MOBILE MAPPING SYSTEMS FOR AIRPORTS – CASE STUDY TIMIŞOARA "TRAIAN VUIA" INTERNATIONAL AIRPORT

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Abstract: *The article focuses on the benefits of employing mobile LiDAR technology for airports surveys to deliver faster, safer and better geographical data. Airports administrations are bound to provide geographic data related to infrastructure and obstacles in nearby areas according to international regulations. Acquisition of these data using conventional surveying methods is slow but with low cost. Using airborne LiDAR technology is fast but very expensive. An appropriate compromise is the use of terrestrial mobile mapping LiDAR system. Surveys for Timisoara airport are presented together with the results of the study. In the end, a SWOT analysis is shown for the technology used in the study. Three results are introduced: "Certification Specifications (CS) for Aerodromes (EU) No 139/2014", "International Civil Aviation Organization (ICAO) Annex 14 Obstacle Limitation Surfaces", and "ICAO Annex 15 Terrain and Obstacle Data Collection Surfaces".*

Keywords: *LiDAR, Terrestrial mobile mapping, Airports surveys, GPS.*

1. Introduction

LiDAR data acquisition has been proven a technology that "can provide high speed data collection in areas with restricted access and/or safety concerns" (Keith Williams, 2013). This is a critical factor in case of the operating airports, where the tight schedule of the flights allows only limited access to the runway and airport safety zones.

Gauss srl company, as part of its continuous drive for innovation to employ the latest technologies in geographical data acquisition, has purchased in 2015 Trimble MX2 a "vehicle-mounted spatial imaging system which combines high resolution laser scanning and precise positioning to collect geo-referenced point clouds for a wide range of requirements" (Trimble, 2016).

2. Materials and Methods

Trimble MX-2 system is a "dual head configuration that contains a combined Trimble Applanix GNSS and inertial geo-referencing module for precise positioning. Trimble MX2 is capable of acquiring 72,000 points per second, up to 250 m with an accuracy of ±1 cm at 50 m". (Trimble, 2014). It acquires also still images by using six cameras. These images can be used for visual identification of the elements, for coloring laser points and for performing linear measurements.

Adopted project workflow was derived from the generalized model (Michael J. Olsen, 2013):

- Define project area
- Establishment of the Airport Reference Network (ARSN)
- Define drive paths

- LiDAR data acquisition
- Processing LiDAR trajectory to ARSN
- Process LiDAR and imagery data
- Process LiDAR for surface models
- Extract features
- QA for extracted features
- Deriving products

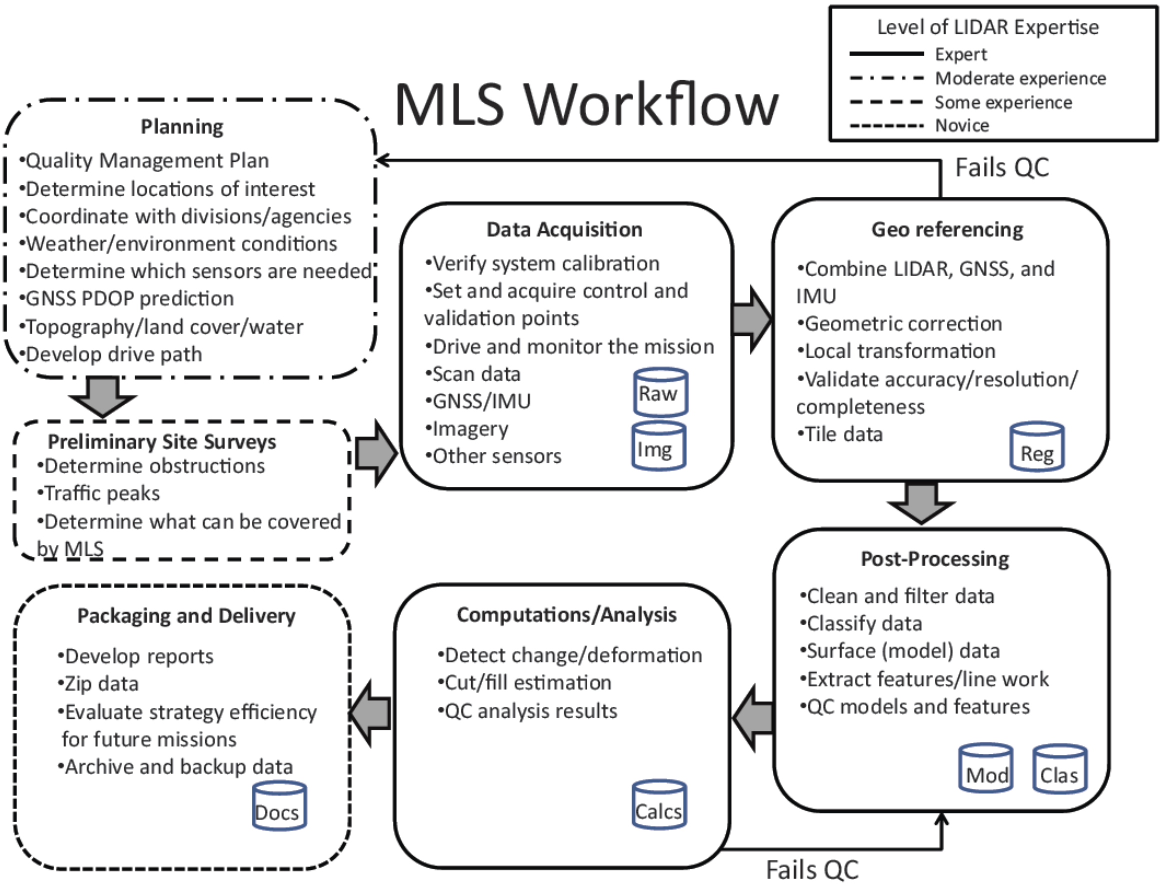

Fig. 1 Generalized workflow diagram according to (Michael J. Olsen, 2013)

Airport Reference Survey Network and the Quality Assurance process were completed using Trimble NETR9 base, Trimble R10 dual frequency GPS receivers and Trimble V10 Imaging Rover.

Post-processed kinematic GPS position of the mobile LiDAR mapping system (MLMS) was determined using a Trimble NETR9 receiver as a base station in RTK and Logging mode, positioned near the airport surveyed area on a geodetic control point "LRTR01" – the farthest MTLS point where 4.7 km away. The base point is one of the 7 geodetic control points marked in the airport area. The precise coordinates of the base point where determined using a static survey and processing of the GPS collected data, using ANCPI stations TIM1, ARAD, FAGE and RESI.

LiDAR scanning phase collected more than 330 million points in less than 4 hours. Average speed of the mobile mapping system was about 20 km/h. Instant positions of the vehicle were determined by processing GPS data as a kinematic survey. Applanix POSPac Mobile Mapping was used for trajectory post-processing.

LiDAR Data processing was split in runs containing up to 9 million points, in order to optimize the computing time, and in the end produced point clouds files stored in .las format. Trimble Trident was used for LiDAR processing and cloud point RGB extraction.

Based on the point cloud obtained at the latest phase, by using Bentley Microstation V8i, Digital Surface Model (DSM) and Digital Terrain Model (DTM) were created for the surveyed area. For airport surrounding area a DTM derived from aerial photography with a 5 m, Ground Sample Distance (GSD) was used.

Using high resolution LiDAR data it was possible to extract, with the accuracies imposed by CE Certification Specifications for Aerodromes, EU No. 139/2014, and many features of the airport/airfield, solely using exclusively LiDAR data, or combined with RGB imagery. These features are:

1. Runway edge lighting
2. Painted lines.
3. Runway and taxiway outlines.
4. Cross section profiles
5. Objects and possible obstacles
6. Communications, Navigation, Surveillance (CNS) systems.

As with any other surveying techniques, a QA process is always part of the survey and data extraction process. Key elements were verified by another method - checking and additional survey were made using satellite technology (G.P.S. + GLONASS) using RTK - Rompos single station, by NTRIP protocol with a GNSS Network Class A base station "TIM1".

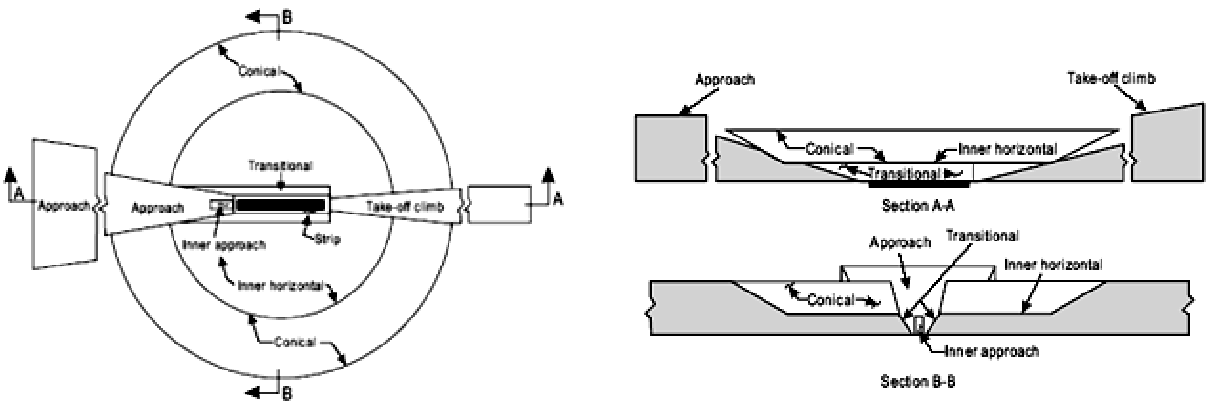

Fig. 2 Obstacle surfaces definition in ICAO Annex 14

The following stage was the definition of the main surfaces described in "ICAO Annex 14 – Obstacle Limitation Surfaces" and "ICAO Annex 15 Terrain and Obstacle Data Collection Surfaces". The scope is to identify the existing obstacles and to limit the height of future buildings/ installations that may obstruct the airplanes operations in the airport vicinity.

By comparing the differences between the measured heights of objects (it was considered only the upper limit of objects), and the limitation of surfaces defined as in regulations we were able to extract only the objects that constitute obstacles.

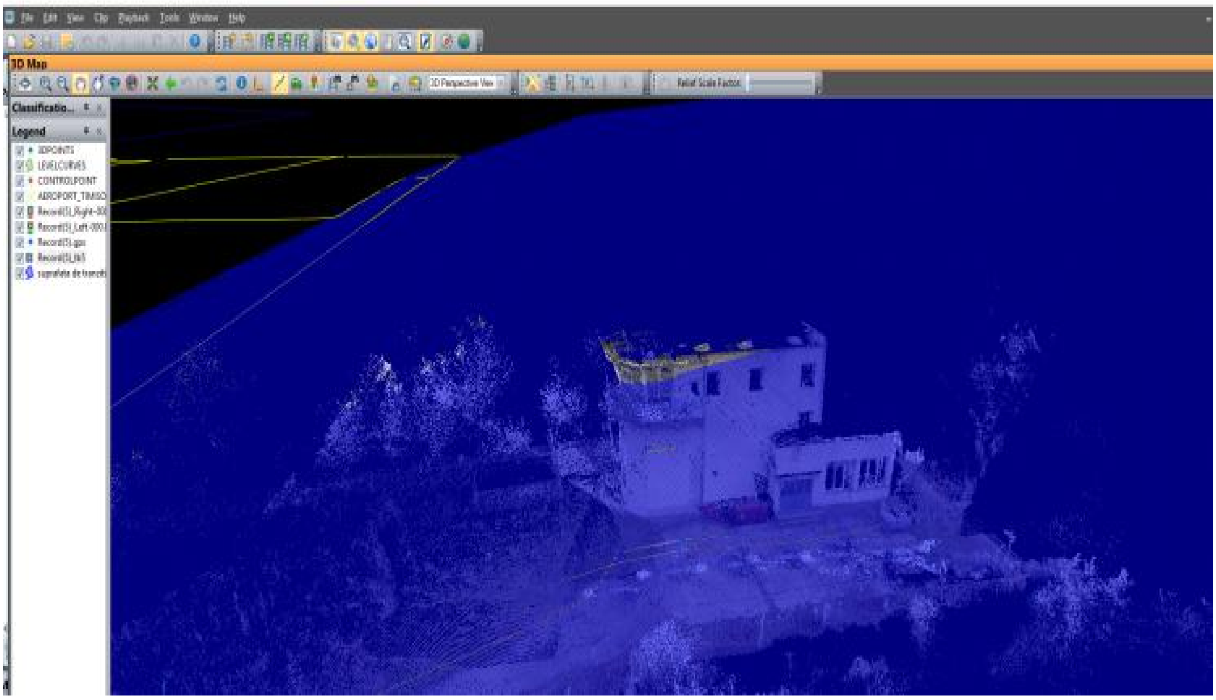

Fig. 3 Existing Obstacle identification – with blue is represented the obstacle surface, with natural color the object

3. Results

Static processing results of the geodetic network – 7 points post-processed for Timişoara airport surveys - are presented below:

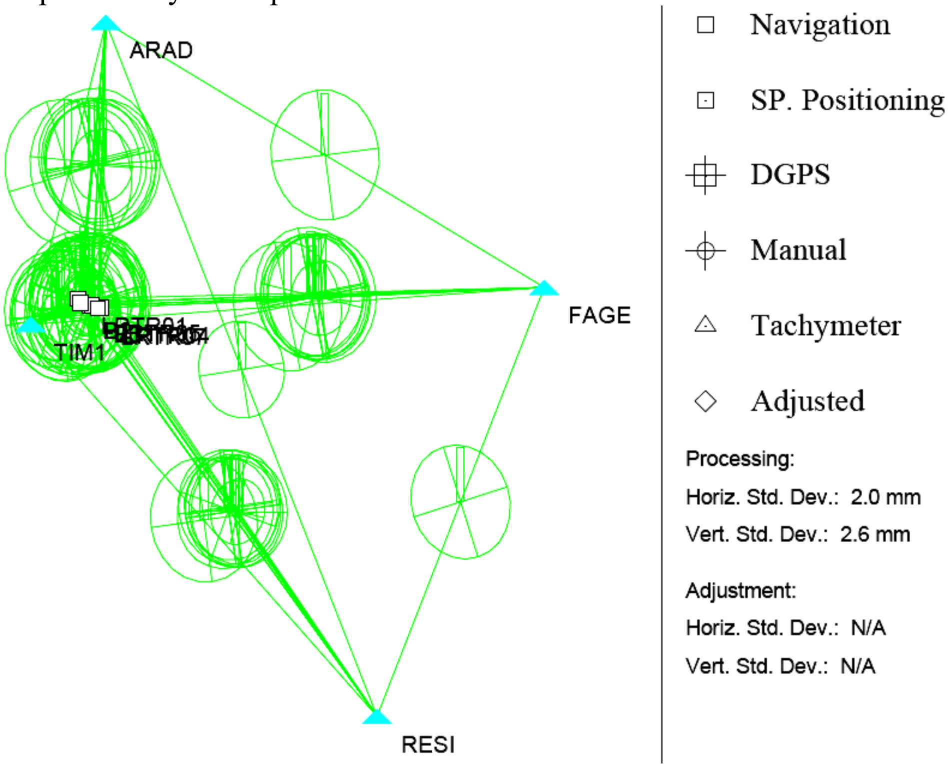

Fig. 4 GPS Static Processing Results

For the GPS kinematic surveys the maximum baseline length was under 4.7 km, which allowed a RMSE for rover position below 0.9 cm for Northing/Easting and under 2.3 cm for height.

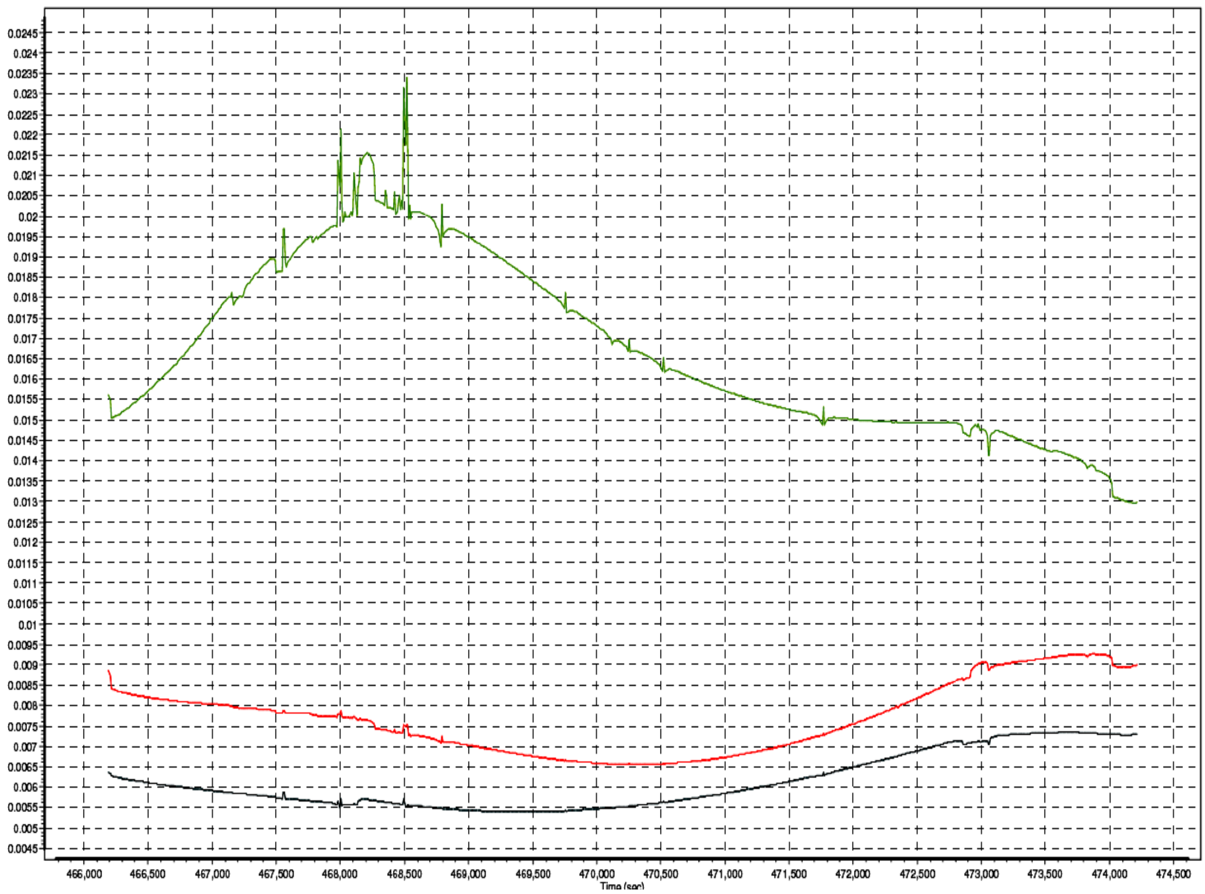

Fig. 5 Rover position error RMSE [m] red – North, grey – East, green – height

As (H. Jing, 2016) stated, when using a surveying grade GNSS intergrated with the IMU, "the errors coming from the laser scanner are negligible compared to the navigation errors, [so] we can assume that the errors seen in the point cloud should be around the same error level as the positioning system."

Fig. 6 Perspective view of the LiDAR processed points – airport main tower

Obstacle Limitation Surfaces (OLS) are a series of surfaces that set the height limits of object around an aerodrome. Objects that project through the OLS become obstacles. (CASA 1999). In Timişoara Airport case, it consists of Conical Surface, Inner Horizontal Surface, Approach Surface, Transitional Surface, Take-off Climb Surface, Outer Horizontal Surface, Inner Approach Surface, Inner Transitional Surface, and Baulked Landing Surface.

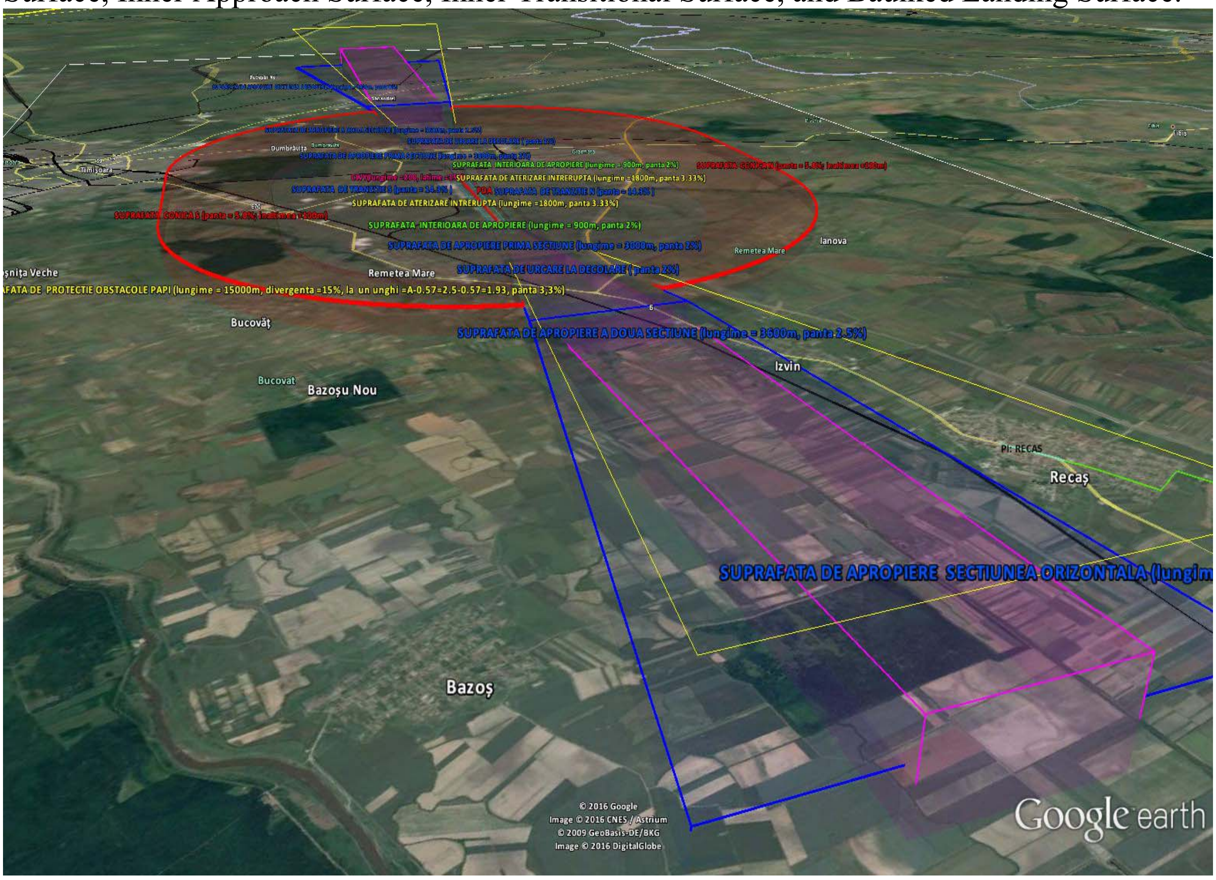

Fig. 7 Timişoara Airport Obstacle Limiting Surfaces, displayed in Google Earth™

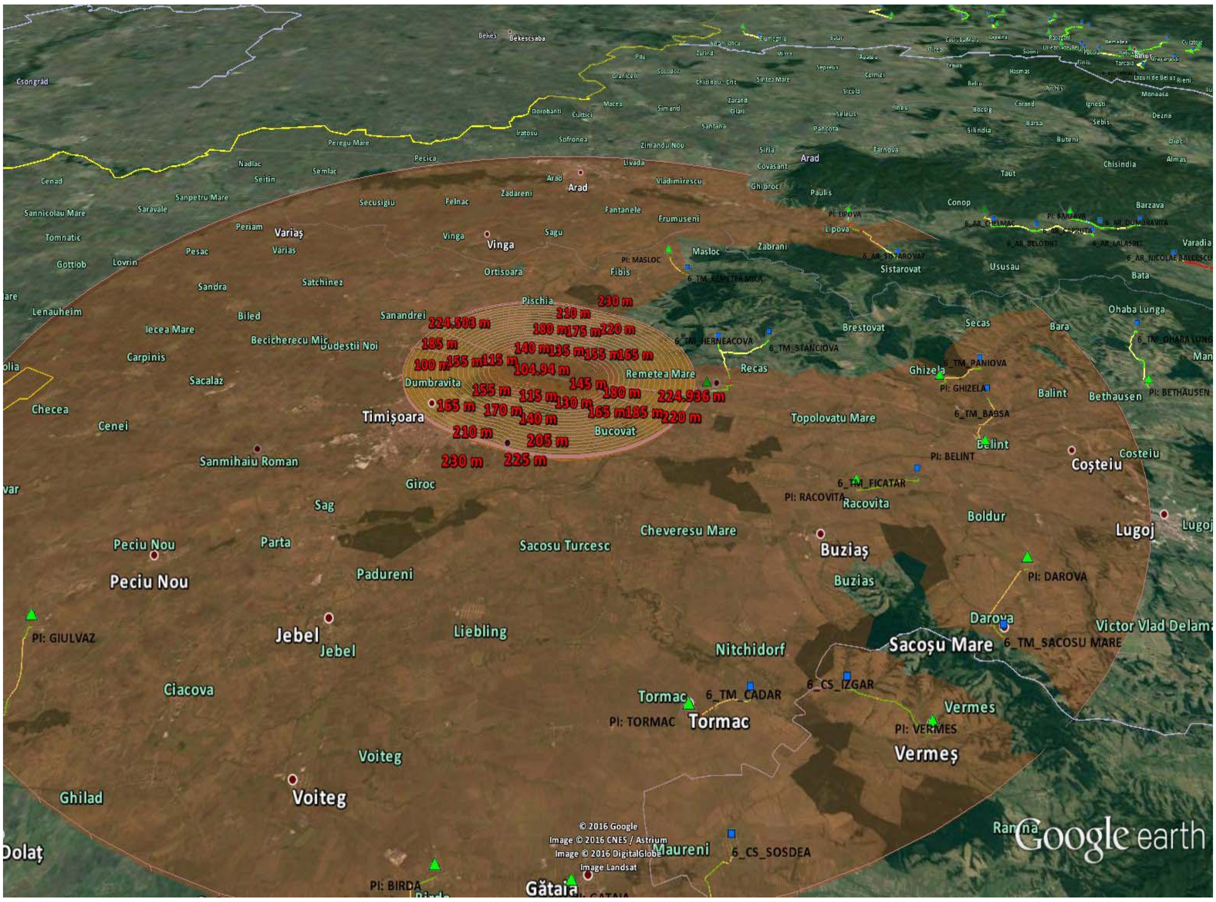

Fig. 8 Timişoara Airport – Terrain and Obstacle Collection Areas, displayed in Google Earth™

During the ongoing project, the following products wee extracted from LiDAR data and delivered:

- Documentations and maps for Obstacle Limiting Surface Areas
- Documentations and maps for Terrain and Obstacle Collection Areas
- Documentations and maps for OACI Type A Obstacle Map
- Airport Certification Specifications
- Maps for OACI Terrain Map for Precision approach
- Romanian civil aviation regulation ZSAC servitude areas
- GIS database

QA process

The points accuracies verified by using RTK Rompos met the requirements of the Manual RACR - WGS -84 Edition 1 / 2016- tables 2-1 , 2-2, 2-3, 2-4 , 2-5 , 2-6, 2- 7 and 2-8.

4. Discussion

Three types of LiDAR collection systems are available today:

- Stationary terrestrial LiDAR scanners (STLS)
- Mobile terrestrial LiDAR systems (MTLS)
- Aerial LiDAR Scanning Systems (ALSS) capabilities

Table 1 STSL versus MTLS versus ALSS capabilities (Jay Farrell, 2016)

Laser Scanner	STLS	MTLS	ALSS
Collection Range/ Speed	Small	Large	Very Large
Point Density	High	Medium	Low

Table 2 Parameters comparison between MTLS and ALSS

Laser Scanner	Mobile Trimble MX2 (Trimble, 2014)	Aerial Riegl Q560 (RIEGL Laser Measurements Systems GmbH, 2010)
Point Density (ppm)	100 – 3000	10-50
Field of View (degree)	360	45-60
Measurement Rate (pps)	70,000	240,000
Relative Accuracy (m)	0.01 – 0.1	0.1
Absolute Accuracy (m)	0.05 – 0.2	0.2

5. SWOT Analysis of MTLS

5.1 Strengths

The identified strengths of the mobile terrestrial mapping systems are:

- It produce survey-grade data (can be used in static and cinematic mode).
- Data collection/survey takes a fraction of time than a survey crew collecting survey points using traditional tools and techniques.
- Scanning runway and other areas of the airport can be done avoiding peak take-off and landing periods.
- Fast data collection time, and digital data could lead to increased cost savings over other survey methods.
- Can generate a 360 video/photo source time-stamped that can be reviewed later after to validate objects, data integrity, etc.
- The LiDAR survey can be conducted at night (it creates its own light source). However, in this case the video capability of the MX2 system will be greatly limited.
- Traceability of the surveys is granted at any moment, if needed.
- Complex 3D analysis of the environment is feasible using point cloud data, including volume reports, clearance and routing analysis, asset management etc.

The result are high resolution and high accurate data points simultaneously collected with oblique, stereo RGB imagery, from a ground-level perspective. This perspective allows data to be collected:

- In between buildings that are close in proximity;
- Under tree canopies, and under bridges;
- Areas where airborne LiDAR surveys are unable to see and collect;

Collected data can be also used for:

- Pavement Management
- Safety and Situational Awareness
- Feature and Asset Extraction and Management

5.2 Weaknesses

Line-Of-Sight (LOS) related issues
- LOS is obstructed by traffic of objects placed in the AOI
- LOS is highly dependent on topography

Weather related issues:
- Survey is greatly hampered by rain or fog– almost completely
- Standing water on the ground could reduce the ability of reflecting laser beam therefore no points will be collected on areas covered by water

Sky-line Visibility is restricted in urban canyons –
Software processing is quite slow and resource consuming.

The training of the personnel for processing data and extracting features is a slow and long term process.

5.3 Opportunities

Mobile LiDAR data of the entire area of interest captured in 3D provides information for additional products that the customers is not yet aware that it need. Further products might be derived from the office without the need of a separate survey, if the LiDAR data acquisition is recent and no changes happened in the mean time.

Point clouds are susceptible to be used by automated procedures for classification. This will allow the fast retrieval of features.

Service based models based on remote sensing data in general and LiDAR in particular are prone to appear, as identified by Alex Philp (Earth Imaging Journal, 2013)

5.4 Threats

"The software is not keeping pace with hardware advances, particularly in the terrestrial scanning market" (Lidar News, 2009)

Huge amount of data is collected during short period. Storage requirements grow quickly and the risk of loosing data is significant high.

6. Acknowledgements

The authors would like to thank Timişoara Airport Administration for providing support during data acquisition. This project was fully funded by Gauss srl.

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