JOINING MMS AND ALS DATA WITH ORTHOPHOTO;

A CASE PROJECT: HIGHWAY DEFORMATION DETECTION AND VISUALIZATION

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Abstract: In 2009 a case project of monitoring the state highway using mobile mapping systems (MMS) has started at the Czech Technical University in Prague. Its aim is to develop and verify the technology of detecting changes in the environment, especially by monitoring the conditions for vegetation along communications, to propose, develop, and test the possibilities of documenting communications surroundings with a mobile 3D scanner. For the purposes of this project the completed part of highway D11 from Prague to Hradec Kralove was mapped using a mobile mapping system LYNX Mobile Mapper. After construction works on D11 highway were completed in 2010, it became clear that some parts of this new highway were of bad quality. New mapping was commissioned to document the known defective parts and detect others. The parts of highway with defects were repaired and after reconstruction mapped again. This project has thus shown the advantages of the mobile laser scanning method. There are many ways to display the differences - cross sections, height images, DTMs and many other outputs. To create cross sections, we used Terra Scan. The differences between elevations from different construction stages were drawn into height image using MatLab and the DTM of the tested area was covered by a combination of the orthophoto and the height image to obtain better visualization. Height images were based on the differences between DTMs of two periods (2009 – 2011 before reconstructions, 2011 before and after reconstruction, 2009 – 2011 after reconstruction – checking) the height images were created using MatLab. In the Czech Republic global aerial laser scanning (ALS) of the entire national territory began in 2009 therefore. So, we had also ALS data and MMS data at our disposal.. Another problem was joining the mobile laser scanned data with aerial laser data. This contribution intends to describe problems and outputs of the above mentioned project.

INTRODUCTION

Commercial Airborne laser scanning (ALS) in the Czech Republic started in 2008. From 2010 to 2012 The Czech Office for Surveying, Mapping and Cadastre in cooperation with The Ministry of Defense of the Czech Republic and The Ministry of Agriculture of the Czech Republic realized mapping of the entire area of the Czech Republic by ALS technology. The goal of this project is to derive a highly accurate Digital Terrain Model (DTM) for purposes of administration, e.g. detection of flooded areas, orthorectification of areal images, etc. Filtered and classified point clouds are characterized by a density of about 1-2 points/m^2. The final DTM will be available in the form of TIN.

MOBILE MAPPING

In the Czech Republic the MMS (Mobile Mapping System) has been used since 2009. In this year a case project started with a hired instrument. In 2010, only one instrument (Lynx) was available in the Czech Republic, and in 2012 4 instruments were available. Why MMS instead ALS? MMS has better resolution and point density in close range. It is ideal for cadastral mapping, precise monitoring in cities, for monitoring power lines, highways and surroundings, and also for mapping historical city centers (facades) etc. This is also a modern and popular technique.

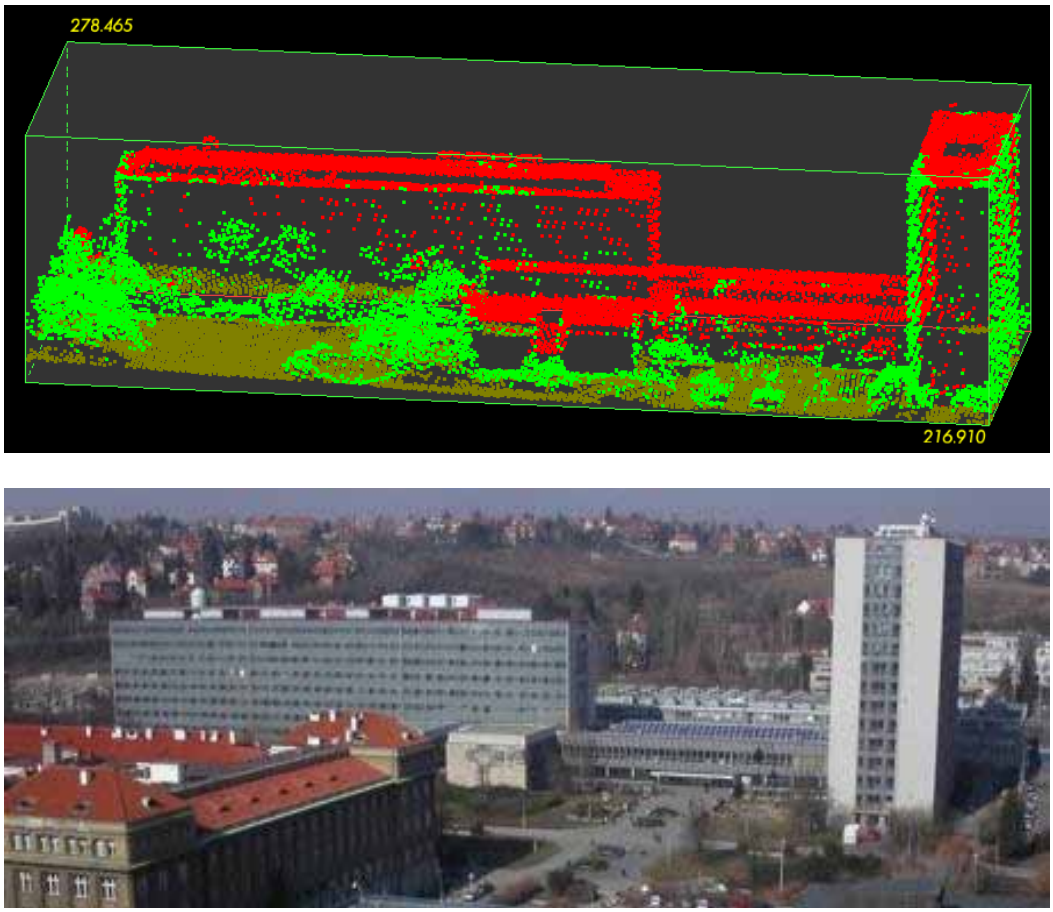

Figure 1: CTU Prague, FCE (classificated point cloud and photo)

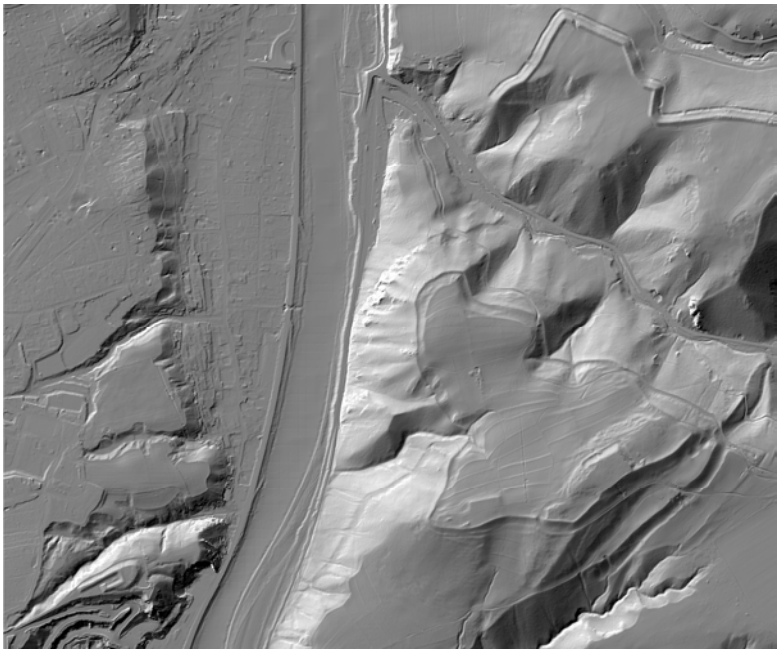

Figure 2: Celtic oppidum near Prague

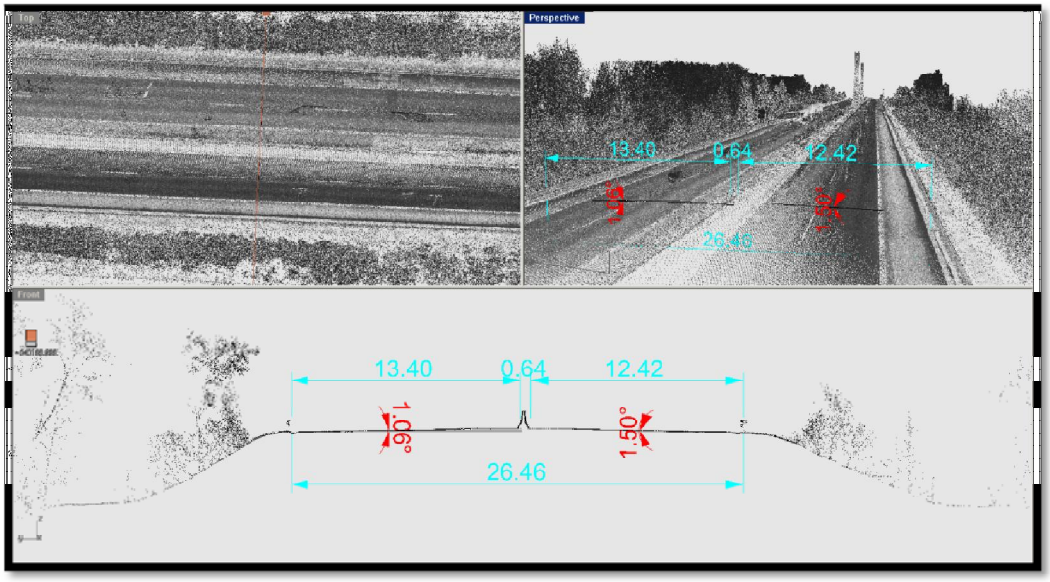

Figure 3: Highway D11 monitoring, 2009

MMS APPLICATION PROJECT - HIGHWAY DEFORMATION MONITORING

Data from MMS - 2009

Faculty of Civil Engineering of the Technical University in Prague was one of the participants in the project of the Ministry of Transport for years 2009 and 2010. Its aim was to develop and verify the technology of detecting changes in the environment, especially by monitoring the condition of vegetation around the communications, to propose, develop, and test the possibilities of documening communications surroundings with a mobile 3D scanner. The completed part of D11 highway from Prague to Hradec Kralove was mapped for the purposes of this project , using a mobile mapping system LYNX Mobile Mapper. Mapping and data preprocessing were performed by GEOVAP Company (Pardubice) and Teccon (Zwijndrecht, Belgium).

Figure 4: LYNX on GEOVAP company car

Data from MMS – 2011

After completion of highway construction works 2010, it became clear that some parts of this new highway were not constructed well. The new mapping by GEOVAP Company was to document the known defective parts and detect others. The parts of highway with defects were repaired and after reconstruction mapped again.

In the dispute finally also the MMS technology were used. The typical problems found were:

1. resistance of authorities to new technology
2. lack of finances
3. bureaucracy and corruption

Figure 5: A problematic part of highway D11

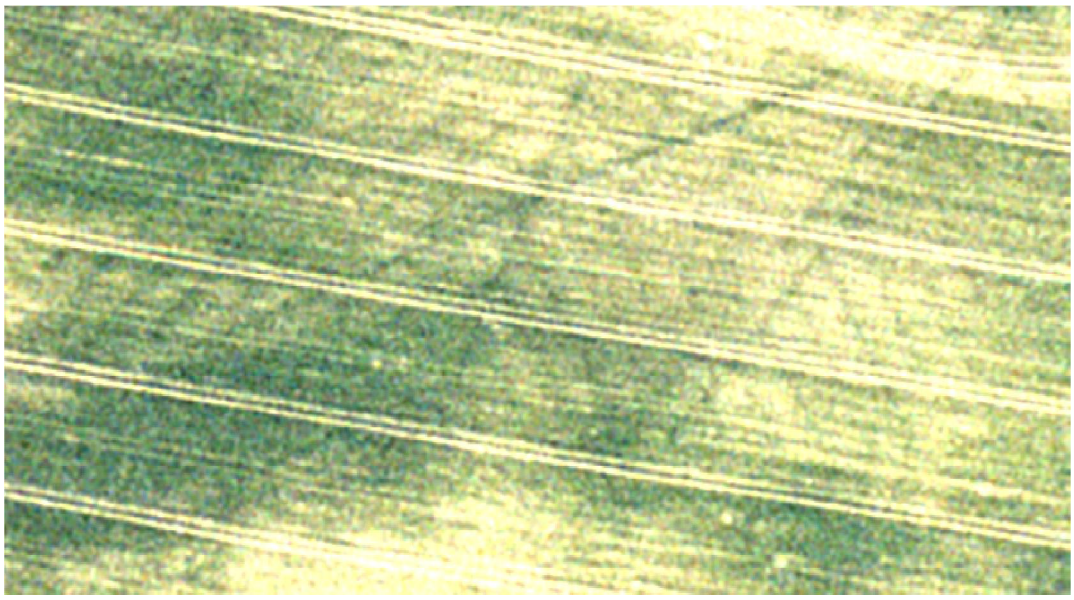

Figure 6: Possible problem with watered ground: old water drainage

The aim of the project was to merge ALS data with MMS. It is not easy, because the Czech Republic uses a coordinate system based on triangulation from the 1920´s. Geometric precision of this geodetic triangulation is not uniform and contains small irregular deformations.

Figure 7: Measurement – leveling on D11

Problems by merging ALS and MMS data:

Files of four places were compared approximately 10 km apart.

- A good comparison with leveling along the highway was achieved by mobile laser data (differences max.4cm).
- A systematic error found in 2010 by ALS; after error correction good conformity was reached
- The accuracy of transformation using a global transformation key in the CR is 15 cm and the resulting data accuracy of ALS is estimated at 19 cm.

DATA TRANSFORMATION

Most geo-data in the Czech Republic remain in a planar coordinate system S-JTSK (Uniform Trigonometric Cadastral Network) which was based in the first half of the 20th century. As the system was based on an earlier system, , the S-JTSK system is deformed in direction and length. Unfortunately, the deformation is not constant for the whole territory of the Republic. Transformation between ETRS 89 and S-JTSK can be solved by seven-parameter transformation with the local transformation key (using local identical points) or with the global transformation key with later application of deflections interpolated from values in a regular grid.

COMPARISON

The data which were at our disposal for the project were in the S-JTSK and the Baltic Vertical Datum - After Adjustment. But the data from different periods were transformed by different subjects and probably in different ways. The data from 2009 did not correspond to the data sets from 2011 - before and after reconstruction. We used the function *global registration* (ICP algorithm) in Geomagic Studio software to minimize the distance between the points of the datasets. The point clouds were then filtered and classified using software TerraScan. There are many ways to display the differences - cross sections, height images, DTMs... We used TerraScan to create cross sections. The differences between elevations from different stages were drawn into height image using MatLab, and the DTM of the tested area was covered by combination of the orthophoto and the height image - to obtain better visualization.

RESULTS

A very good data composition was finally achieved. “Height” images were based on the differences between DTMs of two stages (2009 – 2011 before reconstructions, 2011 before and after reconstruction, 2009 – 2011 after reconstruction – for checking). The height images were created using MatLab with pixel size – 0.25m (only

highway surface) and 0.5m (other areas). The necessary orthophoto was obtained from the Czech Office for Surveying, Mapping and Cadastre (it is characterized by pixel size 25cm and was used for displaying height deformations). Measuring elevation differences between data of two stages has been processed in TerraScan software. Point clouds (from ALS and MM) were preprocessed in this software to the form of a DTM. TerraScan / MicroStation with plenty of setup possibilities enable automatic generation of the profiles (cross sections) from DTM. DTM was created using Geomagic Studio 12 in the form of TIN. This software was also used for other processing steps. The combination of orthophoto and height image was used as a texture for DTM. Finally, the DTM was exported to WRML for presentation purposes.

LANDSLIDES DETECTION

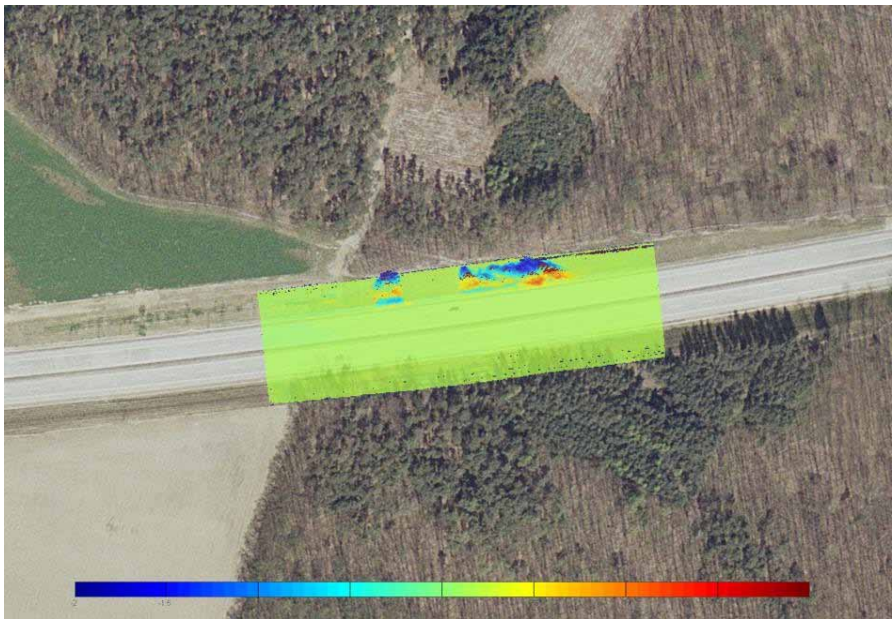

Figure 8: Landslide detection

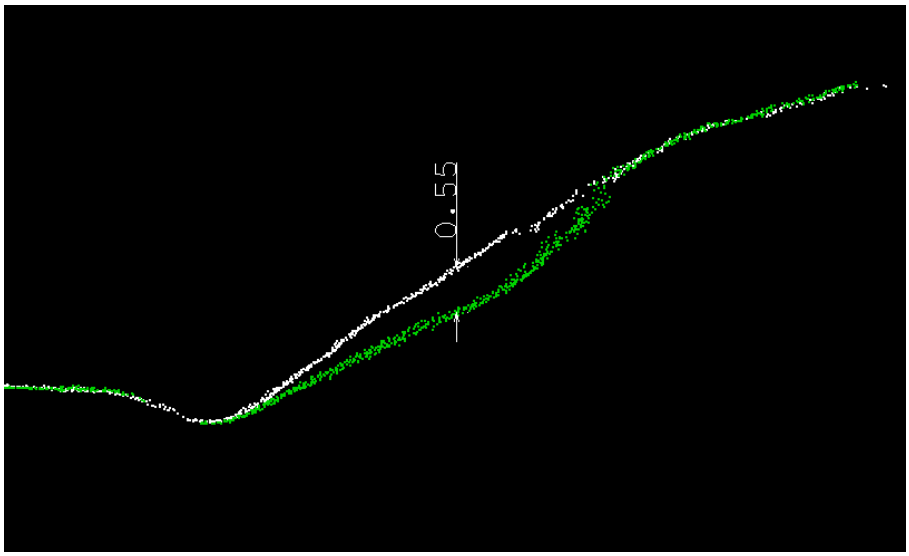

Figure 9: Landslide detection – detail and profile

ROAD-LANE DEFORMATION

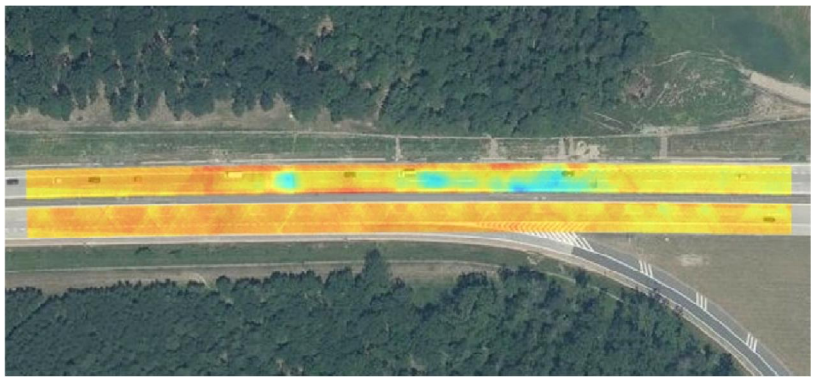

Figure 10: Road lane deformation

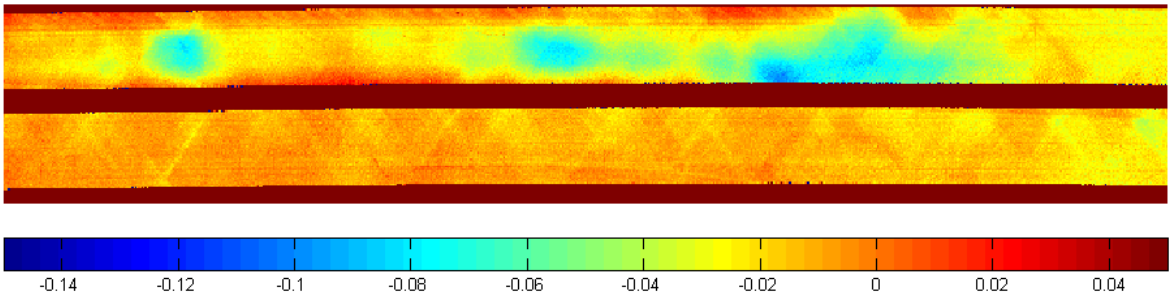

Figure 11: 2009 versus 2011 (before repairs)

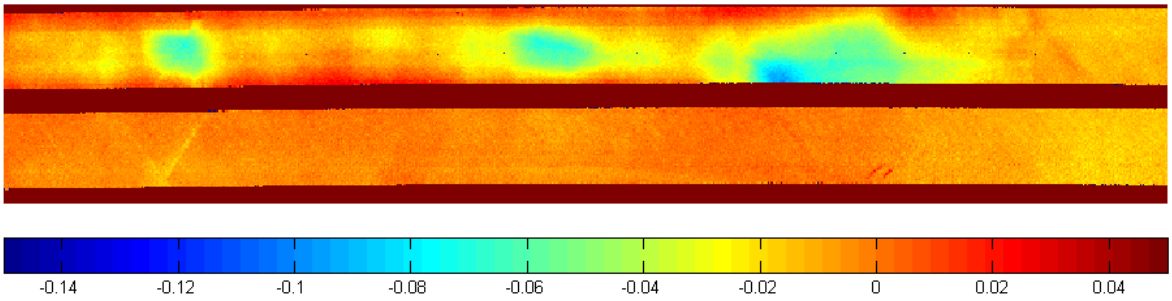

Figure 12: 2011 (new measurement, before repairs) versus 2011 (after repairs)

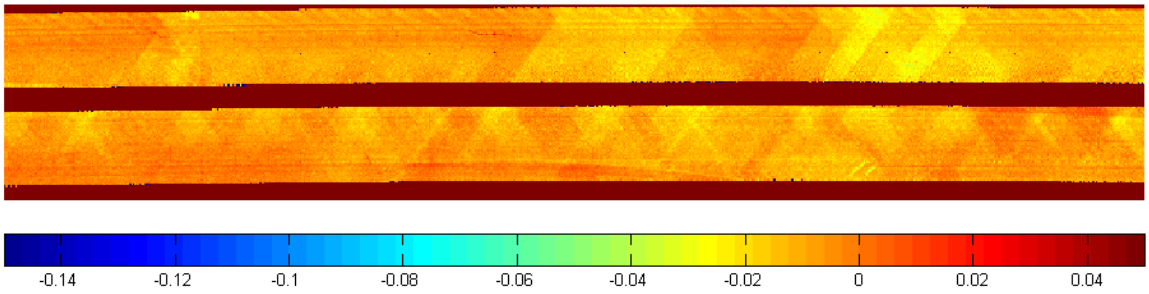

Figure 13: 2009 versus 2011 (after repairs)

CONCLUSIONS & RECOMMENDATIONS

What was monitored?

- Deformation of traffic lane
- Landslides
- New objects in the neighborhood

There is a lot of software to use; we used Geomagic Studio, LAStools, MicroStation, TerraScan/TerraModeler, MatLab. For lane construction it is suitable to use TerraScan/TerraModeler. Accuracy and resolution of the measured points is in cm - this means that for the documentation of small defects (cracks) compared for an additional precise scanner focused on very short distance with mm resolution must also be used. The complex road documentation can be done by special vehicle with a variety of devices.

Figure 14: Double laser scanner (Houston, SPAR2012)

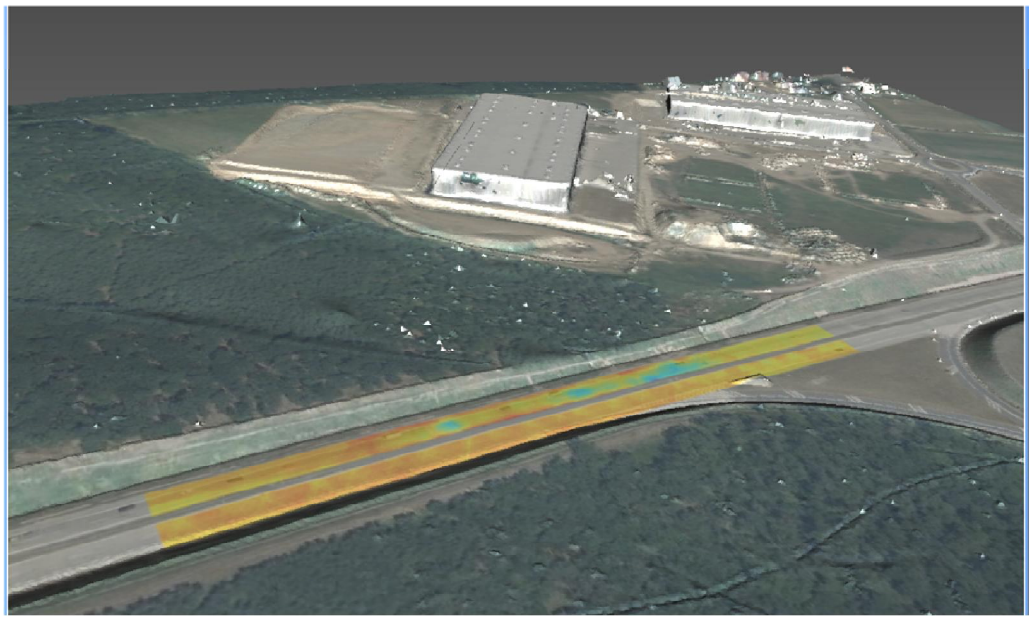

Figure 15: Perspective view – merging ALS with MMS

ACKNOWLEDGEMENT

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