# LONG-TERM MONITORING OF THE DINAMICS OF LANDSLIDES BY AERIAL PHOTOGRAMMETRY

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**ABSTRACT:**

A technology for long-term monitoring of the dinamics of landslides by aerial photogrammetry has been developed and implemented for a couple of years in GEODESY and PHOTOGRAMMETRY Co. for Research and Technology, Sofia. The technology comprises all stages in preparation, field work, aerial photography, photogrammetric measurements, computation and presentation of result. It is based mainly on analytical methods, using analog photogrammetry, orthophotoscopy and computer graphics as well.

**KEY WORDS:** Analog, Analytical, Computer Graphics, Orthophoto.

## INTRODUCTION

Specificity in the development of landslides processes depends on a considerable number of factors, more important being: the geological structure and the terrain; the hydrogeological, hydrological and climatic conditions; the tectonic movements; the nature of vegetation; and human economic activity. Sometimes landslides cause considerable damages and even human casualties. Landslide related problems are particularly meaningful in putting into use of terrains close to mountain slopes, river velleys or seashores.

Direct observation is the most effective approach in studying the nature landslides processes as well as of their mechanics and dynamics. That is why the direct landslide observations have the character of experimental research under field conditions.

Landslide observation constitute one of the most important activities of engineering geodynamics. The principal task here is the location of mutual positioning of points of the earth surface and in its depth, as well as the location of mutual positioning of structural elements of buildings and engineering structures situated inside the landslide region.

Development of engineering geodynamics is closely connected with the issue of defining the absolute values of the elements of displacement of the landslides points, being monumented in one way or another on the region in question. The respective results, however, tend to have a probability character. The control points against which the check points are determined are not absolutely stable in terms of time. This fact puts limitations in taking into account some of the relative displacements of the landslide points. Geodynamic observations have to be organized in such a way as to enable the values of the relative displacements to approximate in the best way the absolute values of the displacments.

## CONCEPTION

Implementation of analytical aerial photogrammetry is the quickest and most objective approach in finding the spatial location of large number of suitably positioned points, describing the geometry of the landslide area at a particular instant without getting into direct contact with its active part. Under certain conditions finding of these pionts can be performed with adequate precision.

A digital model of a landslide at a particular instant can be obtained by means of single photogrammetric measurements. Digital information on a suitable technical carrier can be used for analytical solution of problem of defferent character as well as for obtaining diverse computer graphics of a landslides.

This approach requires a periodical finding of geodetic coordinates and heights of a sufficient number of permanent check points, evently spaced and monumented inside the active part of the landslide area. Comparison of the coordinates and heights obtained at two consecutive instants enables finding how the landslides is behaving.

Finding of these check points is made with the help of the methods of analytical aerial stereophotogrammetry on the basis of minimum number of control points outside the active part of the landslide. As they are monumented their coordinates and heights are established and periodicaly monitored through geodetic methods.

The conception of the analytical block aerial triangulation makes the core of the proposed approach. The General Thechnological Scheme outlines the link between the thechnological processes in

the course of fulfilment of the task as well as type of input and output data.

## SURVEY DATA AND MATERIALS

The final geodetic coordinates and heights of the check points for each instant of observation can be obtained after the last program of the program package for aerial triangulation finishes its action. The consecutive survey data and materials, providing a comlpete quantitative idea of the state of the landslide at a particur instant, are obtained on the basis of the above results.

These data and materials are the following:

1. Differences in the spatial geodetic coordinates between the preceding and the current instant of observation of each check point.
2. A chart of displacement vectors of the check points for all instants of observation.
3. Terrain points presented as a square network.
4. Contours characterizing the landslide terrain at each instant.
5. Axonometry of the landslide at the same instant.
6. Ortophotomap of the landslide area.

The differences between the geodetic coordinates and heights of each check point are obtained through the comparison of the spatial geodetic coordinates, resulting from the analytical aerial triangulation, carried out at two consecutive instants. These differences are the most precise and reliable quantitative data, characteristic of the dynamics of the landslides process.

The displacement vectors of each check point between two consecutive instants are constructed on the basis of differences of the spatial geodetic coordinates. These vectors present a graphic display of dinamics of the landslide process from the initial instant of observation to current instant. The vertical displacement of the check points are presented in graphic terms in a suitable way as well.

The geodetic coordinates and heights of terrain points,spaced as a square network, are obtained by analog photogrammetric measurements. These data also concern each instant of observation and give an idea of the vertical movement of points having the same planimetric position on the landslide at all instants.

The data of location and heights of the terrain points, being spaced like a square network, are introduced into a computer. Based on these terrain points the program interpolates countours through a preset interval.

The data thus obtained are taken out of the computer for a continuous plotting of the contours. In this way the landslide at each instant is expressed through countours.

Based on the same square network tarrain points the program builds an axonometric projection of the landslide at a particular instant. This projection is plotted as well. The axonometry presents a clear and comprehensible view of the landslides at a particular instant. It can be built at various scales along its three axes as well as at different angles between the axes or at different angles of view.

The orthophotomap makes use of the aerial photographs for the particular instant and the control points, being densified through aerial triangulation, carried out at the same instant.

## OBSERVATION OF ORSSOYA AND TSIBAR LANDSLIDES

The methods of aerial photogrammetry for monitoring the dynamics of landslide processes were applied at two projects along the Danube - Orssoya and Tsibar. The assignment was given to Geodesy and Photogrammetry Company for Research and Technology, Sofia.

During the 1986-1990 period observations were carried out on the above two landslide massifs, distributed into the following nine stages:

1986 Autumn,
1987 Spring and Autumn,
1988 Spring and Autumn,
1989 Spring and Autumn,
1990 Spring and Autumn.

Prior to taking aerial photographs at each stage certain preparations were made on the terrain, namely restoration of the marking of monumented check points, used for monitoring the dynamics of the landslides as well as marking of geodetical control points outside the active landslide area. All these points were monumented and signalled in a suitable way meeting the requirements for such kind of operations.

The necessary control points for the photogrammetric measurements were measured by means of an electronic tachymeter. The geodetic measurements and computations were repeared at each instant to make sure of a stable geodetic network.

Aerial photographs were taken by RMK A 15/23 Zeiss wide-angle survey camera, using black-and-white Agfa-Gevaert panchromatic film. Aerial photographs at an approximate 1:5700 scale were taken of the Tsibar project from an average 850 m flying height, and at an approximate

1:7500 scale of the Orssoya project from an average 1050 m flying height.

Fulfliment of the assigment involved the following three kinds of photogrammetric processes:

1. Stereocomparotor measurements.
2. Analog photogrammetric measurements.
3. Ortophotoscopy.

First come the stereocomparotor measurements, the data of which are used for carring out of analytical aerial triangulation, aimed at obtaining the spatial geodetic coordinates of the check points at each instant. These measurements were made with the Zeiss Jena Stecometer stereocomparotor and were rigistered on magnetic tape by means of the connected Isot 9115E/EC9002 (Bulgaria) automatic recording system. Measured and recorded were the image coordinates and parallaxes of the geodetical control points outside the active landslide area as well as of the check points inside the active landslide area. The accuracy of the measured image coordinates and parallaxes was within ± 2 micrometers.

The analog photogrammetric measurements aimed at finding the position and heights of the terrain points, situated as a square network. These measurements were carried out by means of the Zeiss Jena Stereometrograph analog plotter.

The orthophotoscopy was carried out by means of Zeiss Jena Topocart-Orthophot orthophotosystem and the orthophotomap produced was at a 1:2000 scale.

The photogrammetric measurements were followed by two kinds of electronic computations:

1. With ABA program package for analytical block aerial triangulation.
2. With GEOCAD program for interpolation of contours and building of axonometry.

The computations following the stereocomparator measurements were carried out on IBM 370/148 computer by means of ABA package of programs for analytical aerial triangulation. The geodetic coordinates and heights of the check points inside the active landslide area were obtained for each instant of observation on the basis of the geodetical control points outside the active landslide area. The respective differences make possible the computation of the components of the spatial vector of displacement for each check point.

The computations following the analog photogrammetric measurements were carried out on PC-XT or PC-AT microcomputers, fitted with a CTX colour monitor, using GEOCAD program. The necessary output data for plotting of the contours and building of the axonometric projection for each instant of observation were obtained on the basis of the square network terrain points.

## CONCLUSION

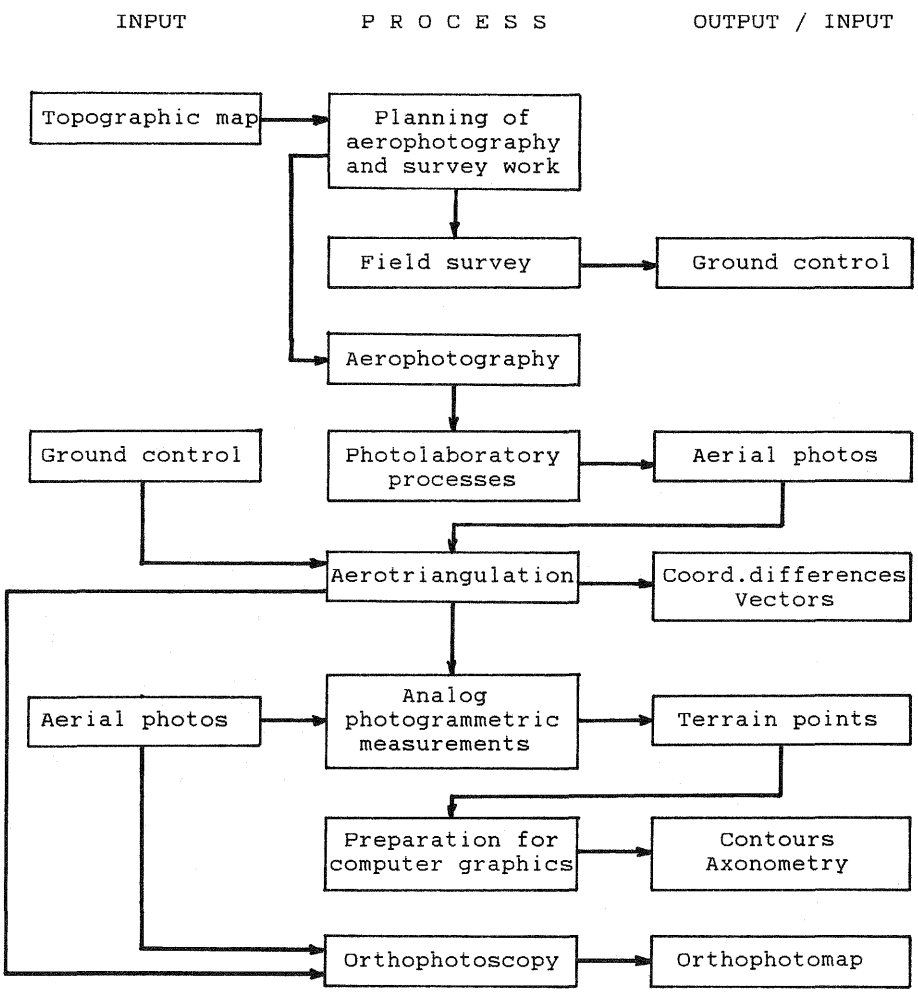
Practical results of the investigations related to Orssoya and Tsibar landslides during the 1986-1990 period indicate that aerial photographs and the photogrammetric measurements made on them as well as the photogrammetric by-products thereof are a plentiful source of numerical, graphical and half-tone data whose authenticity presents a reliable foundation for the study of the dynamics of landslide processes and for planning of landslide preventive projects.


+ References from JOURNALS:
  a) Katzarsky, I., Antonov, D., 1981. A program package for analytical block aerotriangulation (in Bulgarian). Geogezia, Kartografia, Zemeustroistvo, Sofia, 3:28-32.
  b) Katzarsky, I., 1986. Analytical block aerotriangulation (in Russian). Geogezia i Kartografia, Moskva, 3:30-33.
  c) Katzarsky, I., 1986. On the aerial triangulation and the results of an experimented technology (in Bulgarian). Geogezia, Kartografia, Zemeustroistvo, Sofia, 6:13-15.
  d) Katzarsky, I., 1987. Experimentelle Ergebnisse der Aerotriangulation-technologie ABA84X. Vermessungstechnik, Berlin, 5: 163-164.
  e) Katzarsky, I., 1988. Experience in analytical aerotriangulation by bundels (in Russian). Geogezia i Kartografia, Moskva, 10:23-26.
  f) Katzarsky, I., Genov, G.,Postadjian, S., Staykov, I., 1991. Observation of landslides by aerial photogrammetry (in Bulgarian). Geogezia, Kartografia, Zemeustroistvo, Sofia, 5/6:48-50.

+ References from BOOKS:
  Grigorienko, A.G., 1988. Measurements of Landslides Displacements(in Russian) Nedra, Moskva.

+ References from GREY LITERATURE:
  a) Katzarsky, I., 1980. Analytical aerial triangulation in practice. Int. Arch. Photogramm. Remote Sensing. Hamburg-Germany, Vol.XXIII, Part B9, Suppl., pp. 387-391.
  b) Katzarsky, I. et al., 1990. Application of aerophotogrammetric methods for deformation measurements of landslides (Orssoya and Tsibar). Technical Report (in Bulgarian). Geodesy and Photogrammetry Co. for Research and Technology, Sofia, Bulgaria.

GENERAL TECHNOLOGICAL SCHEME

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