Project For The Producing Of 1/1000 Scale Base Maps From Colourful Images With Taken Digital Camera in Bursa Metropolitan Area in Turkey

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SUMMARY

Large scale, up-to-date and reliable base maps are necessary for any projects, planning tasks and GIS applications in relation to land.

Existing maps and geographical data tend to go swiftly out of date in regions and countries such as Turkey where topography rapidly changes due to natural and cultural reasons.

Therefore, there arises the need to update or renew the existing maps in these regions and countries. Today the swiftest and most economic way to meet these needs for large areas is to produce maps by digital photogrammetric method and digital aerial photographs.

This article gives a detailed explanation of a project being conducted with the supervision of Zonguldak Karaelmas University regarding the production of vector and orthophoto maps in scale of 1:1000 from color aerial photographs with 10 cm GSD value obtained from a region of 3500 kilometer squares in Bursa Metropolitan City using a digital aerial camera

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1. INTRODUCTION

Project of Generation Digital Map of Bursa covers Metropolitan Area of Bursa Metropolitan Municipality, and is located between 39.90-40.50 North latitude and 28.35 – 29.45 East longitude ranging 0-2300 m height in the Region of South Marmara (Figure 1). Bursa, the centre of national automotive industry, is a developed-area of agriculture, textile and tourism. The population increases yearly 4-5% caused by the migration from other provinces.

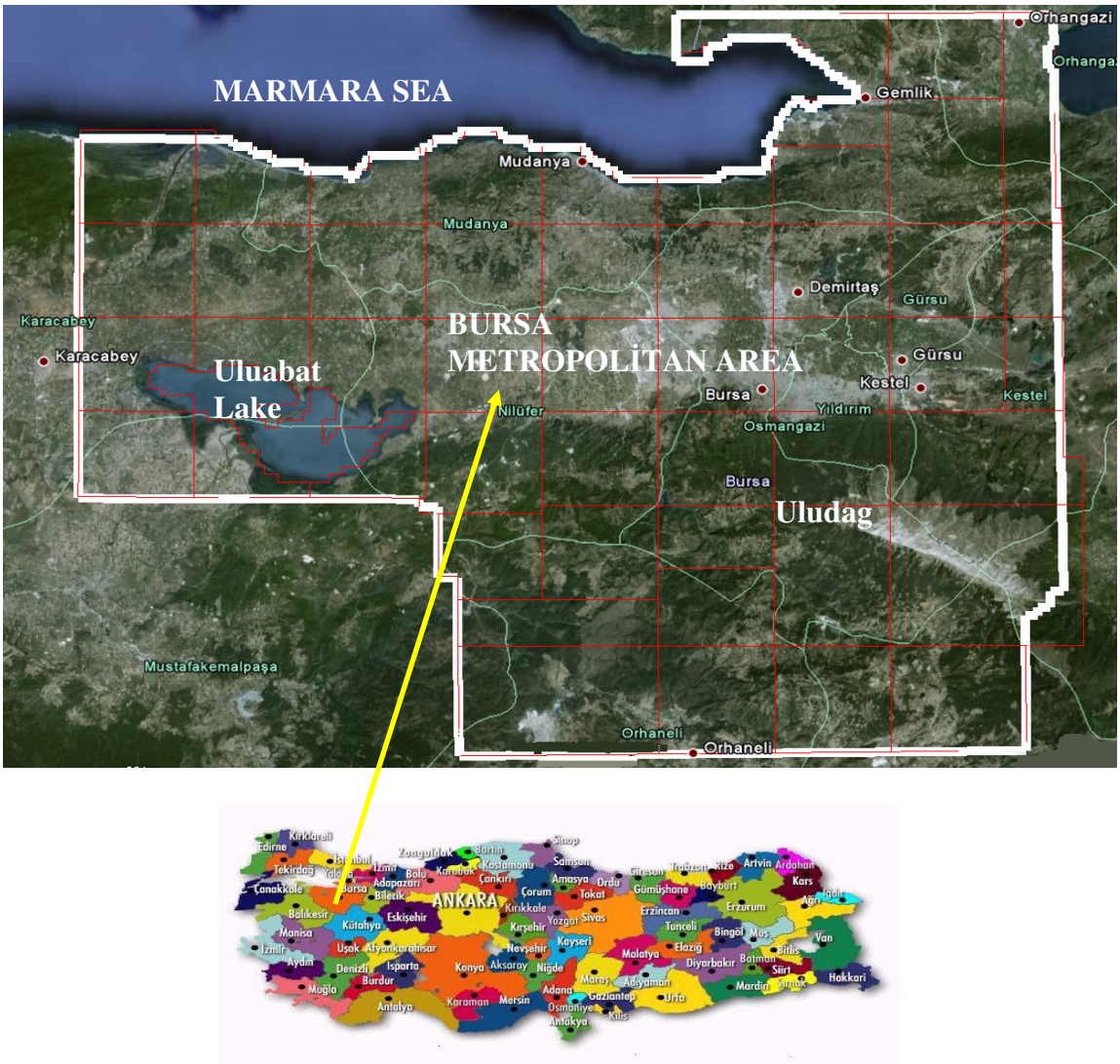

Figure 1. Position of Project Area

Requirements of planning, reconstruction, project generation, and application facilities are increasable needed depending on the population-grow and rising of general riches. Herewith, correct and updated maps and geographic data are elementary requirements. This project is also important since the project area is located on a 1st degree earthquake zone in the extension of the North Anatolian Fault, and in the area of co- and post-seismic earthquakes occurred as 6.5 and 7.5 Richter magnitudes.
The main aim of the project is to generation of 1:1000 photogrammetric maps serving planning and GIS base of Bursa in the Metropolitan Area of Bursa Metropolitan Municipality covering 3500 km^2.

The basic specifications of large scale maps generated by the project started November 2008 for 24 months are expected as following in the PTS:

- Maps based on the national basic geodetic network,
- In the form of national geographic base and serving for the GIS of Bursa,
- Accommodation with existing cadastral, topographic and base maps,
- Planimetric and vertical accuracy of ±10 cm.

The main steps of project, as in the similar projects, consist of the following steps:

- Establishment of geodetic base,
- Photogrammetric flight and imaging,
- Image processing,
- Photogrammetric triangulation and adjustment,
- Photogrammetric compilation,
- Generation of map sheet and quality control,
- Field completion.

This project is the first project of generation 1:1000 maps using images with 8-10 cm ground sampling distance taken by the digital cameras in Turkey.

Zonguldak Karaelmas University Department of Geomatics Engineering advises and controls the project which is currently in the stage of photogrammetric compilation. This project is an important example for the cooperation between University-Industry rarely in Turkey in this scope. Here the information including the application and results of the project is presented.

2. ESTABLISHMENT OF GEODETIC BASE OF PROJECT

The national geodetic base established in 1940s is deformed and defective for the large scale maps because Turkish territories are located on the region covering many geodynamic movements. To overcome this problem, Turkish National Fundamental GNSS Network (TUTGA) and Turkish National Vertical Control Network (TUDKA) were established by 700 geodetic points with 25-30 km distance thanks to GPS technology in the ITRF datum 1997 through 2001. 3D coordinates with ±2-3 cm of these points and the time dependent

(geodynamic) changes (velocity) and orthometric height (H) and geoid undulation (N) were determined.Following these establishments, geographic referencing and mapping are enforced basing on this national geodetic base for country-wide since 2003. This rule is followed in the Bursa project covering 3500 km^2, and the following issues exist for establishment of geodetic base accommodating PTS:

- The major (GNSS) triangulation network with totally 73 points whose 6 points as B degree (TUTGA) depending on TUTGA 99, 24 points as C1 with 15-20 km distance, 43 points as C2 with 5-15 km distance have been established in ITRF 96 2005.00 reference epoch (Figure 2).

- Helmert Orthometric Height System based on TUDKA and GPS levelling geoid and also local GPS levelling geoid have been defined in this project.

- 1215 C3 GNSS densification points have been established and their orthometric heights have been determined accommodating photogrammetric blocks, photogrammetric imaging aided by kinematic GPS and further photogrammetric compilations in the project area for the purpose of generation of 1:1000 photogrammetric maps.

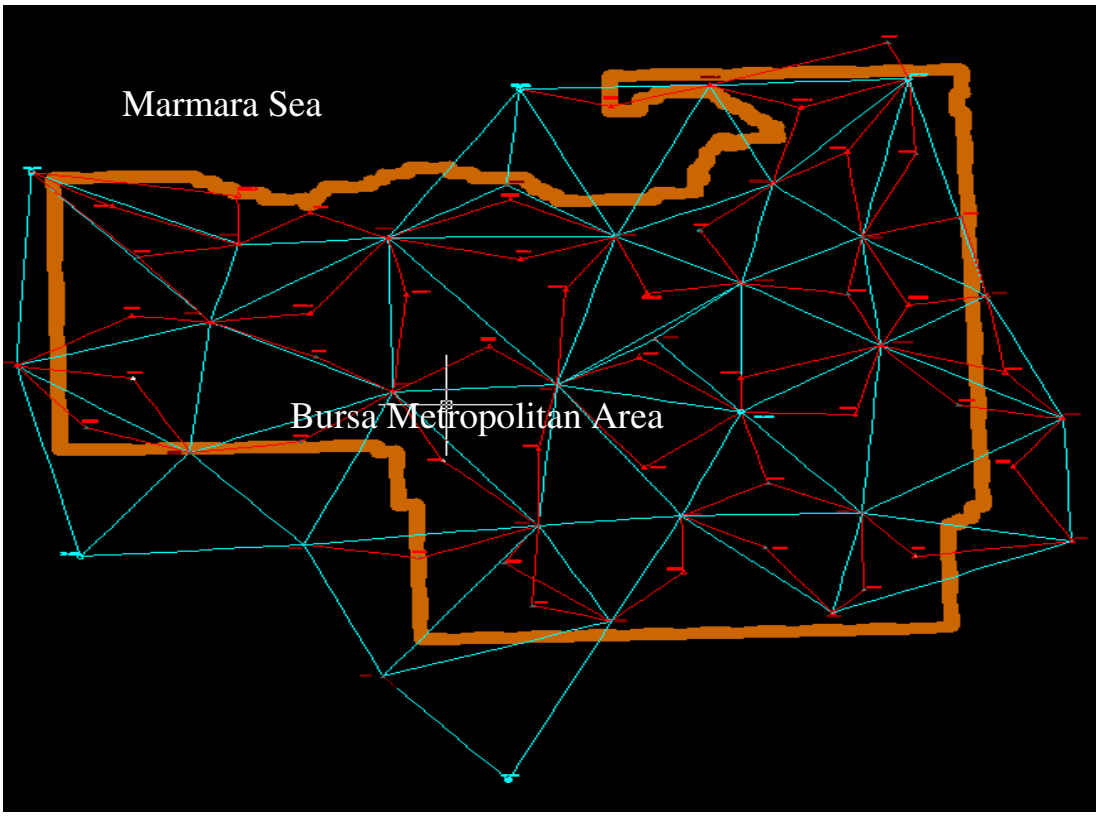

Figure 2 Main Triangulation Network in Bursa project

2.1 GNSS Observations And Evaluations About Basic Geodetic Network

Basic GNSS network consisting of 73 B, C1 and C3 points was observed in static mode along 2 hours, instead of 1 hour suggested in the PTS, from 1st to 5th July 2009 using 9 GPS receivers, and evaluated based on 2009.50 epoch.

Independent adjustment of base vectors has been performed in the 3D WGS 84 datum. 219 ΔX, ΔY and ΔZ base components of 73 points and standard deviations ($\sigma_{\Delta X}$, $\sigma_{\Delta Y}$ and $\sigma_{\Delta Z}$) were estimated. These deviations were compared with the following requirements in the PTS:

$\sigma_{\Delta X}, \sigma_{\Delta Y}, \sigma_{\Delta Z} \leq \pm$ (10 mm + 1 ppm)

and all of these components provides this requirement. Besides, the valid closings exist with maximum 0.90 ppm and 0.24 ppm average in 129 loupes shaped by base vectors.

2.2 3D Bluring Tests And Adjustment Of Basic Network

A 3D similarity transformation between the coordinates previously known and available in observation time epoch using velocity values and results of independent adjustment of 6 TUTGA and 12 C1 GPS points of main GPS network with 73 points were controlled using scale-conformation and blurring test in the network with the help of $1-\lambda \leq \pm$ 3 ppm given in the Technical Specification (λ: scale factor).

The adjustment has been iteratively run taking out the outlier bases (points) by sequential 5 statistical tests.

Results of 1st test using 6 TUTGA and 12 C1 points and of 5th test using 3 TUTGA points are given in the Table 1.

Table 1. 1st and 5th Results of Blurring Test

Test No	M_0 (m)	Scale Fact. (ppm)	M_X Max (m)	M_Y Max (m)	M_Z Max (m)
1	0.0635	0.4045	-0.0663	-0.1179	-0.1370
5	0.0085	0.1534	0.0087	0.0045	-0.0001

3 TUTGA points were defined as datum points since the results of last test are agree with the criterions of Technical Specifications.

The outlier points may be inquired by the geodynamic characteristics of the area and 1999 earthquake.
Main GPS network consisting of totally 73 points has been adjusted using 3 points whose coordinates are assumed fixed. φ, λ and h (ellipsoidal height) and σ_φ, σ_λ and σ_h are estimated.
Standard deviations are:
$\sigma_\varphi = \pm 0.0004$ m, $\sigma_\lambda = \pm 0.0003$ m, $\sigma_h = \pm 0.0007$ m

These findings are agreed with the PTS as following:

$\sigma_{\varphi,}\sigma_{\lambda} \leq \pm 3.0$ cm and $\sigma_h \leq \pm 5.0$ cm

2.3. Measurement and Calculation of Vertical Measurement

1287 B, C1, C2 ve C3 points are coordinated by static GPS observation in the project area covering 3500 km^2. Helmert orthometric heights of 459 points were determined with the accuracy of ±1.5 mm/km depending on TUDKA.

Uncorrected observations were re-measured following detection of outlier and points using the appropriate test in the independent adjustment.

Connecting adjustment has been performed following the independent adjustment. Of all 459 points in the adjustment 40 points were considered constant. m_0 is ± 12.01 mm in the connecting adjustment. Orthometric height of 49 points were estimated by GPS levelling since these points are located between the height zone of 1800-2300 m where the precise geometric levelling is difficulty performed.

3. ESTIMATION OF LOCAL GEOID SURFACE

Local geoid surface has been estimated on the project area for the purpose of improvement of TG03 (Turkish Geoid 2003) developed for the countrywide.

404 points with both GPS coordinates and precise levelling and 42 points whose orthometric heights determined by GPS levelling, totally 446 points, have been used as control point. 5^{th} degree polynomial model with 21 coefficients and blunder test has been performed removing 13 points in the estimation of local geoid.

Finally geoid height of 433 control points (N) has been modelled by 5^{th} degree polynomial with 19 coefficients giving the brief information in the Table 2.

Table 2 Brief Information of Local Geoid Estimation

# Point	433
Degree of freedom	414
Thereshould	3.8278
Degree of polynomial	5^{th} degree 19 coefficients
Root mean square error	± 0.054 m
Min residual	-0.159
Max residual	0.185

Minimum and maximum geoid heights are estimated as N_{min} = 37.30 m, N_{max} = 39.03 m.

Geoid heights and related orthometric heights of 854 C1, C2 and C3 points are estimated using this surface model.

Figure 3 illustrates the surface model consisting of 1287 ground control points (GCPs) whose Helmert orthometric heights and GPS coordinates are known in the project area.

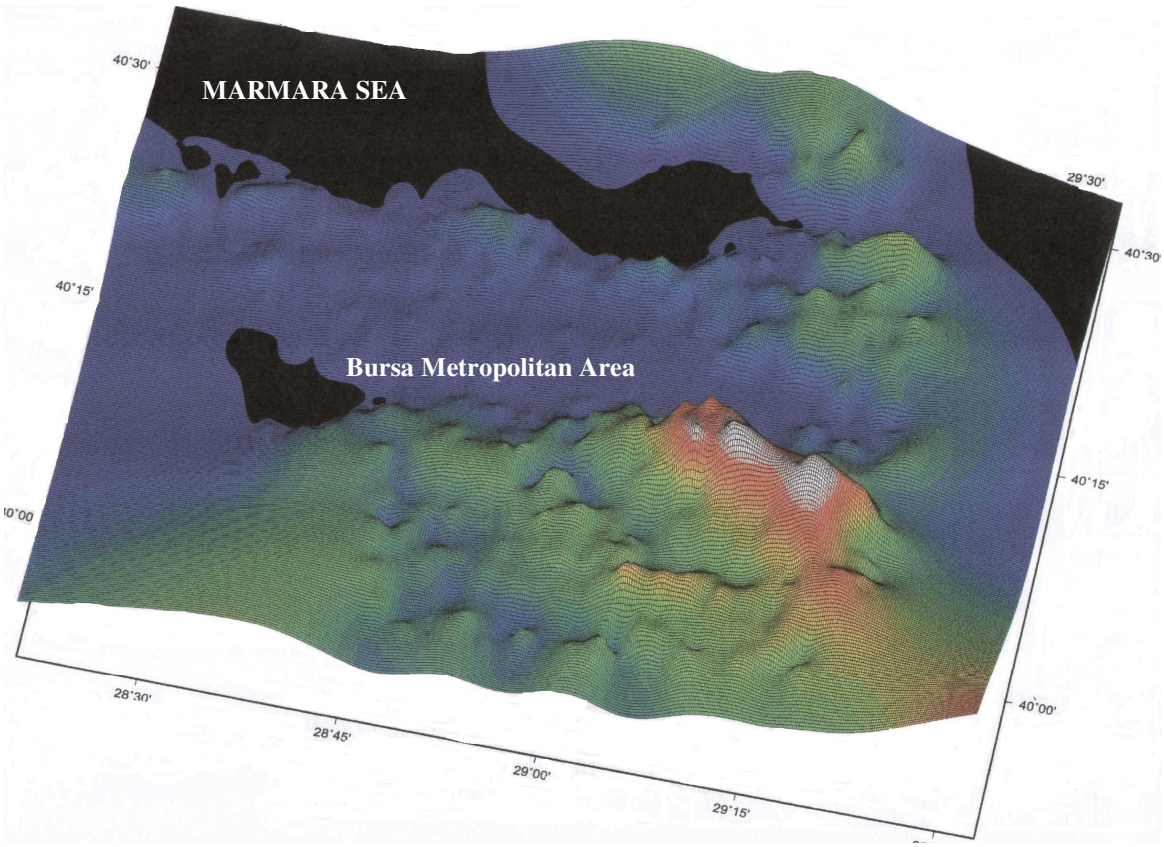

Figure 3. DTM of Project Area Producing From 1287 GCPs

4. IMAGING AND PHOTOGRAMMETRIC TRIANGULATION

4.1. Selection of Aerial Camera and Determination of GSD

National Technical Specification dated 2005 arranges generation of photogrammetric maps in Turkey and suggests photogrammetric imaging with film based (analogue) cameras determining the rules and criteria about the hardware, materials and processes. Usage of digital camera is available by the special permits.

Vexcel UltraCam XP series camera is used in the Bursa project considering the technical and economical conditions of usage of analogue and digital cameras. So the difficulty of usage 70 film roll for 15000 photographs, photographic processing, materials and the requirements of manpower, stuff and hardware, and the storage and archiving for the project area covering 3500 km^2 are removed by the using digital camera.

Usage of digital camera improves the image quality supporting the increase of speed and accuracy of photogrammetric triangulation and processing, and finally more qualitative orthophoto and vector map has been generated.

$250000 – 300000 in the project has been saved by the usage of digital camera although radiometric correction of raw images and GPS/INS calculations charge some expenses.

The imaging process was performed between 09:30-16:30 hours of 14^{th}-20^{th} June 2009 by the Vexcel UltraCam XP series digital aerial camera, one of the cameras known by its high technology. 60% of project area has been covered whereas out of this area could not be imaged by the reasons of its height elevation ranging 1500-2300 m with snow and haze and low-altitude of aircraft. The imaging of this area will be performed on July-August 2010.

The relation and criteria between technical specifications of digital cameras and their images, such as GSD, and the scale of photogrammetric map (or its specifications) used in the purpose of generation of large scale vector maps and orthophoto maps are not defined worldwide and also countrywide up to now. It is well known that the specifications of image of digital aerial camera are not affected by the specifications of sensor and other hardware. GSD is the term used and mostly preferred instead of photo-scale.

Literature and sample applications have been searched for the definition of GSD value accommodating the technical specifications of camera and scale of the vector map to be produced. So it is decided that GSD value with 10 cm is enough for the project, and the flight height is defined based on this GSD value.

The information about the flight and imaging is given in the following:

- Camera focal length (f) : 100.5 mm
- Image size : 11310 pixel x 17310 pixel
- Pixel size (Ps) : 6 μm
- Distance between columns : 1100 m
- Base : 340 m
- Flight height (h) : ~ 57000 ft = 1733 m
- Photo-scale : ~ (100.5/1733000) = 1/17300
- GSD : $(Ps/f)\cdot h = 0.1034\,\mathrm{m}$
- Direct sensor orientation : GPS/IMU (relative kinematical GPS positioning / intertial measurement unit)

4.2.Measurement and Adjustment of Photogrammetric Triangulation

Points of photogrammetric triangulation are semi-automatically measured using ISAT (Image Station Automatic Triangulation) software Z/I Imaging. Measured image coordinates were

adjusted by bundle block adjustment using ISAT. Adjustment of 2, 5, 6,11,15. blocks results are given in table 3.

Table 3 Adjustment results of 2, 5, 6,11,15. Blocks

Block No	In Tie Points (m)		In Ground Control Points(m)(GCP)			In GPS Data (m)			$\sigma_{o(}$µm)
	mx	my	mx	my	mz	mx	my	mz	
2	0.008	0.008	0.014	0.014	0.010	0.009	0.017	0.030	1.420
3	0.015	0.010	0.006	0.013	0.012	0.010	0.021	0.035	2.665
6	0.012	0.010	0.010	0.003	0.003	0.011	0.020	0.029	2.329
11	0.011	0.010	0.002	0.010	0.011	0.001	0.001	0.002	1.649
15	0.010	0.010	0.002	0.002	0.002	0.011	0.019	0.034	2.162

These values are smaller than 8 µm (13 cm) suggested for the scanned analogue photographs according to the PTS. Position of perspective centre (X, Y, Z) were measured by kinematical GPS method and estimated by the AERO OFFICE software for the usage in adjustment.

High quality results were acquired from adjustment of photogrammetric triangulation through well-qualified camera, software and hardware that using in this project

5. STEREO EVALUATION AND GENERATION OF ORTHOPHOTO MAP

A DEM was extracted from the models generated by the digital aerial photographs whose relative and absolute orientation elements are determined by the photogrammetric triangulation. Digital orthophotos are generated by the geometric and radiometric correction and the rectification of digital aerial images using this DEM. Digital orthophoto maps are produced by the mosaicking and tone-contrast adjustment. Geospatial and semantic information about 250 geographic characteristics in the national standards are obtained by the vectorization and evaluation from these orthophoto maps.

This information formed various symbols, line and colours are formatted for the standards (dxf, dgn etc.) for graphical software.

Editing, quality control, field completion and naming processes have been done from this information. 1:1000 vectoral and orthophoto maps have been produced and delivered to the project control unit for the checking.

6. CONTROL AND CHECKING

All processes done by Mescioglu Engineering Company as contractor are controlled by ZKU Geomatics Engineering Department as advisor on behalf of administrative master, i.e. General Directory of BUSKI.

The method, criteria and sanctions of these controls are defined in the PTS. The control, its results and the current condition are handled and followed by the project manager in the project management meetings. Mescioglu and ZKU report the performance and developments in the project to the BUSKI.

The checkings of 1:1000 maps by ZKU are:

- 10% checking of maps produced for the accommodation with GIS by partial check, and cartographic completion for all of them.
- Checking of detail transfer and naming by the field study and comparison by the existing maps for all maps.
- Partial check of planimetric and height check thanks to the comparison of the coordinates from the map and from the terrestrial measurements.
- Counter check by the comparison of intersections derived from both the maps and the field.

They are checking issues which are most extensive, time-consuming and affective on the results.

Up to now, any results not accommodating with the PTS or not removed are matched in the checking performed in the office or in the field. Mistakes and absences are removed.

7. CONCLUSION

Project of producing photogrammetric map in Bursa is the fist leading project where the 1:1000 vectoral and orthophoto maps are produced in the national standards using fully equipped digital aerial camera. So this project supports information and experiences and is monitored countrywide.

Suspending on technical rules and criteria of usage digital aerial cameras and images is available since the existing technical instruction on generation of large scale photogrammetric maps, dated 2005, considers the usage of film based camera. These suspending issues were removed by the decisions of experts in the project.

It is well known that professional technical staff in the governmental agencies is absent for the effective application and checking of the great projects which uses high technologies in Turkey. Therefore, receiving advisory from a university (such as ZKU) having enough staff is a conformable decision and an important example to provide development of University-Industry cooperation countrywide. No important problem has been done in the applications and results expected up to now.

Existing and new geodetic data is an important source for the monitoring the tectonics movement of the project area. It is planned by the ZKU Geomatic Engineering Department that these photogrammetric and geodetic data and experiments will be the source for the master/doctorate studies and the scientific publications.

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BIOGRAPHICAL NOTES

Senol Kuscu is a Professor for Engineering Surveying science in the Department of Geodesy and Photogrammetry engineering at Zonguldak Karaelmas University. He received his Phd degree with thesis about Mining Subsidence and mining damage at Yıldız Technical University in 1983. His research interests are engineering surveying, project management and mining subsidence. He is head of the department of geodesy and photogrammetry engineering at Zonguldak Karaelmas University,Turkey. He is project consultant on behalf of Zonguldak Karaelmas University.

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Eray Can graduated from the Department of Geodesy and Photogrammerty Engineering at Zonguldak Karaelmas University in 1999. He received his Msc degree with the thesis about Highway horizontal geometry in 2005. He is PhD student and currently study on his PhD thesis in this university. His research interests are engineering surveying, highways and railways horizontal geometry. He is research assistant Department of Geodesy and Photogrammetry Engineering at Zonguldak Karaelmas University, Turkey.

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