The Development of Photogrammetry in Russia

Prof. Dr. Ivan T. Antipov
Siberian State Academy of Geodesy (SSGA)
10, Plakhotnogo Ul., 630108, Novosibirsk, Russian Federation,
e-mail: antipov@online.nsk.su

In Russia some interest in photogrammetry was first revealed at the end of the XIX century. Many enthusiasts (scientists, engineers and inventors) worked in this field. At its earliest stage photogrammetry developed both on the basis of the experience taken from abroad and that of the home original decisions and equipment.

In 1885 Aeronautical crew was formed in Russia under the command of the military engineer A.M. Kovanko. In May 1886 he became the first in Russia to take a photograph from the balloon during a flight over St.-Petersburg. Special camera constructed by V.I. Sreznevsky was used for this purpose. Since 1887 photographic film was used in aerial cameras.

The first phototheodolite mapping was conducted by N.O. Willer in the Caucasus in 1891.

R.Yu. Tile was one of those who made much for popularization of photogrammetry. He got education in Dresden and later worked at the Ministry of Railways in Russia. In 1896 R.Yu. Tile visited some countries of Europe and the USA where he studied the practice of photogrammetric methods. In 1897 R.Yu. Tile took part in phototheodolite surveying (being at the head of it) for projecting the line connecting the railroads of Transbaikalia and Manchuria. The topographic map with the projected railway line was exhibited at the Paris World Fair.

In the years that followed, R.Yu. Tile carried out some more topographic surveys for railroads and large engineering constructions using both phototheodolite and photography from the balloon. In 1899 R.Yu. Tile designed a special photocamera – "panoramograph", incorporating six cameras with declined optical axes around the central camera with a vertical optical axis. This device allowed receiving a complete cycloramic terrain image. The panoramograph was supplied with a special device to let all the camera shutters act simultaneously only when the focal plane-plate of the central camera was horizontal. In 1902 the first strip photography in Russia was performed from the balloon supplied with panoramograph.

In 1908 -1909 the three-volume monograph "Phototopography in Modern Development" by R.Yu. Tile was published. It analyzed terrestrial and aerial photogrammetry and described all the instruments, methods of image processing and the range of photogrammetry application known at that time.

There were also other specialists who made a great contribution to the development of photogrammetry in Russia at the beginning of the XIX century. As, for example, V.F. Naydenov, who was the first to make topographic maps by aerial images. He constructed phototransformer for converting oblique images into vertical ones. In 1908 his book "Measuring Photography and Its Use in Aeronautics" was published.

In Russia, likewise all over the world, a great impact to the development of photogrammetry was made by the advent of aviation. Great attention was paid to the aerial photographic survey and photogrammetry by military departments. A reconnaissance survey was established in the Russian army. In 1913 a military engineer V.F. Potte invented a film camera for strip and block aerial photography. During the World War I all significant military operations at the fronts were supported by aerial photography. Images served both for reconnaissance and as initial data for topographic maps updating, as well as for making new maps for military purposes.

In 1917 two revolutions took place in Russia, which were followed by the Civil war. The events resulted in dethronement of the monarchy replaced by the new social and political system. Instead of the former country the Union of Soviet Socialist Republics (USSR) was formed with Russia as its core. According to one of the first decrees of the new government the Main Geodetic Administration (MGA) with the functions of the geodetic and cartographic survey was established. It was also charged to conduct regular topographic surveys of the country. In the years that followed, the MGA was reformed time and again. Since 1992 it has been called Roscartographia.

The period of 1917-1991 of the photogrammetry development in USSR may be conventionally called a Soviet one. Though the USSR united several republics, the most important processes reflecting the state of the Soviet photogrammetry took place in Russia. In 1991 the USSR disintegrated into 15 independent states, which established their own social and economic regulations. As concerns Russia, it inherited everything connected with the Soviet photogrammetry on its territory. Thus there are total reasons to consider the history of Russian photogrammetry as a single whole with the Soviet period.

As far back as in autumn 1918 the aerial survey for topographic mapping was started. Approximately at the same time the Military Air Forces established the school of aerial survey including special departments for aerial photography, photolaboratory processing and photogrammetry. A short time later photogrammetry was started to be taught in other educational institutions: since 1920 – in Moscow surveying institute, since 1921 – in Military-engineering academy (later Military-engineering university), since 1923 – in Military-topographic school (later Saint-Petersburg branch of the Military-Engineering University). In 1925 the department of photogrammetry was established at Moscow Surveying Institute, with N.M. Alexapolsky at the head. Afterwards it was subdivided into photogrammetry department and that of aerial survey. The specialists like V.S. Tsvet-Kolyadinsky and P.P. Sokolov were invited to teach there. A.S. Skiridov and F.V. Drobyshev started their teaching career just at this department. Running ahead, it should be noted, that in 1930 Moscow surveying institute was divided into two independent higher educational establishments: the Moscow Institute of Engineers for Geodesy, Aerial Photography and Cartography (MIIGAiK) and the Moscow Institute of Land Management (now the State

University of Land Management). The latter included the department of aerial photographic survey. In 1932 the department of photogrammetry was organized at Military-Engineering Academy as well, with N.M. Alexapolsky being the first head of it.

1920 saw an appearance of aerogeodetic enterprises with certain territories assigned to them. The enterprises were charged to carry out all the topographic and surveying works on their territories. Each enterprise incorporated a photogrammetry department. Before long the number of aerial survey enterprises amounted to thirty. Their activities were guided by the unified state standards and plans.

In 1923 a voluntary association Dobrolet was formed, which incorporated the state bureau for aerial survey, headed by M.D. Bontch-Bruyevitch. The department of aerial photography of the bureau was headed by V.S. Tsvet-Kolyadinsky. In addition to the above mentioned, the department of aerial survey was established at Ukrvozduhoput. Later the two subdivisions joined to form the state enterprise Gosaerosyomka (State aerial survey) which became a part of the Main Geodetic Administration.

In 1923-1924 the Soviet government allotted significant funds on both manufacturing domestic instruments and buying the latest equipment abroad to be used in aerial surveys and photogrammetric works. But expensive complicated high-precision streophotogrammetric instruments like stereoplanigraph did not suffice for the Soviet Union with its huge territories. It was clear that to promote topographic mapping, simpler and more efficient methods of photogrammetry were needed.

First of all, the attention of scientists and manufacturers was drawn to the combined method of surveying. In this case, to receive planimetric components of the map, the photomap was made which was later interpreted in the field, and the relief was mapped by means of the plane-table survey. The picture control points to be used for rectification of images and mosaicking originally were determined through geodetic surveys. Beginning with 1929 graphical phototriangulation came into use for this purpose. For image rectification, photorectifiers of Russil (France) and Luftbild (German) were used, moreover the last one was improved by N.M. Alexapolsky and P.P. Sokolov. In addition to the mentioned the rectifiers of the Moscow Institute of Geodesy and those of professor Sokolov were employed. To scale and adjust phototriangulations networks, the production of N.A. Popov magnifiers was started.

A lot of the credit must go to professor N.M. Alexapolsky for the development and introduction of the combined method. In addition to the latter, F.V. Drobyshchev and M.D. Konshin became pioneers in using graphical triangulation in the country on the basis of the research of Finsterwalder (Germany) and G.P. Zhukov.

Efforts were made to replace a graphical triangulation by some more efficient one. In 1929 V.F. Deyneko developed an analytical version of phototriangulation. The plant “Aerogeopribor” produced several copies of F.V. Drobyshev nadir-triangulator. The device was capable of doing the same operations as “Karl Zeiss” radial-triangulator. Still graphical phototriangulation remained the basic method for extension of horizontal control for a long time. Many years had passed before photopoligonometry came into use though the principle was offered by F.V. Drobyshev as early as in 1930.

At the end of the 20s of the last century alongside with topographic mapping, aerial photography and photogrammetry came into use for natural resources exploration. In 1925 a trial aerial forest survey guided by P.M. Orlov and V.M. Platon was conducted in the Tver region. As compared with the field maps of the ground survey traditional at that time, the aerial mosaics provided more detailed information on the forest state. In the same year a special organization was established to deal with aerial surveying for land management. In 1926-1927 V.F Deyneko and N.N. Veselovsky were in charge of the pilot aerial surveying of the cities. The survey of the Volga tract was also conducted in order to study its waterway and rifts. An aerial survey of the large area was conducted for routing Turkestan-Siberian railway. The experience acquired and the techniques, developed for the above mentioned works, provided the basis for the subsequent surveys of the kind.

It is obvious that the combined method of topographic surveying based on the plane-table was inappropriate for surveying mountainous areas. That is why in 1929 -1937 the 1:100,000 scale maps of the large Pamir area were made by means of the ground stereophotogrammetric survey. But the combined method could not provide prompt mapping of the country vast plane territories as well. In 1928 the State Institute of Geodesy and Cartography (now Central Research Institute of Geodesy, Aerial Survey and Cartography, TSNIIGAiK) was established in Moscow and a year later – the research institute of aerial survey in Leningrad (now Saint-Petersburg). Consequently the two institutes were united. The specialists of the two institutes together with the scientists of the Research Institute of Military Topographic Survey had to look for the efficient methods of relief survey by means of aerial photography. This kind of research was conducted at higher educational establishments as well.

Though the universal method of image processing by means of analogue stereo restitution-devices was not in common practice, it was still used. Unfortunately the share of stereo-restitution techniques was negligible to cover the vast territories under survey. The theoretical investigations in this direction, conducted by professor A.S. Skiridov, enriched and summarized the experience of other countries. He offered the method of extension which permitted to process successive stereopairs of the strip. On his initiative the light colour floating mark was installed in the instrument called “stereouniversal”, produced in a small batch in 1931-1935.

Unfortunately there were no instrument-making plants at that time to start mass production of complex photogrammetric instruments to meet the demands of the State topographic survey. On the other hand, the unique samples of foreign analog photogrammetric instruments could not help with the map coverage of the country. That is why the efforts of specialists were to be focused on finding some simpler methods of ground survey.

As concerns topographic surveys of 1:50,000 and 1:100,000 scales with contour interval minimum 10 m, one of the simplified methods was initiated by G.F. Gapochko who offered drawing contour lines by means of a stereoscope. Preliminary on a stereoscopic model it was necessary to define heights of the big number of surveying stakes, placing them on the features of the terrain relief. For definition of elevations it was necessary to conduct photogrammetric extension of control points for the stereopair.

For all plotting scales the problem of photogrammetric contouring was solved by F.V. Drobyshev who offered rather a simple instrument - a topographic stereometer. The production of topographic stereometers was started at "Aerogeopribor" plant in 1933. The instrument comprised a measuring stereoscope with photo carriages and threads as the floating marks. The photoprints were placed into carriages. The instrument had correction mechanisms to control mutual displacement of carriages and threads. With properly adjusted correction mechanism the horizontal parallaxes screw reading remained constant for all the stereoscopic model points of equal heights. The points with the known heights, distributed in a standard scheme, served as initial data for images orientation in a topographic stereometer. Then the necessary parallax screw reading was calculated for each contour and the points of the contour were penciled on the right photograph where the spatial measuring threads crossed the surface of the stereoscopic model.

Originally the topographic stereometer was designed for drawing relief with rather small horizontal parallax differences. But later, as recommended by M.D. Konshin, additional correction mechanisms were introduced that enhanced the application field of the instrument as far as processing images of mountainous regions.

To transfer the contours to the map, the photograph was reduced and the received negative was rectified with a special projector. When necessary, rectification was conducted by zones.

Several suggestions were made on how to determine elevations of the points for proper orientation of stereopairs by a topographic stereometer.

"The method of the direct line", developed by G.V. Romanovsky, is of interest even nowadays. It permitted determination of points elevation in photographs using a measuring stereoscope. F.V. Drobyshev suggested to use parallactic sine bars to realize the method. The idea of the method was based on the statement that the deformations of coordinates and parallaxes are nearly equal for closely spaced picture points. Thus the parallax and coordinate differences of such points may be considered correct to some degree. Choosing the identifiable point, close to the direct line, connecting two initial control points, one can find the height of the chosen point by measuring the parallax difference between this point and the nearest point of the direct line, as well as by interpolating the heights of the initial control points to the nearest point.

G.V. Romanovsky and M.D. Konshin developed the method of "undistorted model" to be used for photogrammetric extension of control points. It was based on the statement according to which in a stereopair coordinate system there is an interdependence between vertical parallaxes and deformations of horizontal ones. Thus, when vertical parallaxes of some stereopair points are measured, it is possible to apply corrections for the horizontal parallaxes and consequently receive undistorted heights of the points. For realisation of this method stereocomparators were required and their manufacture has been adjusted, and Romanovsky's suggestions were used in an instrument design. «The precision stereometer» of F.V. Drobyshev was also used. This device, as a matter of fact, was conceptually identical with a stereocomparator completed with correction mechanisms.

The methods of the direct line and undistorted model were not widely recognized. Preference was given to the techniques developed at the Central Research Institute of Geodesy, Aerial Survey and Cartography. The process of extension of a vertical control was partitioned into a number of operations.

First of all, the elements of images relative orientation were determined by means of stereocomparator measurements. The analytical solution of the relative-orientation problem was found by A.S. Skiridov as far back as 1928. Later G.P. Zhukov derived simple formulae for solving this problem, using for calculation an arithmometer or a slide-rule.

Through the elements of relative orientation angular elements of images exterior orientation were calculated in the conventional coordinate system of the strip. Then corrections for tilt were applied to abscissas of the points. Special measuring transparencies made for the typical focal distances and some preset angle values were used for the purpose. The values of the corrections taken from the transparencies overlaying the picture were specified for the difference between the actual tilt and the preset value. As a result horizontal parallaxes were got and the points' elevations were calculated. Then the stereopairs were united into the free vertical control net, which subsequently was externally oriented with simultaneous elimination deformations. Horizontal positions of the points needed for the external orientation were achieved by graphical phototriangulation.

The techniques used before for receiving planimetric components of maps, one of the variants of vertical control extension, relief drawing by topographic stereometer which was followed by transferring contours onto the map provided the basis for the differential method of aerial phototopography. The theoretical basis for the method was made by M.D. Konshin and G.V. Romanovsky. The method used for more than twenty years was an aid in solving the urgent problem of making topographic map (scale 1:100,000) for the whole territory of the USSR. At the same time the surveys of the vast areas were conducted even for larger scales.

Production of the upgraded equipment for aerial photography, primarily, wide-angle aerial cameras, made a great contribution to mapping. Computation of camera lenses was facilitated by the research of the eminent scientist-optician M.M. Rusinov. Guided by the phenomenon of aberration vignetting (discovered by him in 1938) he worked out the construction diagram for the wide-angle lens with low distortion and improved (compared to the former lenses) illumination distribution all over the frame.

The Karl Zeiss aerial cameras of that time did not suit for the new lenses. That is why they were upgraded at the Central Research Institute of Geodesy, Aerial Survey and Cartography under the supervision of S.P. Shokin and G.G. Gordon. As a result the new wide-angle aerial cameras АФА ТЭ with 180x180mm frame, focal distances 100mm and 70mm (later 55mm and 36mm) were produced. Aerial cameras with focal distances 140, 200, 350, and 500mm were also produced.

The ideas put forward by M.M. Rusinov were supported in other countries as well. In 1972 the French Academy of sciences awarded him with E. Lossed prize.

For АФА ТЭ with focal distances 70, 100 and 200 mm the stabilizing platform Н-55 with gyroscopes was developed. It made possible standing the tilt angle of about 15', with the limiting value of 1^0.

Much attention was paid to the techniques and devices used for the determination of the images exterior orientation elements. K.P. Bychkovsky and Yu.S. Dobrokhotov developed some models of statoscopes. I.L.Gil created radio altimeter PB-10 and A.I. Gruzinov – radiogeodetic system.

The above mentioned and some other works on upgrading the aerial photography equipment guided by G.V. Romanovsky as well as the use of new aircrafts and the transition to the instrumental air-navigation made it possible to improve the quality of aerial photographs and rationalize some processes of horizontal and vertical control extension. All this resulted in the reduction of the field works volume.

Of great importance for that period was the construction diagram for the aerial slit-camera developed by V.I. Semyonov (1936). M.M. Rusinov designed a wide-angle lens for it, with angular field of $126^{0.}$ In this camera the photographs were taken through the narrow slit to the continuously moving film. Conceptually it was the prototype of scanning cameras. Thus, it was the works by V.I. Semyonov that initiated the development of slit photography. In the USA this kind of cameras appeared only six years later.

The role of photogrammetry constantly growing, its fundamentals were introduced and taught as one of the sections of geodesy or as a special discipline in many higher educational establishments of the country (those specializing in civil engineering, transport, agriculture, mining, and polytechnic). The departments of photogrammetry appeared in some of them. Little by little independent scientific schools headed by qualified scientists were formed at these departments. Professors V.Ya. Finkovsky (the Lvov Polytechnic Institute), V.I. Pavlov (Leningrad Mining Institute) and A. Bukholts (Riga Polytechnic Institute) were among them. By the way, in 1947 -1960 A. Bukholts worked in Drezden Higher Technical School (Germany). These departments were engaged both in academic and research work. Many specialists were trained by them.

In 1939 the faculty of geodesy of the Novosibirsk Civil Engineering Institute was reorganized into the Novosibirsk Institute of Engineers for Geodesy, Aerial Photography and Cartography (NIIGAiK), later renamed into the Siberian State Academy of Geodesy (SSGA). It was the second (after the Moscow Institute of

Engineers for Geodesy, Aerial Photography and Cartography) higher educational establishment in the country specializing in geodesy. Little by little the institute arranged its structure, faculties, departments, teaching staff and material base like those in MIIGAiK. The char of photogrammetry was founded in 1943.

There appeared some colleges of specialized secondary education as well, which trained specialists in all the geodetic specialities including photogrammetry. At the production enterprises, as a rule, all the important technological operations were carried out by engineers or technicians.

New photogrammetric equipment and techniques which appeared at the aerogeodetic enterprises of the State geodetic service were adopted at once by the organisations of land and forestry management as well as in other branches. The coordination of researches on aerial photography and photogrammetry application for earth resources exploration was carried out by “Laboratory of Aeromethods”, affiliated into the USSR Academy of Sciences. Significant was the role of scientific conferences (“The All-Union conferences on aerial survey”) regularly (since 1929) held by this laboratory. Collective decisions were taken which determined the line of further development for aerial photography and photogrammetry.

During the Great Patriotic War (1941-1945), which the USSR waged against Germany and its allies and which became the part of the World War II, the most important problem faced by aerial photography and photogrammetry was providing support to the Soviet army with reliable photographs and maps both of the front zones of action and the enemy’s defended localities. The military topographic service of the country was successfull in implementing the task, thus making a great contribution to the victory.

In the after-war period the basic topographic map of the country was chosen that of 1:25000 scale, and for some regions it was 1:10000. At that, the contour interval for the flat areas was 1 meter. The differential method of aerial surveying could not ensure the accuracy required for this type of maps. That made the scientists involved in photogrammetry to draw attention to the analog plotting instruments. universal photogrammetric devices.

The first experience of using such instruments was acquired through the multiplexes whose production had been started in the country by that time. They were used both for stereotriangulation and for compilation of original maps. To promote the practice, a small batch of stereoplanigraphs was produced. They were analogous to Carl Zeiss C-5 instrument, but had some essential fundamental drawbacks which quickly cooled interest to them.

Stereoplanigraphs like all the analog instruments known by then were designed for the reconstruction of projecting rays bundles existing at the time of exposure, i.e. the elements of the internal orientation of the projecting cameras of the plotting instrument and the aerial camera ought to be exactly equal. This requirement made the construction of the instrument too complicated, or limited its application field.

The research on rectification of images with anamorphic affine bundles of projecting beams was started by M.D. Konshin in 1944. For vertical photographs the application of affine bundles results in difference between the vertical and horizontal scales of the restituted geometrical model, which is easily treated. But for tilted photographs, in projecting beams bundles oriented according to the strict rules of rectification, the nadir beams, which were vertical at the time of exposure, deflect from the vertical. Therefore the general geometric model of the terrain cannot be created without taking into account this feature.

One way of solving this problem was given by A.N. Lobanov who suggested decentering every photograph in the projecting camera by the value twice as great as that required for rigorous rectification of the affine bundle. As a result of the double decentration, the nadir projecting beams took vertical position in the instrument and the geometrical model was restituted, if only approximately. As applied to his solution, A,N. Lobanov made a field stereoplaniograph, and M.D. Konshin constructed a stereoscopic drawing device. But these instruments were made as just experimental samples.

The geometrically correct solution for orientation a pair of affine bundles was realized by F.V. Drobyshev in his photocartograph. It was an analogue instrument with optical projection and special guide lines for sliding the carriages with floating marks. In the process of a stereopair orientation in the instrument, the guide lines were set along the oblique nadir rays. Thus it looked as if eigen axis Z was introduced for each projecting bundle.

In process of the above mentioned investigations it became obvious that the optimal device would be that with mechanical projection. Before restituting each projecting ray of the bundle, it was necessary to introduce the corrections into the corresponding image point to eliminate its coordinates distortions due to the image tilts. This principle of projecting beams modeling was realized by G.V. Romanovsky in stereoprojector (SPR). In this plotter the coordinate carriage of each photograph was connected with the corresponding lens of the observation system by means of the mechanical rectifier. This mechanism shifted the observing line on the needed value along the radius-vector, connecting the visualized point of the photograph with the isocenter. Therefore when the photo carriage was moved to the position corresponding to the coordinates of the geometrical model point on the vertical photograph, the point of the real tilted photograph appeared on the observing line of the plotter.

Another way was chosen by F.V. Drobyshev. The idea of his stereograph SD was that of the inclined photograph was as if dissected with an infinite set of horizontal planes. In this case each point of the photograph was considered as the point of the virtual horizontal image with its own focal length. Smooth variation of focal lengths of the instrument projection system was implemented by means of the correcting plates with feelers connected with the cardans of space projecting rods and the photographs coordinate carriages. The correcting plates were to be tilted relative to the two axes in proportion to the tilts of the photographs. As a result the focal distances of each branch of the projection system were continuously varied.

As in both above mentioned instruments (SPR and SD) the bundles of projecting rays were restituted in (as if) vertical photographs, these devices were suitable for any focal distances. The correction units were set in a proper position on these devices by means of images relative orientation and exterior orientation of the restituted terrain model. These processes, like those on the plotters with similar projecting beams bundles, were realized in a standard way, though some special features were taken into account. Thus instead of rotating projecting cameras, the setting of the correction mechanisms on SPR or the tilt of the correcting plates on SD were changed. The difference between the horizontal and vertical scales of the model developed by the instrument was also to be taken into account.

It did not take long for SPR and SD to become basic devices in photogrammetric workshops of the production enterprises. On the basis of these devices the universal method of aerophototopography was developed. It is quite reasonable that in favor of the new method former techniques were abandoned as concerns separate control extension both horizontal and vertical. They were substituted for the spatial phototriangulation by means of analogue instruments. Various aspects of photogrammetric extension of control points were developed and improved by many scientists. Of special note is the role of A.S. Skiridov who put forward the idea of taking into account some additional conditions in geodetic control.

At the same period some other lines of photogrammetry were being developed. Making photomaps of mountainous areas started with the principle of rectification not into the plane surface, but into the reverse model of the terrain. In 1954 the first russian slit orthoprojector was constructed at the suggestion of G.P. Zhukov and G.I. Kolontarov. In 1973 the production of orthoprojectors was started on the basis of Drobyshev stereograph.

The role of the terrestrial stereophotogrammetry reduced significantly, but the method was not abandoned. It was used mostly for all types of engineering surveys with phototheodolite complexes produced in the country. It should be noted, that at one time, as suggested by P.N. Rapasov, the points coordinates determined by phototheodolite surveying of mountainous areas were then used as control points for photogrammetric processing.

The advent of computers profoundly changed most of the photogrammetric restitution processes. The transition to analytical methods started with aerial triangulation based on the works of N.A. Urmayev, who investigated the problem as far back as the pre-war years. In 1941 his book “The elements of photogrammetry” was published, which presented mathematical description of analytical treatment of photogrammetry as concerns photographs orientation and terrain models creation.

The theoretical provisions for the analytical procedures presented in the works of N.A. Urmayev were caught up and developed by A.N. Lobanov. The first program of analytical phototriangulation was worked out under his supervision at the department of photogrammetry of the Military engineering academy in 1956-1957. Soon many other specialists got interested in the subject. A scientific school was formed by A.N. Lobanov, with joint efforts of the scientists being aimed at the investigation of different aspects of analytical phototriangulation. They included strip- and block triangulation with approximate and fine adjustment; additional data to be taken into account; elimination of systematic errors effect; adjustment of triangulation with self-calibration, etc. At the same time the corresponding programs were developed, and analytical air triangulation was efficiently introduced into topographic and geodetic production. Before long it became the main technique for horizontal and vertical control.

Since 1968 the program complexes for analytical treatment of image measurement developed under the supervision of I.T. Antipov were widely recognized by the production enterprises. He put forward some suggestions on general problems as well. His book “Mathematical Aspects of Analytical Aerial Triangulation” published in 2003 summarizes investigations of many years concerning analytical phototriangulation. In 2008 he substantiated simultaneous use of several coordinate systems (in adjustment) for the photographs different from those accepted for the ground points. This allows establishing phototriangulation nets in the form of a ring or a sphere. The technique may be used when photographs of some engineering or laboratory objects were took from all sides. It may be suitable for mapping celestial bodies as well.

Introduction of analytical phototriangulation could not be efficient without proper instrumentation. The problem was solved due to the development and mass production of the automated stereocomparators. At the beginning of 1970s stereocomparator СКА-18 and later СКА-30 were developed. The instruments features were high precision (2–3 microns) and automated image measurement and recording.

In parallel with the above mentioned the traditional technologies were improving, with hardware being upgraded. By the end of 1980s aerial cameras with image-motion compensation had been developed. In 1988 mass production of АФА-ТК-10/18 with focal distance 100 mm was started, and a few years later those with other focal distances. The research on aerial cameras conjugation with GPS-receivers was conducted. That was necessary for definition of position of projection centers.

The success of photogrammetric methods permitted completing the mapping in scale 1:25000 for all territory of the country in 1988.

It should be noted that the surveys were successfully completed mostly due to the good instrumentation of aerogeodetic enterprises, namely Drobyshev photogrammetric instruments. The life of F.V. Drobyshev was full of many interesting events. In the years of the World War I (1914-1916) he served as a military topographer at the Russian-German front. He took part in military operations and was heavy wounded. He was awarded the order for military valour and courage. Since 1926 to 1986 F.V. Drobyshev was connected with MIIGAiK. He developed original devices for all the directions of photogrammetry. His creative activities were marked with many government rewards including the two State prizes (the highest in the USSR).

F.V. Drobyshev was generous at sharing his experience and knowledge with his post-graduate students. Many of them became prominent professors later on. From among his post-graduate students it is possible to name A.N. Lobanov already mentioned above, and L.N. Vasilev who one of the first has concentrated on automation of processes of image understanding and pattern recognition, having applied the theory of fractality and self-similarity in an environment. One of post-graduate students was I.T. Antipov who assisted his teacher in developing stereograph SD. His candidate's degree dissertation was translated into German and the outstanding German specialists came to know about the principles of image processing with the affine bundles of rays and the realization of these principles in Russian analogue photogrammetric instruments.

F.V. Drobyshev was a highly educated and creative person, he liked music and composed chamber music himself. His works were highly appreciated by the professional musicians and he has been accepted the Union of the Soviet composers.

At the end of the XX century rapid development of computer engineering resulted in the new products of aerial photography, i.e. digital terrain models and digital maps. Investigations in this field started at approximately the same time with the transition to analytical phototriangulation. Hardware-software complexes made the technical basis for collecting digital information on the terrain from images. The first of them was Analyt complex, its production testing started in 1977. In 1979 the production use of analytical stereoprojector SPA was started, and in 1984 – that of the automated analytical complex "Oromat". But the above mentioned complexes were operated by rather bulky computers and their quantity was negligible. The situation changed for the better with the advent of PCs. In 1991 serial production of analytical photogrammetric instrument – stereoanagraph was started. It was developed at TSNIIGAiK under the supervision of G.A. Zotov. In 1995 by the licence of "Leika" the production of the analytical plotter SD-20 was started, the latter was a complete analog of SD-2000 instrument.

In 1992 one of the priority directions of Roskartographia national-scale works was digital-maps production. To meet the demand, the main geoinformation centre and some regional ones were established. Alongside with the digitization of the existing map materials, digital maps were derived from aerial photographs, using stereoanagraphs, analytical plotters SD-20 and other equipment.

By that time several creative-minded teams of the country were developing digital photogrammetric workstations (DPW) which opened the way to complete automation of all the photogrammetric processes as concerns collection and processing of digital data on the terrain.

The idea of the station is usually ascribed to the Finnish scientist U. Helava. Giving credit to his contribution, it should be noted that many years before him the idea of automated stereomeasurements was put forward by A.S. Skiridov. As far back as 1927-1933 he received several author's certificates on devices for automatic drawing of contours by comparing the grey level around the identical points of stereopairs. In 1937 A.S. Skiridov wrote that "… we should turn to photoelectric effect and substitute a human eye (with its stereoscopy) for it when drawing the relief …".

The first Russian DPWs were presented at the congress ISPRS held in Vienna in 1996. Later the two types of stations which met the production demands best of all came forth.

One of them, DPW “Delta” was a result of cooperation of the department of photogrammetry of TSNIIGiK and the team of “Geosystem” company, formed in Vinnitsa, Ukraine (now, after dissociation of the USSR, independent state). The general guidance of the research on this station was provided by G.A. Zotov and S.V. Oleynik. Some other specialists were also attracted for the software development. In particular, to solve the problem of analytical phototriangulation adjustment, the technology package of DPW was thoroughly integrated with the complex of analytical image processing, developed by I.T. Antipov. This complex was time-proved, as it was widely used many years at the production enterprises.

Another DPW, entitled “Photomod”, was the product of the Russian company “Rakurs”.

Both stations were widespread not only in Russia and former republics of the USSR, but beyond their boundaries. The stations permit solving the problems of digitization by deriving digital models and digital maps from aerial photographs and the Earth satellite images.

The experimental optomechanical plant of the Central Research Institute of Geodesy, Aerial Survey and Cartography started producing precision photogrammetric scanners PhS-30, designed for converting analogue images into digital ones. The scanner ensured resolution up to 2300 dpi, geometrical accuracy 3 microns, and allowed scanning of images up to 30x30 sm.

The new trend of photogrammetry appeared with the advent of the artificial satellites, space photography images and their practical application.

The first satellite photograph of the Moon was taken from unmanned station “Luna-3” in October 1959. On board the station there were miniature cameras, equipment for film photoprocessing, and the devices for image scanning and transfer. Nearly half of the Moon surface was photographed, with the two-thirds of the images being those of its averted hemisphere.

In 1966-1973 different parts of the Moon were photographed many times both from satellites series “Luna” and “Zond”, which flew round the Moon, and from descent modules on its surface. As a result, three types of images were received: phototelevision-, radar- and usual satellite photographic images taken from “Zond”. After orbiting the Moon the satellites returned to the Earth with the exposed film.

Involved in image processing were the specialists from the Moscow Institute of Engineers of Geodesy, Aerial Survey and Cartography, the Central Research Institute of Geodesy, Aerial Survey and Cartography, the Institute of Astronomy of the USSR Academy of Sciences, and other organizations. Their efforts resulted in the maps of different parts of the Moon, both visible and far side. The scale of the maps derived from satellite images ranged from 1:1M to 1:10M (M – million). The first complete map of the Moon was of 1:5M scale. The complete globe of the Moon was also made. On the basis of the self-propelled robot data, large-scale maps were made for some limited areas.

At the end of 1971 the Soviet spacecrafts “Mars-2” and “Mars-3”, with photo- and television cameras mounted on them, started transmitting images of the Mars surface, including colour ones. In 1974 the satellites “Mars-4” and “Mars-5” continued surveying. From the received images three maps of 1:5M scale and for some areas 10 times as large were derived at TSNIIGAiK. The images of the planet disk edges allowed constructing profiles of its relief.

The experiments of Venus surface mapping were dated for the launching of unmanned interplanetary stations, series “Venus”, in 1974-1983. Because of the opaque clouds, hiding the planet, radar surveying was chosen for the purpose. The bottom line of the works, carried out by TSNIIGAiK and the USSR Academy of sciences, were hypsographical maps, scale 1:5M, and the atlas of the planet surface. The atlas presented the detailed information on the initial surveying materials as well as the processed and interpreted data.

Satellite surveying was promoted by theoretical investigations including the development of geometrical models for radar imagery and their application for photogrammetric treatment. Significant contribution was also made by the methods of camera calibration, coordinate referencing of radar data, refinement of unmanned stations orbital and navigation parameters and the laws of overlapping radar images stereovision. The conducted investigations were summarized in the monograph “Space Photogrammetry” by Yu.S. Tyuflin, and the books by other scientists.

Regular satellite surveying of the Earth (both manned and unmanned) started in 1960s. In 1973 the State research and production centre “Priroda” (Nature) was established to deal with the development of techniques and technologies for aerospace data acquisition, processing, storage, distribution and application.

In order to receive the material to be applied to the problems of nature study, thematic and topographical mapping, several generations of specialized space complexes “Resurs-F” were created. As opposed to a number of foreign satellites their principle of data accessing was that of a traditional photographing. Since 1974 more than 100 short-term satellites have been launched. Each of them conducted the survey according to the set program. The images were delivered to the Earth by the lander. In addition to the above mentioned, space complexes of “Cosmos” series were created and orbited. All the original satellite images were sent to the State center “Priroda”, whose stock of the space information amounted to nearly 2 million images of the Earth’s surface (multispectral, spectrozonal and panchromatic). The images of “Resurs-Ф” series with 5 - 10 m resolution were distributed in more than 80 countries, with the number of their users surpassing one thousand.

For satellite imagery cameras TK-350 and TK-1000 were used. Photographs of these cameras possessed high measuring and deciphering characteristics, with images exhibiting high measurability and identification characteristics. Theye and many other materials and data formed the information base to be realized by complex hardware-software techniques and the technologies for making and updating digital topographic maps up to the scale of 1:10,000 inclusive. These images were also used for complex mapping of natural resources and monitoring of the state and dynamics of various natural and anthropogenic processes.

Great contribution to the development of the State centre “Priroda” was made by Yu.P. Kiyenko and Ye.A. Reshetov.

The environmental monitoring was conducted in accordance with both Russian and international programs. Thus in 1996-1999 the “Priroda” module worked on the manned space station “Mir”. The information was received in Obninsk (Russia) and Neustrelits (Germany) and applied for various investigations and experiments, including studies of soil and atmosphere hydrological conditions (in cooperation with Bulgaria, Italy, the USA and Germany); distribution of minor gas components in the atmosphere (together with the USA and France); ecological problems (with Kazakhstan). Besides contributing to the concrete problems solution, the investigations resulted in the developed techniques for complex space exploration and quasi-synchronous ground-truth observations.

In spite of the fact that in the XX century the USSR and Russia did not launch satellites with high-resolution opto-electronic sensors for remote sensing of the Earth, the State centre “Priroda” became interested in the images taken not only by photocameras but also by digital ones. In the first years of the XXI century Roskartographia started switching from photography to the on-line optoelectronic satellite imagery. It was getting ready for reception and processing of the information from the new high-performance remote sensors of the Earth, types “Resurs-DK” and “Monitor-E”. The first satellites of this type, capable of solving the variety of problems concerning mapping and nature investigation, were launched in 2006. The long-term plans foresee creating the artificial satellites constellation to provide general view of the Earth with preset periodicity, different spatial resolutions in all possible ranges of the electromagnetic spectrum.

Some proprietary organizations became intermediaries in distributing the satellite images of other countries in Russia. For instance, the “Sovzond” company, established in 1992, became an official distributor for the ten world leaders in the field of remote sensing data supply. It is through this company that the customers in Russia and the former republics of the USSR could obtain most of the satellite images, including those with highest resolution.

The “Sovzond” company’s activities were based on the cooperation with higher educational institutions. Thus the innovation centre “SSGA-Sovzond” trained and retrained specialists in digital techniques for aerospace information processing by means of program complexes ENVI and ERDAS.

By 2008 more than the half of Russian territory was covered by high-resolution satellite images from WorldView, QuickBird, Ikonos and OrbView. During this period all the distributing companies reported annual growth of orders for satellite images from other countries. The customers were mostly the organizations dealing with environment and earth resources exploration. The scientific books, collected works of various conferences and scientific works of higher educational establishments, published in Russia, included many articles on the remote sensing of the Earth and these data application for the successful solution of different problems.

The first experiments in aerial photography using laser scanning were started at the end of the XX century. One of the pioneers in this field was Ye.M. Medvedev, a prominent specialist in laser location and some other new techniques of aerial photography and pertinent software. He did his best to make the method of airborne laser scanning popular. He wrote a number of articles and took part in scientific conferences on the subject. In practice laser location began to apply in engineering prospecting, which demanded digital models of extended precision.

In the XXI century the scientific information exchange was promoted by the annual International congresses “Geo-Siberia” initiated by SSGA. The subjects of the congresses embraced all the Earth sciences, including photogrammetry as a technique for the earth surface state documentation. These congresses, as the name implies, primarily covered only some part of Russia, i.e. its territory from the Urals to lake Baikal. Nevertheless at these congresses took part a lot of the most famous professionals of ISPRS, the most prominent scientists from the largest universities of Europe and Asia, and the representatives of the leading world and Russian companies dealing with photogrammetry, development of software or equipment. The chair of photogrammetry of SSGA, headed by A.P. Guk since 1991, presented its new research results at each congress. The influence and the authority of the chair significantly gained owing to the fact that outstanding scientists of the Siberian division of Russian academy of sciences, including L.K. Zyatkova, V.P. Pyatkin, Yu.I. Kuznetsov, many years delivered lectures at the chair, actually being its members.

By means of the congresses partner relations started to develop between MIIGAiK, SSGA a number of universities of Europe, Asia and America. The general approaches were outlined for perfection of higher education in the field of all sciences about the Earth, and first of all - geodesies, photogrammetry and cartography. To a number of large scientists from foreign universities ranks of honourable professors СГГА are appropriated. Among those who received this rank there was G. Konecny – an outstanding figure of the international photogrammetric community. He and F. Akkerman became also honourable professors of MIIGAiK.

Until 1966 Soviet specialists in photogrammetry took part in social and scientific events of the country within the framework of the All-union astronomical and geodetic society. Then the National Committee of Photogrammetrists of the USSR was established, which assumed coordinating functions as a public organization. In 1968 the National Committee joined the International Society of Photogrammetry as an ordinary member.

In 1976 at the XII congress of the International Society of Photogrammetry (ISP), which was held in the capital of Finland, the National Committee of Photogrammetrists of the USSR was entrusted to head the technical commission III “Mathematical Analysis of Data”. I.T.Antipov was elected its president. The international symposium of this commission was held in Moscow in 1978. In 1980 at the XIII congress in Hamburg the IPS was renamed into the International Society of Photogrammetry and Remote Sensing (ISPRS). I.T. Antipov was elected the second vice-president of the society. On the instructions of that time council of the society, I.T. Antipov elaborated the projects of new Status and By-Laws. The documents were adopted by the society at the regular congress in Rio de Janeiro. The preliminary independent expertise stated that the presented projects surpassed the analogous documents of other organizations, cooperating with

ISPRS. Since 2004 I.T. Antipov has become a member of “The White Elephants Club” of ISPRS.

In 1996 one more public organization was established in Russia, i.e. “Society for Contributing Development of Photogrammetry and Remote Sensing”. Yu.S. Tyuflin was elected its first president. This society also joined ISPRS (as an associate member) at the congress held in Vienna in the same year. At that congress Yu.S. Tyflin was awarded the Brock gold medal for his contribution to the solution of the theoretical problem of mapping the Solar System celestial bodies.

One more ISPRS award was given to the representative of Russia at the congress in Ankara in 2004. It was V.P. Savinykh, a graduate from MIIGAiK, who later became a space-pilot and took part in three space flights. On finishing his space career he was a rector of the institute, he graduated from, for about 19 years. He made a great contribution to training engineers for all the specialities including photogrammetry. Under his rectorship the institute got the status of the university. In 2007 V.P. Savinykh became the president of this university. As an eminent personality V.P. Savinykh was granted the Samuel Gamble Award.

On the whole the state of photogrammetry in Russia was in agreement with the development level of that in the leading countries of Europe and America. The research works of the Russian scientists were corresponding to the world standards, and in some directions even above them. Some original devices, technologies and techniques were developed which allowed to solve production goals effectively. The annual number of graduates from higher educational establishments and technical colleges met the demands of the country in full. As concerns application of photogrammetric techniques in Russia in the XX century, the scope and scales of solved problems was unprecedented.

The dissolution of the USSR had a negative effect on all the branches of the economy and living conditions of many citizens of the country. The amount of the annual state orders for topographic and geodetic works, including map updating, decreased. Financing of scientific research was cut down. The posts of teachers of higher educational establishments and research workers were no longer prestigious. As a result, the influx of young specialists into the field of science decreased, with the scientific personnel of many institutions ageing. The situation like this resulted in a lower rate of photogrammetry development in the country. But in history of Russia there were difficult periods, however the country always left them got stronger. The people of Russia keep being sure, that in the XXI century the country is going to flourish.

References

1. Yu.S. Tyuflin. Development of Domestic Photogrammetry. Journal “Geodesy and cartography”, 1994, #3.

2. B.V. Krasnopevtsev. Main events in the history of photogrammetry, aerial- and satellite survey in our country after 1917. Journal “Geodesy and cartography”, 2000, ##5,6,7.

3. R.M. Khrushch The stages of Russian photogrammetry formation and development. Journal “Geodesy and cartography”, 2003, #7.

4. Geodesy, cartography, geoinformatics, cadastre: Encyclopedia. Two volumes. M.:Geodezizdat, 2008.