGIES FOR MEASUREMENTS OF BUILDINGS

As GNSS technologies have various applications, one of them is the measurements of buildings (in certain conditions). There measurements often are burdened with errors like multipath. Even though, due to the continuous modernization of GNSS constellations the results are continuously improved.

Below are listed some of the possible examples for GNSS positioning in the specific case, i.e. for measurements of buildings:
https://www.researchgate.net/publication/325831626_GNSS-Based_Verticality_Monitoring_of_Super-Tall_Buildings
https://link.springer.com/chapter/10.1007/978-3-319-61914-9_36

In [Minchev et al., 2005] it is stated, that the probability for producing of erroneous results in RTK mode is almost impossible. This paper studies a case in the geodetic practice where this might happen, even in the open field.

3. EXAMPLES FOR POSSIBLE APPLICATIONS OF 3D TERRESTRIAL LASER SCANNING FOR MEASUREMENTS OF POWER-SUPPLY OBJECTS

In the public space it could be found a number of various publications, dealing with 3D terrestrial laser scanning of power-supply objects:
https://www.powermag.com/3-d-laser-scanning-of-nuclear-plant-piping-systems-reduces-radiation-exposure/
https://static.spacecrafted.com/a65fbb5439ca4e279d24e347447b9072/r/bc389d4694164c9999221d3c7a88b7d9/1/3D%20Laser%20Scanning%20a%20Power%20Plant.pdf.

In other to complete the job – to obtain the correct coordinates of the north façade of the power-supply object the following software products were involved: Geomax Geo Office [http://tinyurl.com/h9s4aop], GNSSTransformations [https://tinyurl.com/y83qp2l2], Mkad [http://tinyurl.com/hapgj9l] and Trimble RealWorks [http://tinyurl.com/pdckrlr]. The mentioned software is listed in the order of its usage in data processing and graphical representation.

4. FIELD RECOGNITION. PERFORMING OF GNSS MEASUREMENTS AT THE POWER-SUPPLY OBJECT FOR THIS CASE

After the field recognition, which was performed for the object it was concluded, that:
1. There is a clear sky to perform GNSS measurements;
2. No power lines in vicinity;
3. It is possible to measure the edges of the object via the rover.

Taking in mind the above-mentioned facts, the necessary GNSS measurements were done. It should be noted, that during the field work it was noticed often loss of fixed solution at several places on the north side of the object. This circumstance forced the implementation of two additional field activities:
a) change of the position of the rover to obtain fixed solution and moving it back to the point subject of measurements;
b) performing of more than one measurement for one and the same point and use the result with better quality in the position.

5. PROCESSING OF THE RAW DATA FROM GNSS MEASUREMENTS. ANALYSIS

The logged raw measurements were downloaded and imported in Geomax Geo Office.

In this paper Geomax Geo Office software was applied for import of the raw GNSS measurements and export the coordinates of the terrain points in WGS84 coordinate system for further use.

5.1. Results from the GNSS measurements in RTK mode

Quality:	Sd. Lat: 0.0169 m	Sd. Lon: 0.0115 m	Sd. Hgt: 0.1050 m
	Posn. Qlty: 0.0205 m	Sd. Slope: 0.0121 m	

Figure 1. Results for quality assessment for point N 12

Quality:	Sd. Lat: 0.0168 m	Sd. Lon: 0.0094 m	Sd. Hgt: 0.0522 m
	Posn. Qlty: 0.0193 m	Sd. Slope: 0.0098 m	

Figure 2. Results for quality assessment for point N 13

Quality:	Sd. Lat: 0.0168 m	Sd. Lon: 0.0143 m	Sd. Hgt: 0.1268 m
	Posn. Qlty: 0.0221 m	Sd. Slope: 0.0146 m	

Figure 3. Results for quality assessment for point N 17

The information from Geomax Geo Office was converted in *.txt format via GNSSTransformations [https://tinyurl.com/y83qp2l2] and prepared for coordinate transformation.

5.2. Analysis of the results

From the information given in figures NN 1, 2 ad 3 it could be clearly seen the high quality in the position of points NN 12,13 and 17 of the power-supply object. The position quality is in the closed interval [19mm-22mm]. Based on the results in this chapter it could be noted, that all measured points satisfy the quality requirements.

The measured coordinates of all points were used to be created the required graphical part of the object, detail of which is given in the next chapter.

6. GRAPHICAL REPRESENTATION OF THE CONTOUR, CREATED FROM GNSS MEASUREMENTS

After completion of the satellite measurements and raw data processing the contour of the power-supply object was created in the plane, see fig. 4. Obviously, the north part of the object did not correspond to the actual geometry, which existed on the terrain. This fact required performing of new geodetic measurements in another day, via another surveying technology, e.g. 3D terrestrial laser scanner.

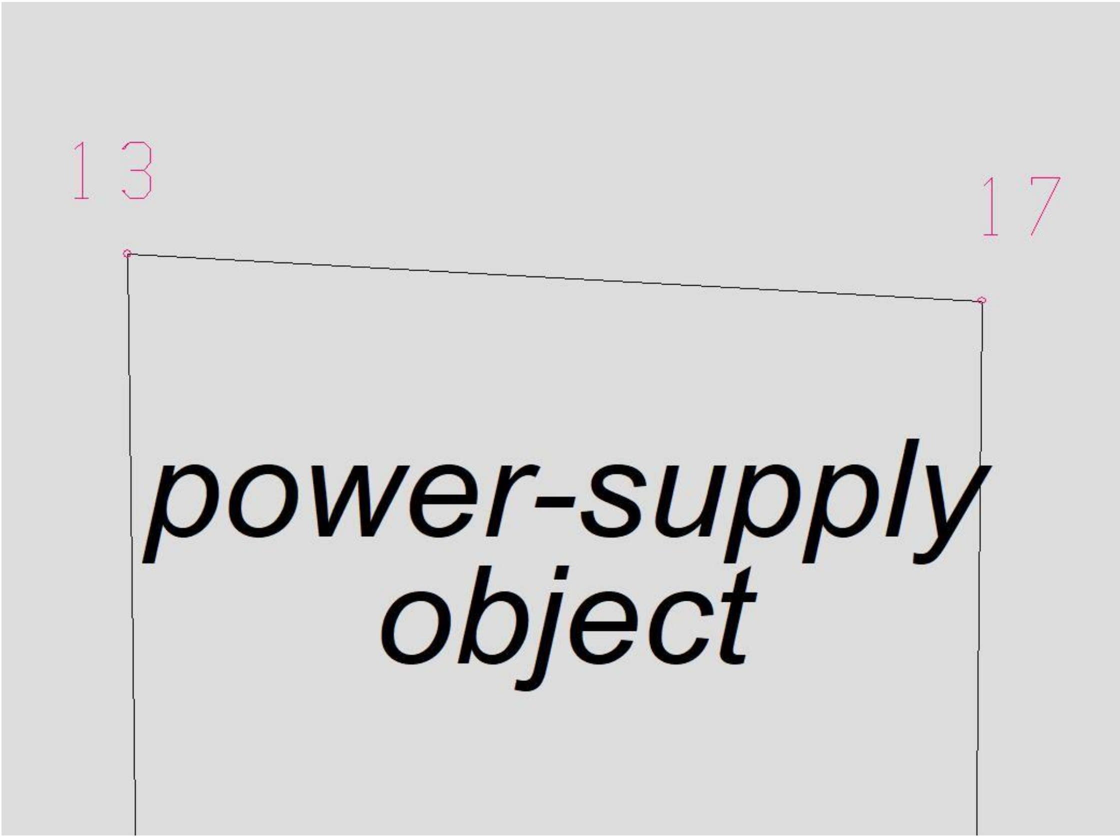

Figure 4. North part of the created contour of the object - data from GNSS measurements

7. 3D TERRESTRIAL LASER SCANNING OF THE POWER-SUPPLY OBJECT

It should be noted, that this specific case studies only the north part of the power-supply object.

Based on the graphical results from the GNSS measurements (fig. 4), it was obviously necessary to scan the object and check its contour, applying contactless technology. As it is known terrestrial laser scanning “seals” the object as it is on the terrain. The choice of this technology was done also in order to eliminate the influence of the disturber, which in fact deteriorated the satellite signals in the north part of the object.

According to [Kostov, 2018] in case of using a laser scanning for geodetic measurements “…the geodesist could be sure, that all edges of the cadastral object would be measured. Also, nothing will be missed, and data will be reliable.”

In this specific case, below are listed several factors, which led to the choice of laser scanning for the object under study:

- possibility to perform reliable contactless measurements for power-supply objects;
- available photo realistic data;
- possibility to explore the object afterwards and extract any type of information via Trimble RealWorks.

The aim of the measurements via laser scanner was to perform field check and to create correct contour of the object.

The created scans were imported and processed in Trimble RealWorks. The edges of the contour of the power-supply object were measured using two stations. The last were registered using "Target-less" option of the software. The results for the quality of this process are shown on fig. 5. It could be noted the "Overall Cloud-to-cloud error: 0.001 m".

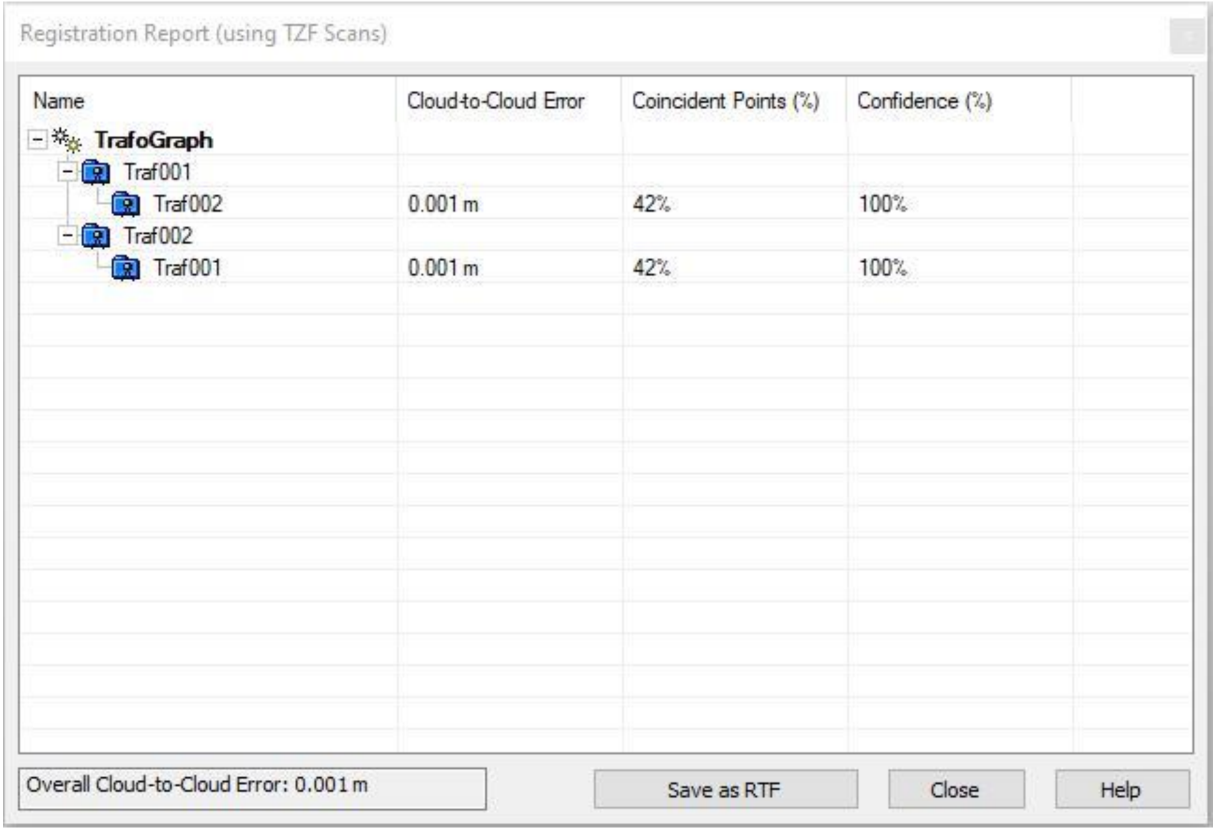

Figure 5. Registration results and quality control from two stations of the scanner

"Georeferencing tool" option of the menu was used for georeferencing of the created point cloud and calculation of the coordinates of the object in the national coordinate system. Screenshot of the results of this technological step from Trimble RealWorks is given in fig. 6 below. There it could be seen the obtained high accuracy of the data after the georeferencing of the object. The value of the average error completely satisfies the accuracy requirement both for the transformation and geodetic task.

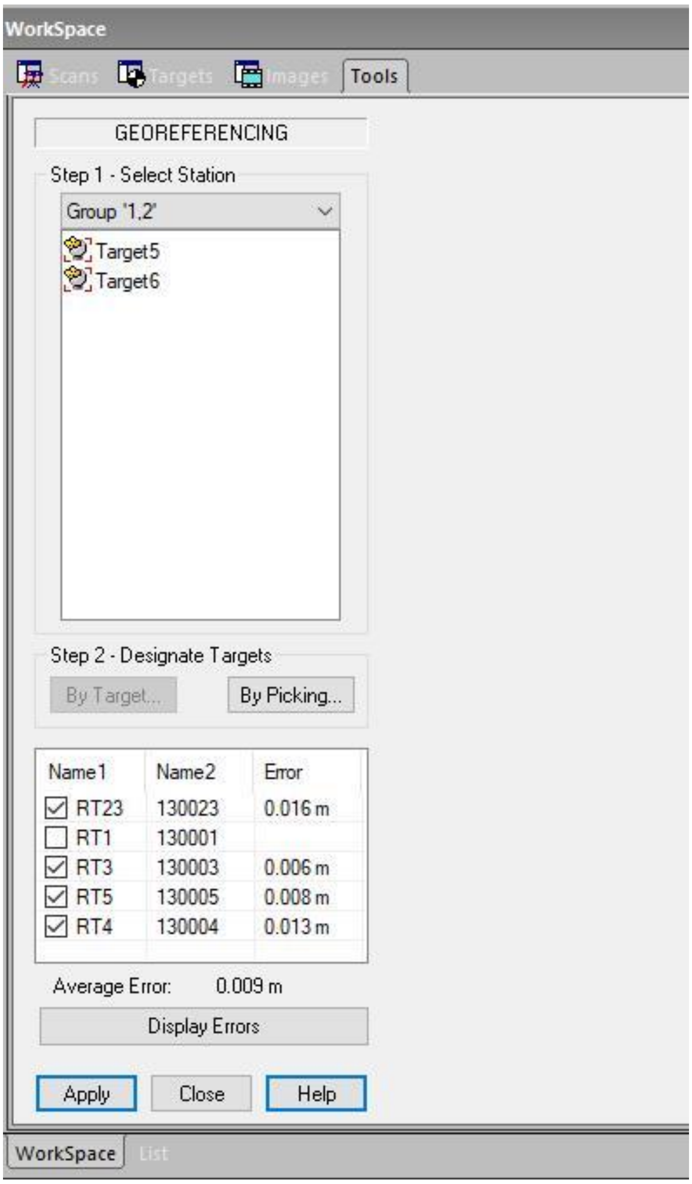

Figure 6. Georeferencing of the point cloud and average error

8. GRAPHICAL ANALYSIS FOR THE CONTOUR OF THE POWER-SUPPLY OBJECT

In order to solve the issue at the north part and to create correct contour for the object, the graphical results from both measurements were united as shown on fig. 7. It could be seen three discrepancies leading in various directions. The values of the differences also vary and are between 18 and 37 cm. It could be also noted, that the discrepancies from the correct contour (created via the data from laser scanning and given in fig. 7 in black colour) also vary at the east and west parts of the object.

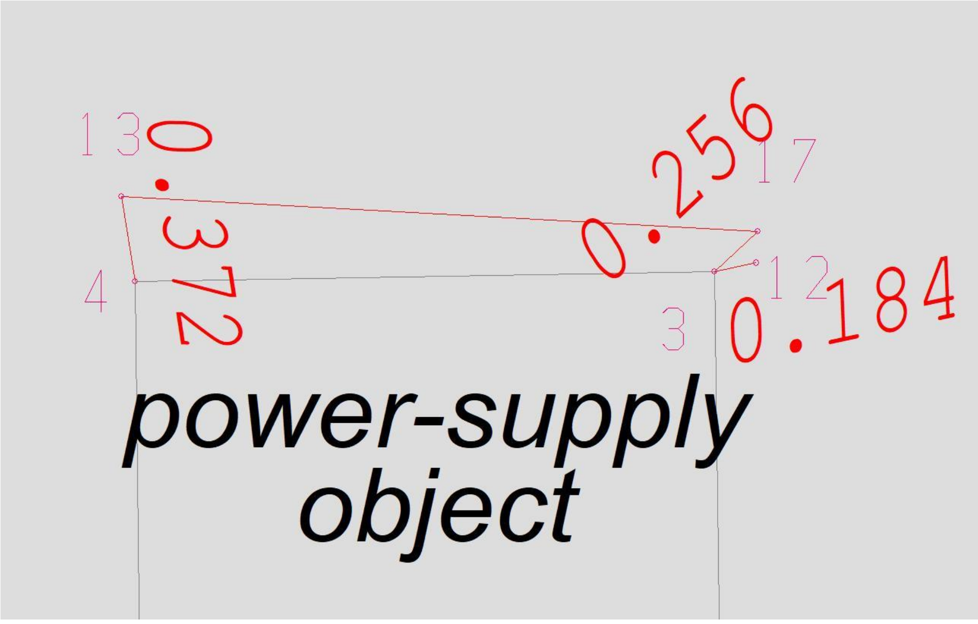

Figure 7. The north part of the contour of the power-supply object and the distance discrepancies

On fig. 8 are denoted the linear differences to the north (given in bold blue colour) from the correct contour on the both sides of the object – east and west.

All given discrepancies do not have any systematic direction or value:
1. 0.372 m to the north-west from the correct contour of the object;
2. 0.256 m to the north-east from the correct point;
3. 0.184 m to the east from the correct position;
4. 0.364 m straight to the north from the correct point in the west part;
5. 0.185 m straight to the north from the correct point in the east part.

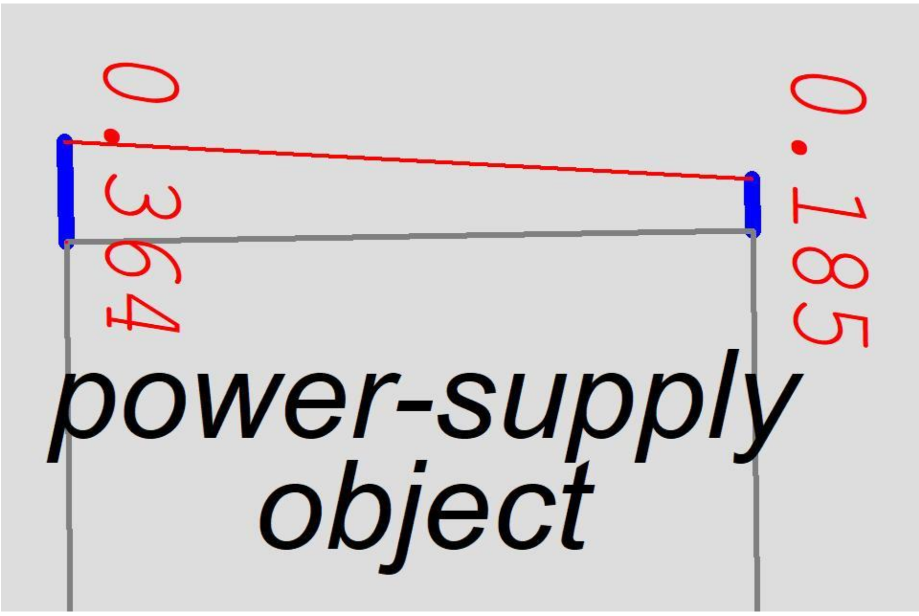

Figure 8. Discrepancies to the north

9. CONCLUSION. RECOMMENDATIONS. FUTURE WORK

This paper studied the issues, which encountered in the process of measuring the contour of a power-supply object via GNSS equipment. Due to obviously incorrectly determined part of the object's geometry it was necessary to be applied another geodetic technology and to be performed control measurements.

In the study were analysed the accuracy results both from GNSS measurements in RTK mode and 3D terrestrial laser scanning, given in details in chapters NN 5 and 7.

3D terrestrial laser scanning as part of LIDAR was applied for performing of contactless measurements for this specific object. Correct results (coordinates) were obtained and used for further geodetic activities.

The results from:
-GNSS measurements;
-registration of the stations of the scanner;
-georeferencing of the point cloud,
show the obtained high accuracy from the conducted geodetic measurements, using two types of surveying technologies.

It should be noted, that although (as shown in chapter 5.1) the quality of the results from the GNSS measurements met the accuracy requirement they were excluded from the final results.

It could be concluded, that even without existence of power lines above the area of the object and clear sky, it might exist other type of active disturber and influence the performed GNSS measurements.

The studied case from the geodetic prctice led to a number of topics to be discussed for the applied end-user GNSS equipment:
1. Possibility for determination of eventual influence of disturber in the field, before calculating the position and its accuracy (which were in acceptable range);
2. Warning for possible incorrect results, due to the presence of disturber;
3. Option in the firmware to exclude such deteriorated GNSS measurements in RTK mode before their download.

Future work. Based on the given in this paper case, it could be noted, that the choice of surveying equipment for power-supply object should be done with detailed risk-estimation. Measurements should be stopped for instance after losing of fixed solution more than one time in area with active disturber.

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USED SOFTWARE

1. Geomax Geo Office (http://tinyurl.com/h9s4aop);
2. GNSSTransformations [https://tinyurl.com/y83qp2l2];
3. Mkad (http://tinyurl.com/hapgj9l - in Bulgarian);
4. Trimble RealWorks (http://tinyurl.com/pdckrlr);

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