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RADUGA EXPERIMENT: MULTIZONAL PHOTOGRAPHING THE EARTH FROM THE SOYUZ-22 SPACECRAFT

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16. Abstract. The report consists of two parts. The first part (authors are representatives of the USSR) states the main results of the scientific research work and the flight experiments at the basis of the "Raduga" experiment. It gives the theoretical foundations for selecting the parameters of the MKF-6 equipment. The main tasks of the experiment are presented, technical, method and practical; data on its fulfillment are reported. In the second part (authors are representatives of the GDR), technical parameters are presented for the MKF-6 camera and the MSP-4 projector. The main characteristics of the obtained materials and certain results of their processing are reported.

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"RADUGA" EXPERIMENT: MULTIZONAL PHOTOGRAPHING OF THE EARTH FROM THE SOYUZ-22 SPACECRAFT

Part 1. Substantiation and Optimization of Parameters for Multizonal Space Camera MKF-6 /3*

by Ya. Ziman, Yu. Chesnokov, B. Dunayev, V. Aksenov, and V. Bykovskiy

In September 1976, during the experiment that received the name "Raduga," the cosmonauts Valeriy Bykovskiy and Vladimir Aksenov on the Soyuz-22 spacecraft conducted experiments of the first model of the multizonal camera MKF-6 designed to photograph the earth's surface simultaneously in six zones of the electromagnetic spectrum in order to solve different scientific and applied problems of studying the earth's natural resources.

The MKF-6 apparatus was developed jointly with the specialists of the Soviet Union and the German Democratic Republic; it was manufactured in the GDR at the national enterprise "Carl Zeiss Jena." The MKF-6 flight tests on Soyuz-22 completed a broad complex of work that included aircraft and satellite experiments conducted by the Institute of Space Research of the USSR Academy of Sciences jointly with a number of other organizations.

The chief purpose of this work was to optimize the parameters of multizonal photographic systems, and on this basis, develop the resources and methods of photographing the earth's surface from space vehicles in order to solve the largest possible number of the most diverse problems of earth science and economic branches. The mentioned works first of all included a study of the spectral brightnesses of terrestrial objects. An investigation was made of the dependence of spectral brightnesses on the condition of the objects and on external factors (direction of the incident and reflected rays, transparency of the atmosphere, etc.).

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*Numbers in margin indicate pagination in original foreign text.

Here we started from the fact that such classes of terrestrial objects as
dry land, water, forests, meadows, pasturelands, population points, roads and com- /4
ponents of the relief are easily recognized and distinguished from each other
on standard, black-white, space photographs based on those identification signs
that are reflected in the spatial structure recorded on the photograph of the
brightness field of solar radiation reflected by the earth's surface and observed
from space. Therefore, first of all, an analysis was made of the possibility of
distinguishing such objects from their spectral sign that are not identified on
standard black-white photographs. The spectral brightnesses were studied both
by ground-based and aircraft methods.

The aircraft used spectrometers, multizonal scanning optic-electron systems,
and a set of synchronously operating aerial cameras equipped with different
light filters and film; here the number and characteristics of the spectral zones
in which the photographing was done simultaneously varied in broad limits.

The photographing from the aircraft was accompanied by ground inspection.
This inspection generally included a thematic analysis of the objects to be
photographed; this was done directly at the locality by the appropriate specialists;
It also included a set of atmospheric and soil observations made on the photographed
sections that were carried out according to an expanded program of hydrometeoro-
logical support for agricultural work and land reclamation measures. In individual
cases, the thematic and agrometeorological observations were accompanied by ground
spectrometering of the test sections to be photographed from the aircraft.

Such aircraft and ground-based inspections were made on specially isolated
test sites located in different regions that represent fairly completely the /5
entire diversity of the natural zones in our country, on sections that meet the
requirements of formulating space methods to study the earth in the interests of
solving the most diverse, but specific, scientific and practical problems.

The most important link in the research of space multizonal photography, on
whose basis requirements were worked out for the MKF-6 characteristics, was
experiments on Soviet spacecraft and orbital stations that preceded the Soyuz-22
flight. These experiments photographed the earth's surface in different spectral
zones with photographic equipment with different focal distances and angles of

the visual field on different films, which in particular, made it possible to make a comparative analysis of the photographs that differed from each other in the amount of the coverage and spatial resolution on the locality. The photographing from space was accompanied by synchronous aircraft photographing and ground inspection of the reference sections. From the materials of such experiments, an evaluation was made of the information content of the space photographs depending on the parameters of the photo equipment; branch specialists analyzed the possibility of solving certain specific tasks.

As a result of all the studies indicated above, requirements were formulated for the characteristics of the photographic system designed for multizonal photography from space.

In particular, the expediency was shown of conducting photography simultaneously in six spectral zones 40-60 nm wide with effective wavelengths 460, 540, 600, 660, 720 and 820 nm.

Figure 1 shows the relative spectral sensitivities that were realized in six channels of the MKF-6. They represent the product of the relative spectral sensitivity of the film and the relative spectral transmission of the light filters, /6
lenses and illuminator.

The angle of the image field was selected as roughly equal to 40°. Here, on the one hand, the covering of a fairly large section of the locality by each photograph is guaranteed, and on the other hand, the changes in the spectral brightnesses linked to the increase in the angle between the vertical and the direction of the photography are still not very great.

In selecting the focal distance and the relative aperture of the lenses, exposure (delay) time, and the light sensitivity of the film the criterion for the quality of the photographic system was its contrast sensitivity, that is the inverse amount of the threshold contrast.

It is assumed that the object of the photographing is a bright-line periodic lattice with sinusoidal distribution of brightness in the direction of the perpendicular strokes of the lattice. The contrast of such a lens is the ratio of the amplitude of change in brightness to the average brightness. The limit

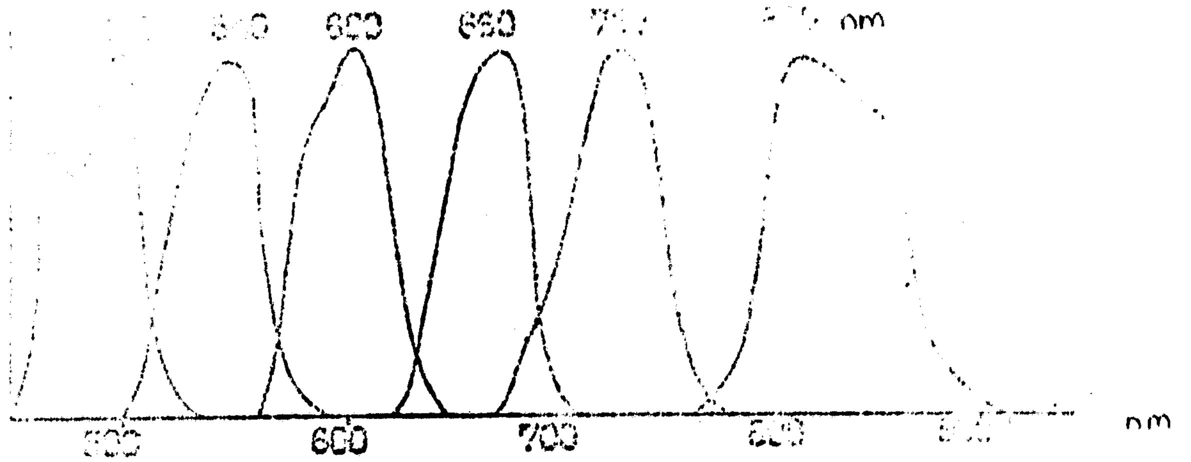

Figure 1. Zones of Spectral Sensitivity of Six Channels of MKF-6

minimum contrast of the lattice in which its strokes are still distinguished on the photograph is the threshold contrast of the photographic system.

Based on the studies mentioned above on the determination of the information content of space photographs it was established that the solution to the majority of scientific and applied tasks advanced by the branch specialists who use space information is guaranteed in that case where the contrast of the photosystem equals 0.1 for the periodic spatial structure with half-period 30 m.

The threshold contrast of the photographic system is determined by its parameters and the photographic conditions. First of all, the threshold contrast is associated with the contrast-frequency characteristics of the lens, which depends on its focal distance, relative aperature, angle of the image field, and /7

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on the wavelength and width of the spectral zone. The contrast sensitivity of the photographic system affects the residual blurring of the image. Since the photography is done from a spacecraft that is moving at high speed in relation to the earth's surface, then during the time that the camera shutter is open, the optic image that is created by the lens is shifted in relation to the film. In the MKF-6 there is a mechanism to compensate for this shift of the optic image. However, due to the limited accuracy of the operation of this mechanism and the orientation and stabilization of the spacecraft, a so-called residual blurring of the photographic image occurs that impairs the contrast sensitivity of the photographic system. With other conditions equal, the amount of the residual blurring of the image is proportional to the time of shutter opening (delay). The delay is inversely proportional to the light-sensitivity of the film, while the latter is linked in a definite manner to the amount of relative lens aperture, and the width of the spectral zone--to the spectral coefficient of brightness of the photographic object and the altitude of the sun at the moment of photographing.

With an increase in the light sensitivity of the film its natural threshold contrast rises; in addition to the already listed factors this determines the general contrast sensitivity of the photographic system.

If spectral zones and the angle of the image field are selected, the accuracy of compensation for the image shift, threshold contrast, and the size of the object on the locality corresponding to it, and the flight altitude and other conditions of photographing are defined, then the necessary size of the focal distance of the lens in the photographic system ,f-stop, can be presented as the function of the denominator of the relative aperture of this lens, F and the delay t (figure 2). /8

The points of the surface depicted in fig. 2, correspond to different photographic systems that produce photographs of the same quality, i.e., with the same amount of threshold contrast for objects of the locality that are of the same size. The system with minimum focal distance of the lens should be considered the optimal.

With the assigned angle of the image field the frame format will also be the minimum. Such a photographic system, with other conditions equal, will have the minimum overall dimensions, weight, power consumption and maximum supply of film in relation to the number of frames. Everything with this corresponds to the

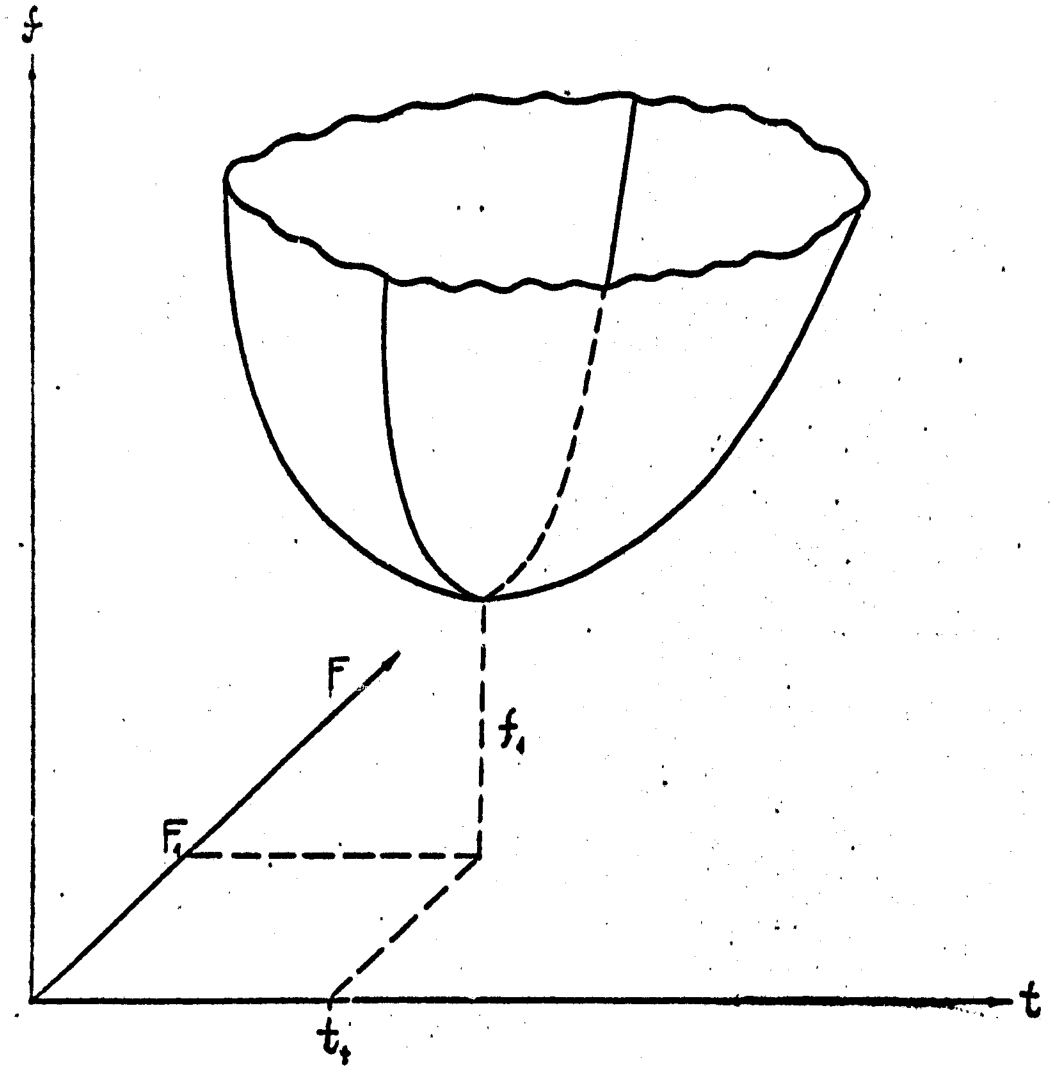

Figure 2. Relationship between Characteristics of Photographic System
f--focal distance of lens
F--denominator of relative aperture
t--delay
f_1, F_1, t_1--optimal values

minimum net cost of photographs and the greatest economic effectiveness of the space photographing.

The minimum focal distance of the photosystem lens is corresponded to by certain values of the denominator of relative aperture and the amount of delay, which should be considered the optimal, and which unambiguously determine the

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selection of film. With delays greater than the optimal the residual coating of the image is increased. The use of delays shorter than the optimal forces one to use highly sensitive large-grained film. In both cases the contrast sensitivity of the system in relation to the locality is impaired, which can be compensated for by increasing the focal distance of the lens.

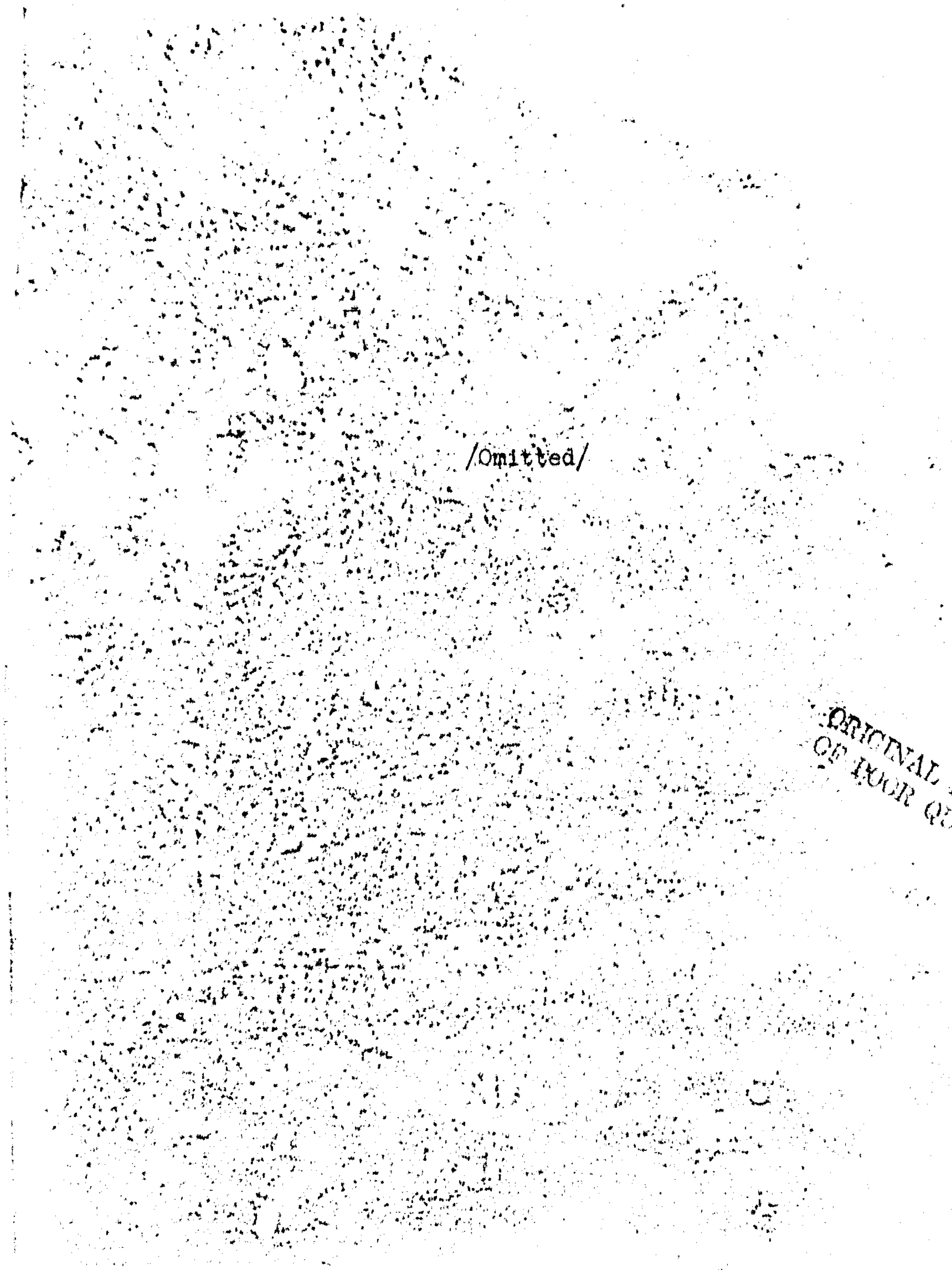
With an increase in the denominator of relative aperture, the effect of light diffraction is increased in the lens, impairing its contrast-frequency characteristics; in addition, the intensity of illumination of the film is reduced, which requires an increase in its light sensitivity. A reduction in the F amount, on the one hand, makes it possible to use low-sensitive fine-grained film, and on the other hand, results in a decrease in the quality of the photo- /9
graphs due to the rise in lens aberrations.

Thus, there exists an optimal (in the sense indicated above) combination of characteristics of the lens, film and amount of delay. The given technique was used to select the MKF-6 parameters.

Analysis of the obtained photographs demonstrated that their characteristics correspond to the calculated.

The enterprise "Carl Zeiss Jena" developed at the same time as the MKF-6, the MSP-4 instrument that is designed to synthesize color images from black and white zonal photographs. An example of such a color image is shown in figure 3; the photograph covers part of Lake Baykal and adjacent regions.

Such photographs are now successfully used to work out different scientific and applied problems of using the earth's resources.



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/Fig. 3 - not reproducible/

Figure 3. Color Image of the Lake Baykal Region, Synthesized from Black and White Zonal Photographs on the MSP-4 Instrument. (Journal Ogonek, No.3, 1977).

Part II. Realization and Technical Parameters of MKF-6 Camera and MSP-4 Projector

By Dr. R. Ioakhim, Institute of Electronics, GDR Academy of Sciences, Professors K. Myuller, V. Choppe and D. Vol'ter, National enterprise "Carl Zeiss Jenz," GDR

In the framework of the "Intercosmos" program, the national enterprise "Carl Zeiss Jena" developed the space multichannel camera MKF-6 and the multichannel projector MSP-4.

Both instruments were developed in close cooperation with the Institute of Space Research of the USSR Academy of Sciences. Based on the vast basic theoretical and experimental work done by the Institute of Space Research in the area of multizonal photography, and taking into consideration the experience and know-how in the area of optical precision instrument making of the national enterprise "Carl Zeiss Jena," the necessary scientific research program was worked out at the stage of problem definition. The purpose of the given development was to create a camera that would have the optimal geometric and spectral-resolution capacity, and a projector that would synthesize the color images for visual processing of high-quality photographs obtained with the help of the camera.

1. Six-channel Camera MKF-6

1.1. Technical Concept of MKF-6

The quality of the camera's operation is significantly determined by the parameters of its lenses. For the given MKF-6 camera a lens type was developed that can be called the optimal in the area of multizonal photography. Thus, in the manufacture of the lens the following parameters were optimized:

--The correspondence with the given spectral zone in order to attain a high /11
geometric resolution. The frequency-contrast characteristic curve depicted in fig. 4 for the PINATAR 4/125 (1) lens demonstrates that the course of the curve almost meets the theoretical (2).

--Establishment of camera constants. All six lenses of the MKF-6 camera are adjusted to the same constants; here the error does not exceed 5 μm. As a result of this, each of the six multizonal photographs of one set has the same

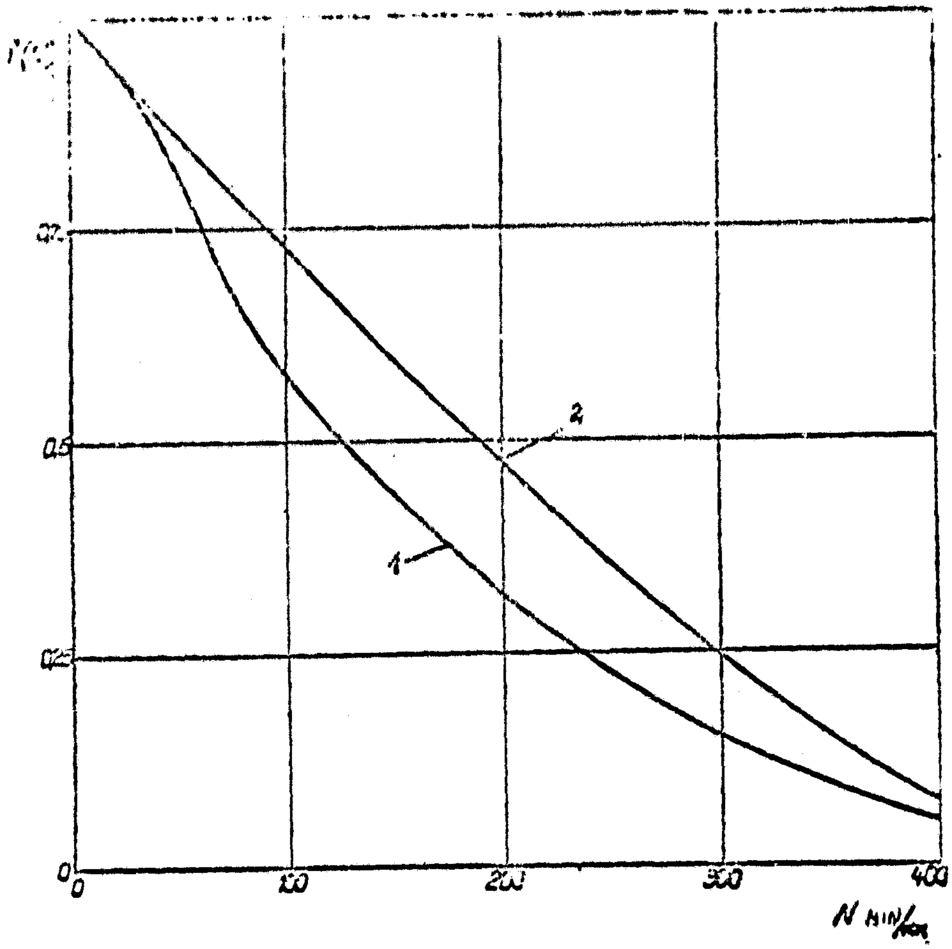

Figure 4. Frequency-Contrast Characteristic Curve of PINATAR 4/125 Lens

image scale, which significantly facilitates the orientation of photographs in the MSP-4 projector, or other instruments for processing.

--Accurate adjustment of the outside glasses with the markers that serve to apply nine coordinate marks on each separate photograph, in relation to the optic axis of the lens. According to this system of marks, each lens in the MKF-6 is adjusted, the camera is oriented on the spacecraft, and finally, several photographs are combined into one image on the MSP-4 projector or on other instruments for processing.

The high quality of the lenses and the high quality of the employed Soviet aerial photographic film required compensation for the effect of image blurring as a consequence of the spacecraft's movement in relation to the earth's surface during film exposure. Taking into consideration the good stabilization of the spacecraft, only compensation for the image shift in the flight direction by turning the entire camera around one axis was selected as the optimal variant. Inaccuracy of the movement by the compensation system at the maximum of 0.8 mrad/s = 2.7 min. of arc/s was permitted.

The characteristics of the light filters (fig. 5) have a significant effect /12
on the spectrozonal resolution. For the MKF-6 camera light filters were especially developed that, based on a combination of dielectrical marginal interference filters and colored glasses have very good characteristic slope of the front and high transmission.

The shutters of the high quality multichannel camera meet the following requirements:

--great accuracy of the delay with a small spread on each channel. Such requirements follow from the desirable high accuracy of the subsequent photometric processing of the developed photographs.

--High efficiency and great synchronism of triggering the shutters on all the channels to attain high geometric resolution.

In order to realize these requirements, a disk two-stage shutter was developed for the MKF-6 camera, that was installed in the interlens space of the aperture diaphragm.

High accuracy of delay is attained by accurate regulation of the number of revolutions of the shutter electric drive. All six shutters of the MKF-6 camera are connected mechanically, as a result of which all the requirements of synchronism and simultaneous action of the delay on all camera channels are fulfilled.

In addition to the visual methods of processing photographs, the objective photometric methods of processing with the help of a computer are acquiring more and more importance. In particular, photometric processing of photographs requires accurate radiometric calibration of the multichannel camera. The given problem was solved by accurate printing of the sensitometric key on each photograph. The key was printed on each channel with the help of a calibrated lamp. /13
For accurate establishment of the lamp brightness the key printing occurs only approximately in 2 s after the lamp is turned on. The printing delay time is

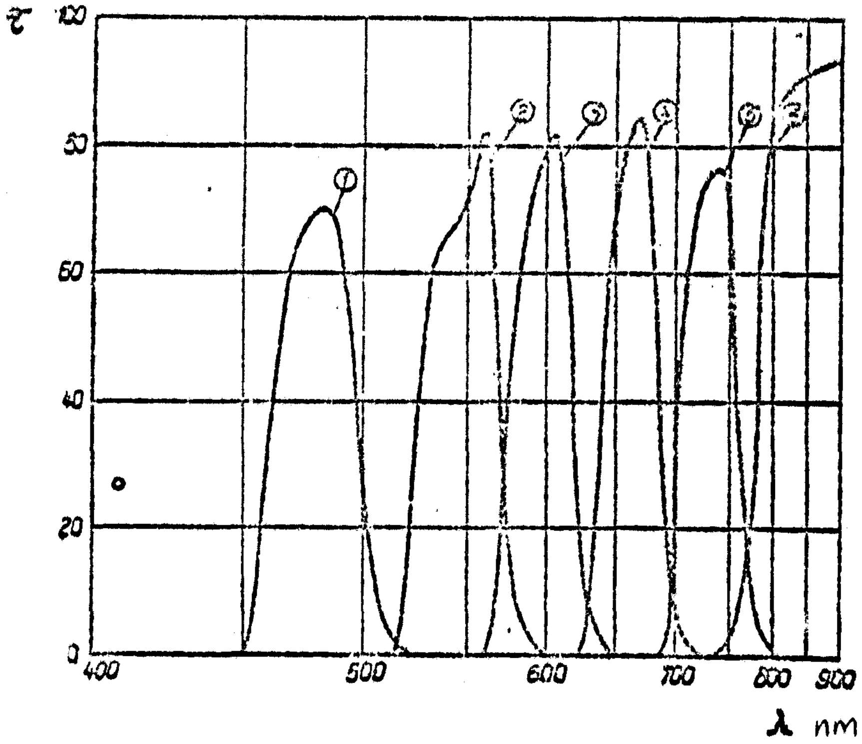

Figure 5. Transmission Curves of Light Filters

700 ms for each channel; it is reached by a special shutter that is controlled by an electronic system and is triggered from an electromagnet. Taking into consideration all the causes of error, an orientation was made on absolute accuracy of radiometric calibration of the spectrozonal brightness no worse than 15%; here the relative distribution of brightness according to the spectral zones between the channels was less than 3%.

To facilitate the processing of the obtained photographs the following information was additionally printed on the film: number of frame, number of channel, hours, delay, as well as information from the writing pad.

1.2. Description of the MKF-6 Camera

The MKF-6 camera consists of the following assemblies: camera, six film holders, block of electronics and control panel (fig. 6).

In order to compensate for the shift in the image the camera is installed such that it can make turns around one axis on a frame attached to the spacecraft.

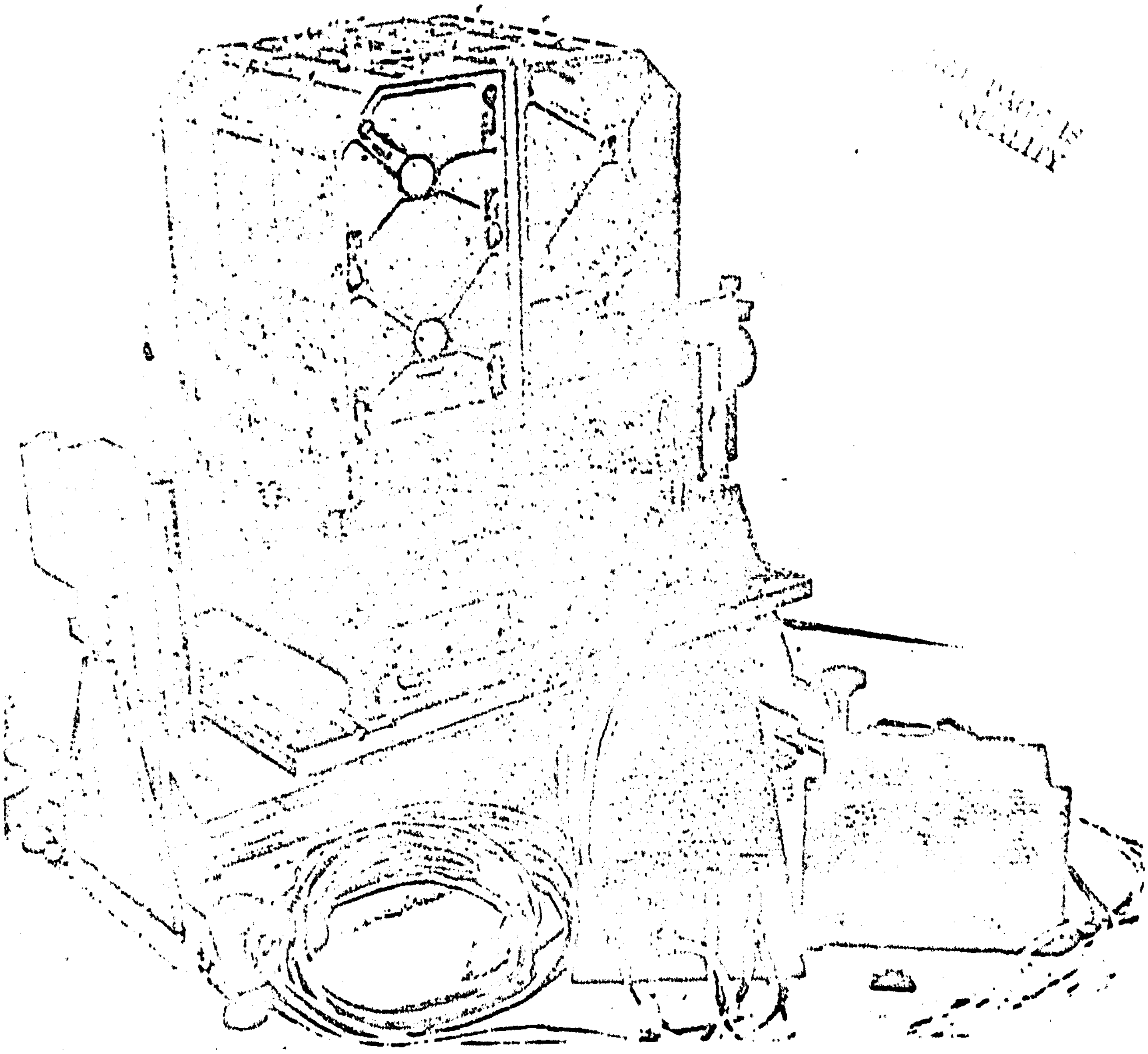

Figure 6. MKF-6. Camera with Film Holders on Installation Stand.
Block of Electronics. БЭ
Control Panel. ПУ

Between the frame and the camera, as well as between the frame and the installation platform of the spacecraft a packing is provided for dust-protection of the space between the lenses and the illuminator. This space is conditioned in order to prevent condensation on the illuminator.

At the stage where the spacecraft is put into orbit the film holders are located in a special container, and in orbit the cosmonauts easily installed them on the camera. Such an approach has recommended itself because it considers the requirements for preserving the highly accurate adjustment of the camera in order to exclude the effect of a high mechanical overload of the installed film holders /14
during the time that the spacecraft is put into orbit. The camera is controlled and the telemetric signals are generated to control the camera's operation in the ground-based station with the help of electronic assemblies: control panel and block of electronics.

The following parameters of photography are established on the control panel: rate of compensation, delay and degree of frame coverage during route photography. Control over the operation of the following assemblies is further provided: mechanism of shift compensation, shutters, and mechanism of film rewinding. On the two frame counters one can count the total number of all exposed frames and the number of frames in one series of photographing.

The following parameters are controlled on the line for transmission of telemetric information on earth: established delay, actual delay, triggering of system of shift compensation and shutters, as well as film rewinding, moment of shutter opening (average point of delay), as well as the temperature at certain important instrument sites.

The values of the lens diaphragm are established directly on the camera. In addition, the camera has signal devices to control operation of the printing assemblies of the sensitometric key and the counter for film supply control.

The MKF-6 camera set also includes control and measuring apparatus that makes it possible to verify all the functions of the electronic circuits with the minimum time outlay (fig. 7).

1.3. Specifications of MKF-6

Optic System:

Number of lenses	6
Type	PINATAR 4/125
f	(125±0.5) mm
Difference between camera for 6 lenses of one camera	±0.005 mm

Relative aperture	4-13.5
Angle of image free from vignetting	38°
Frame format	(56 x 80) mm^2
Radial distortion: (on 4 channels of visible spectral region)	±0.003 mm
Resolution: (with relative aperture 4 on 4 channels of visible spectral region, with the use of T-18 type film)	160 pairs of lines/mm
Parallelism of optic axes of all six lenses	$\pm 10^{n}$
Light filters:	
Range of main wavelengths	480-840 nm
Half-width of transmission band	40-100 nm
Transmission	~70%
Shutters:	
Type: rotary-disk central shutter with two reciprocal motion sector diaphragms	
Delay	5-56 ms /16
Tolerance	3%
Reproducibility	1%
Relative change in delays between 6 channels with one photographic cycle	less than 1%
Synchronism	less than 2 ms
Efficiency	more than 75%
Compensation for image shift:	
Range of compensation rate	(16.8-39.8) mrad/s
Maximum error	0.8 mrad/s
Counting of intervals:	
degree of coverage	20-80% in 10 steps
Tolerance	±3%
Printing of sensitometric key:	
Delay time of printing	700 ms
Number of key steps	10
Light filter	same type of filter as on corresponding channel
Tolerances of radiometric calibration	no worse than 15% according to absolute spectral brightness

	no worse than 3% for relative brightness distribution between channels
Film supply:	6 x 120 m (film thickness 0.18 mm) 6 x 240 m (film thickness 0.09 mm)
Power supply	/17
Voltage	23-34 V
Consumed power	approximately 100 w
Overall dimensions	
Camera	775 x 645 x 620 mm
Block of electronics	550 x 275 x 190 mm
Control panel	310 x 220 x 150 mm
Weight of camera	170 kg, in complete set

2. Multichannel Projector MSP-4. Instrument for Synthesis of Color Images to Process Spectrozonal Photographs /18

2.1. Purpose

The multichannel projector MSP-4 is a visual instrument to process aerospace synthesized black and white photographs of the earth's surface. It is a result of the close bilateral cooperation between the Institute of Space Research of the USSR Academy of Sciences and the national enterprise "Carl Zeiss Jena." It was made especially for interpreting black and white spectrozonal photographs of the six-channel MKF-6 camera. However, with its help one can also process photographs from other multichannel cameras with format no more than 70 x 91 mm ^{2}. In addition to the processing of spectrozonal photographs the MSP-4 can also be employed to interpret other multizonal photographs. The possibility of its use far surpasses the purpose of remote sensing of the earth. Its site is precisely where visual processing of several multizonal or similar photographs is required; in addition, the projector can be used to obtain color photographs from black and white.

Simple analog processing of the multizonal photographs of the MKF-6 camera is possible without resorting to complex automatic scanning instruments and computer technology. It serves to retranslate the relative difference in the optic density on the photographs into color difference. A color image is synthesized for this purpose from black and white photographs with the help of individual

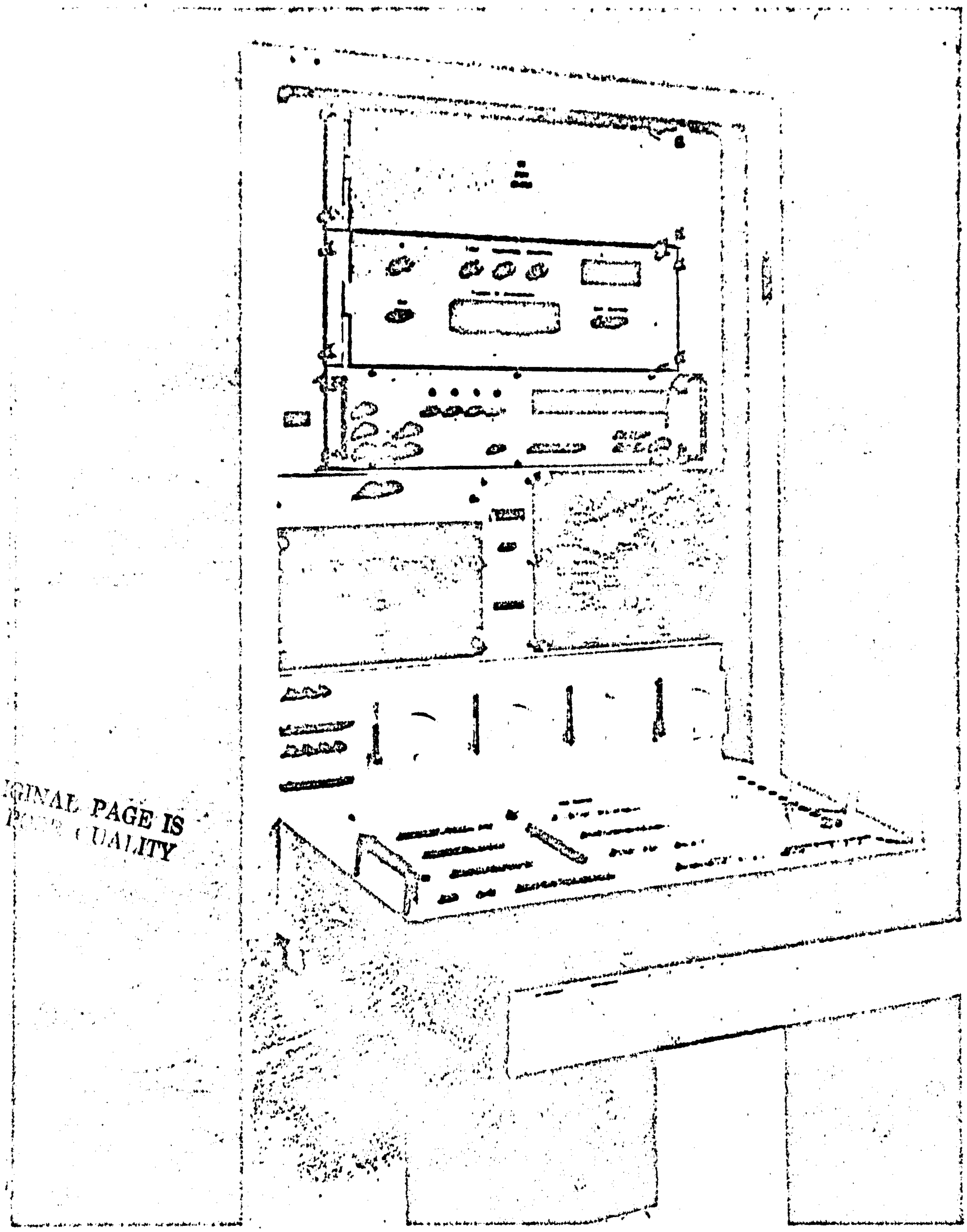

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Figure 7. Control and Measuring Apparatus of MKF-6

projectors. Each projector can be equipped with different light filters. Here the colors are formed according to the law of additive mixing of colors. A large volume of multizonal information of black and white photographs is graphically presented to the processor as a color image. Such combination of photographs into one image significantly increases the processing efficiency.

2.2. Main Requirements /19

The method of obtaining black and white photographs and their subsequent synthesis into a color image, on which the multizonal equipment is based with the help of the MKF-6 and MSP-4 apparatus, places high requirements for the instrument making technique. In the development of the MSP-4 projector the task was set of combining up to four black and white photographs of the MKF-6 in an additive manner into one color synthesized image with the minimum outlay of time for adjustment, with high geometric resolution, and with the least errors in combination, in order to transform small, relative differences in the optic density on the photographs into large color differences of the synthesized image. Realization of these requirements is a prerequisite so that with the help of the MKF-6 and MSP-4 instrument complex one could solve the problem of long-range sensing of the earth. Its requirement surpasses the potentialities of standard black and white and color photography, as well as photography in false colors. The instrument design had to guarantee the possible operational combination of four photographs depending on the subject matter of the processing in the given field of interpretation, so that the processor from a set of black and white and color images or images in false colors could select the optimal variant for the assigned goal of the interpretation. In addition to the direct visual processing, a system was made on the instrument for photographing a synthesized color image in order to supply a large number of processors.

2.3. Description of Instrument

The multichannel MSP-4 projector consists of the projector itself and cabinet of power supply (fig. 8). The projector has four independent optic channels which provide unlimited combination of the individual photographs.

Each channel includes the following (fig. 9): /20

--Illumination device (1)-(4) with halogen lamp 24 v, 250 w (2), with whose help one can accurately establish the light stream in a ratio of 25:1.

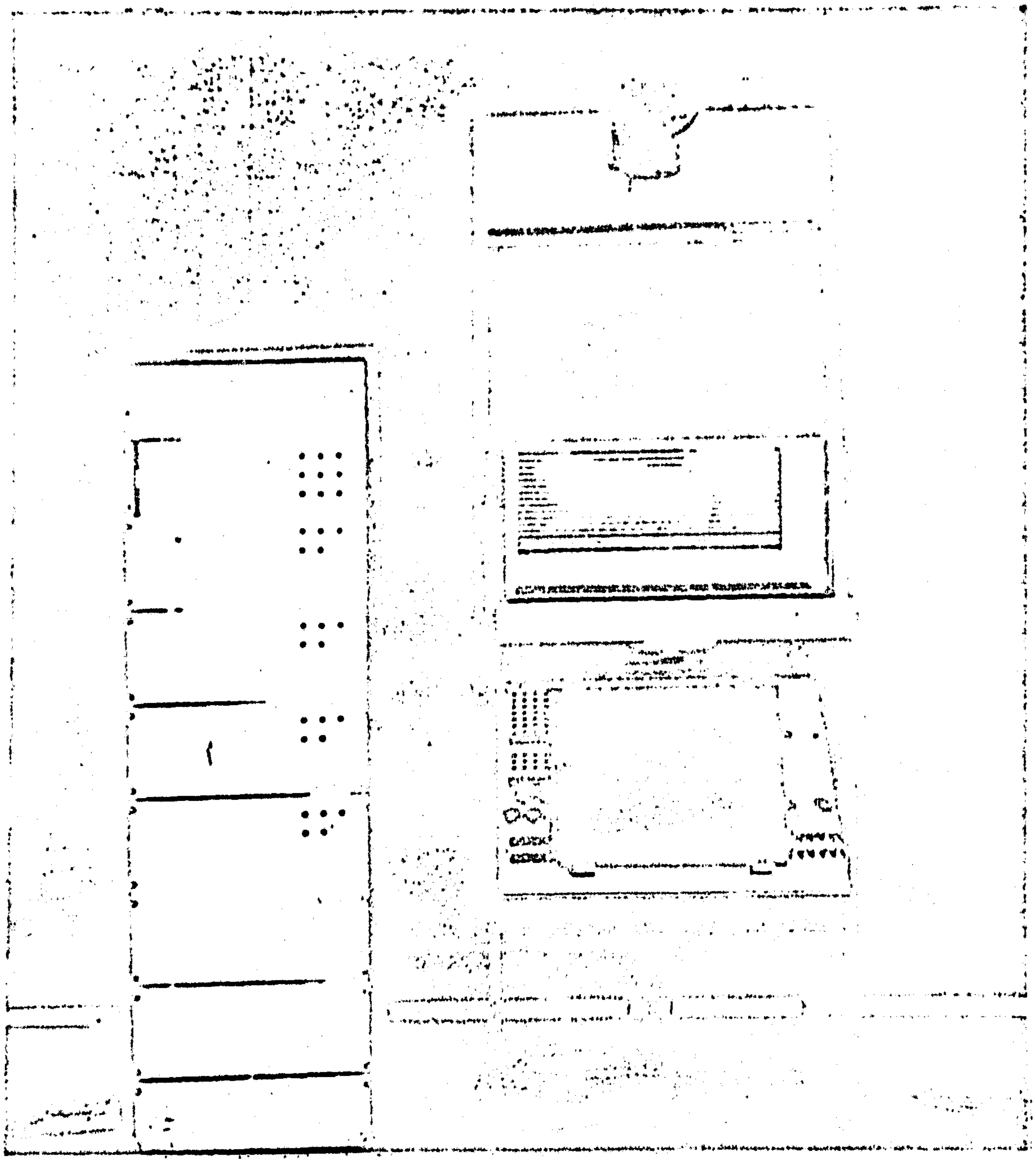

Figure 8. Multichannel MSP-4 Projector

--Holder forsheet film (5) with format up to 70 x 91 mm with high planeness to prevent depiction of Newton's interference rings.

--Electromechanical shutter to disengage each channel without changing the thermal equilibrium on the film holder. Wheels with a set of light filters (7) with electric drive to select the required light filter in purple, blue,

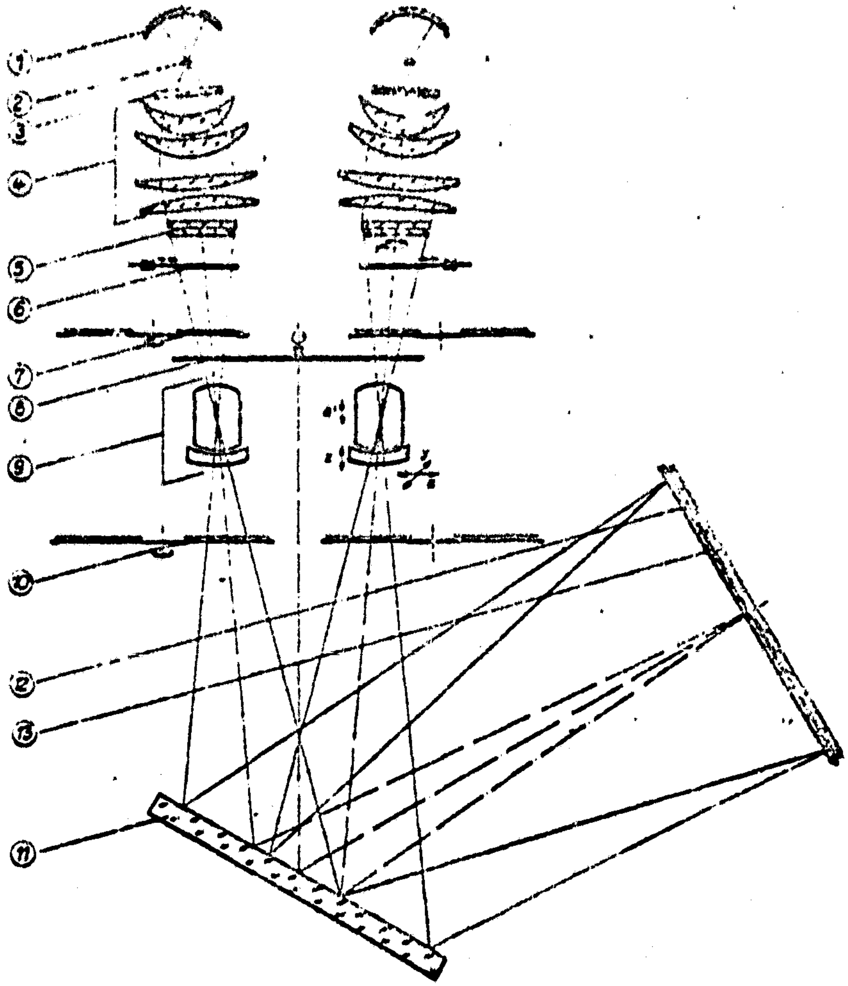

Figure 9. Optic Scheme of MSP-4 Instrument

Key:

1. Reflector
2. Halogen lamp
3. Heat-protective filter
4. Condenser lenses
5. Balancing glasses for film
6. Mechanical shutter
7. Ring mount with color filters
8. Sector shutter on four channels
9. Lenses
10. Ring mount with neutral filters
11. Mirror
12. Screen
13. Fresnel's lens

blue-green, green, yellow, red colors both for visual processing, and for photographic recording.

--Pancratic, spectrally coherent projection lens 5.6/175 (9) without dispersion and vignetting.

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--Wheel with set made of three neutral light filters (10) and one transparent glass with electric drive for approximate establishment of the light stream of the projector in a ratio of 12:1. This is without color changes and with disturbing the thermal equilibrium in the film holder.

--Control blocks with electric drive to sight for sharpness, as well as adjustment of the photographs by misalignment and movement of the frames and by correcting the scale.

An image of the four photographs in a five-fold magnification with format of 350 x 455 mm^2 (11) is obtained by decentralization through one reflecting mirror (11) on a general projection screen in transmitted light. To improve the uniform density of the luminescence of each optic channel on the screen, one can install directly in front of the projection screen in the image field a Fresnel lens (13).

In order to provide the uniform illumination of the projection plane that /21
is necessary for color synthesis, special measures were taken to determine the dimensions of the illumination blocks.

Adjustment of the four photographs was made successively with the help of markers, that were precisely applied to each photograph of the MKF-6 camera, and markers that were applied to the projection screen. Depending on the need, this operation can be carried out rapidly or slowly. A magnifying glass facilitates the adjustment process. The adjustment markers on the MKF-6 and MSP-4 accelerate and simplify the adjustment of the frames. Photographs of another origin must be combined with the help of image details on the photographs, which, however, is less accurate and more labor intensive.

The installed blocks operate in the following ranges:

--sighting for sharpness	±1.5 mm
--angle of frame rotation	±5°
--frame shift x	± 6 mm (± 30 mm in image plane)
-- y	± 6 mm (± 30 mm in image plane)
--change in scale	± 1%

The accurate manufacture of the filters and optimalizing spectral correction of the projection lens permit unlimited replacement of the filters, without resorting to additional adjustment of the synthesized color image.

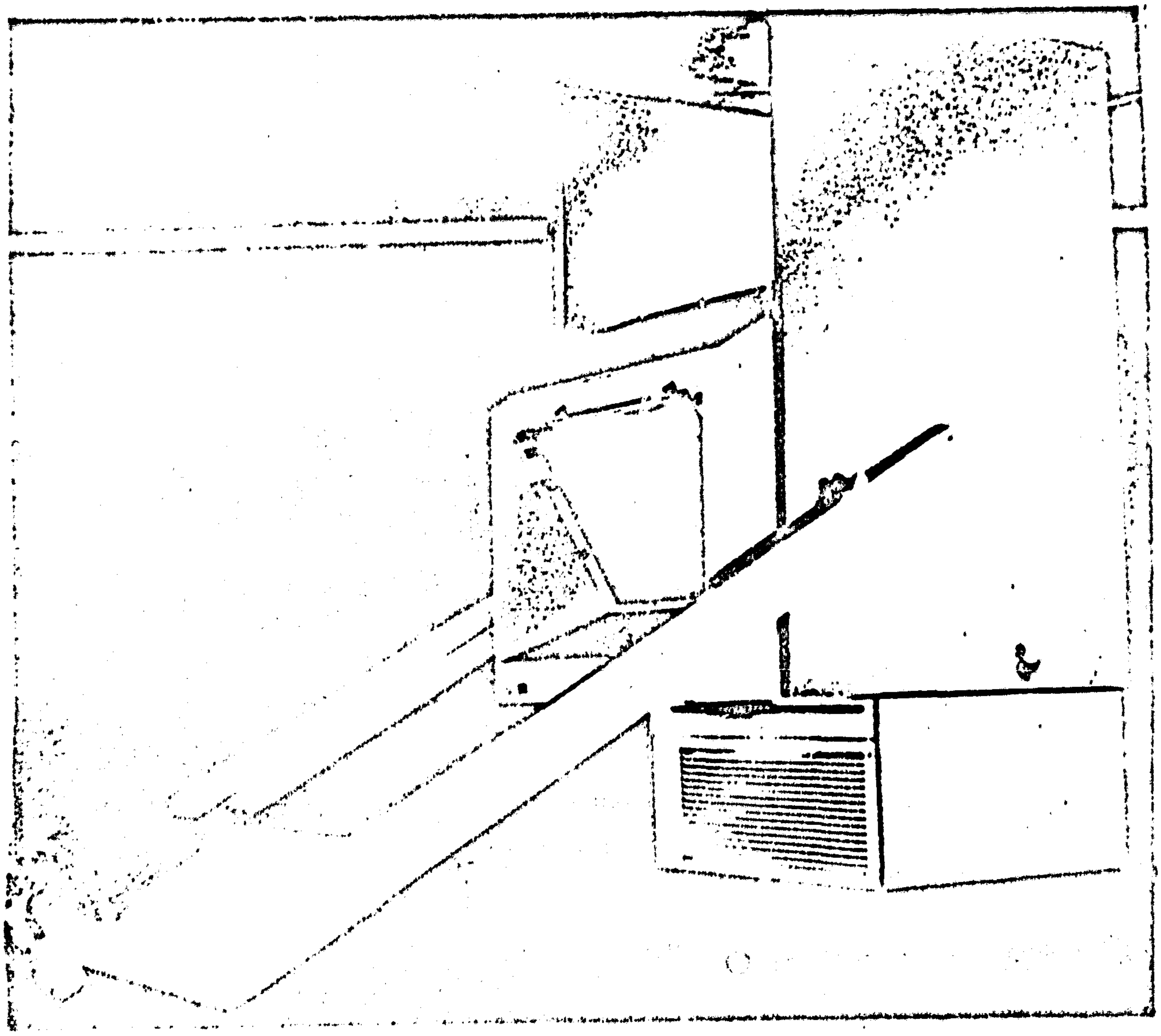

Figure 10. MSP-4 Instrument in Position of Recording on PENTAKON Camera

The MSP-4 projector has two capabilities of photographic recording and duplication of the color image. To record on standard color films with 0.6-fold reduction in the format of the MKF-6 camera, one can use the mirror-reflex camera "PENTAKON " with "Biometar" 2.8/120 lens (fig. 10). It is secured to a swivel lever. /22 After replacing the projection screen with a film holder for photo recording, the color image with a five-fold magnification can be photographed directly in the image plane on sheet color film or color paper of varying format up to size 400 x 500 mm^2 (fig. 11), which yields considerably high geometric and radiometric accuracy.

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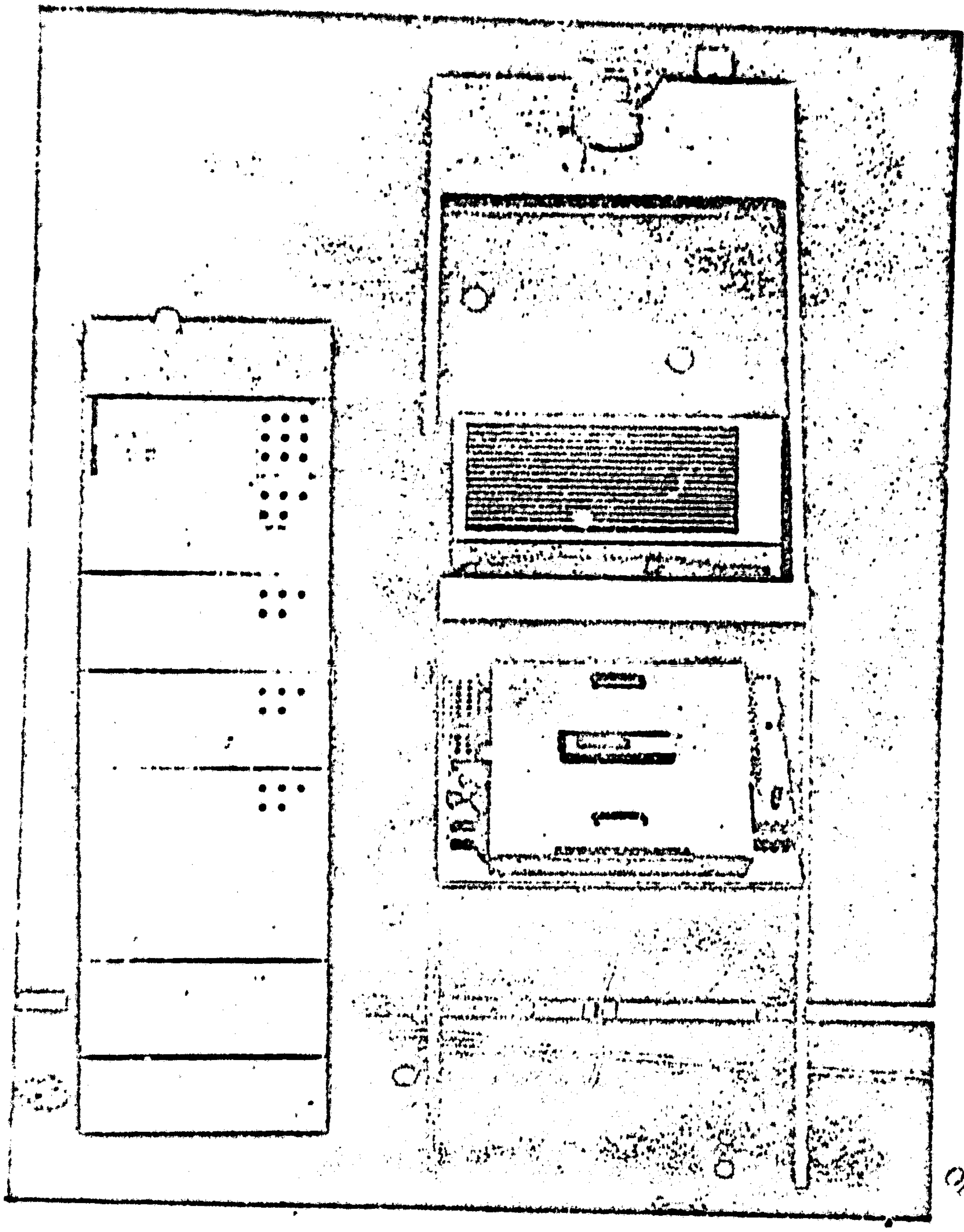

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Figure 11. MSP-4 Instrument with Installed Recording Film Holder

In the designing of the MSP-4 projector a lot of attention was focused on the convenient working with photographs, simple and reliable operation and care for them. The operation and visual processing are done while sitting. The projection screen, for convenient interpretation, is designed with an incline of 30° to avoid reflection. The service panel is located to the left and to the right of the projection screen, which makes it possible to control and regulate the instrument. The sheet film is replaced in a dark room with special lighting. Special precautionary measures exclude alignment error of the image in the case of incorrect maintenance.

Thanks to the light-impermeable design of the MSP-4 projector and the film holders, photographic recording can be carried out in daylight. The stable design of the instrument guarantees great accuracy and good constancy of adjustment. Special measures have been provided to protect the internal parts of the instrument.

In addition to the development and manufacture of the MKF-6 camera and the MSP-4 multizonal projector, as well as the necessary control and measuring apparatus, the GDR specialists in close cooperation with their Soviet partner prepared and conducted a broad scientific research program on the experiment. In the forefront of the program were scientific method studies on the use of multizonal photography in order to solve different national economic tasks and tasks of earth science. For this purpose, test sections were selected on the GDR /23 territory, whose available information and cartographic material were enriched with different studies on earth and with the help of multichannel aerial photography from an airplane. The selected test sections met certain types of landscape and special interests of different fields of application, for example, geology, agriculture and forestry, hydrology, oceanography and environmental protection.

The isolated program tasks consists of the following:

--Testing of the camera on board an airplane before installation on the spacecraft.

--Comparison of the multichannel photographs from space and from the airplane in order to reveal their suitability for use in different areas under conditions of a relatively small territory.

--Study of the effect of the atmosphere on multichannel photography.

The aerial photographic work above the test sections at the stage of preparation and conducting of the space experiment was carried out jointly on board the Soviet airplane laboratory "An-30" by specialists of the USSR and GDR.

The processing of the extensive information on the photographs obtained as a result of the experiment has naturally not been completed yet. However, even today one can state that the method of multizonal photography even under conditions of a relatively small and fairly well studied territory yields valuable additional information for the traditional observational material, and often solves more efficiently the important tasks in different areas of the economy. High geometric resolution and the practical absence of distortion of the MKF-6 camera also make it possible to study the phenomena of small size by using the space photographs.

Multizonal aerial photographs from an airplane at medium and great altitude provide additional information on the details that one simply cannot give up in the future.