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A DESCRIPTION OF A SYSTEM OF PROGRAMS FOR MATHEMATICALLY PROCESSING ON UNIFIED SERIES (Yes) COMPUTERS PHOTOGRAPHIC IMAGES OF THE EARTH TAKEN FROM SPACECRAFT (Unit "SOFI")

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Translation of "Opisaniye Systemy Programm Matematicheskoy Obrabotki na EVM Yedinoy Serii (ES) Fotograficheskikh Izobrazheniy Zemli, Poluchennykh s Kosmicheskikh Apparatov (Kompleks "SOFI"), Academy of Sciences USSR, Institute of Space Research Moscow, Report Pr-336, 1977, pp. 1-30.

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16. Abstract The present paper is dedicated to a description of a batch of programs for the Yes-1040 computer combined into an automated system for processing photo (and video) images of the Earth's surface, taken from spacecraft. Since the processing system in question is the result of present and future collective efforts of many authors, it seemed to us advisable to publish sequentially the individual programs with the detailed discussion of the algorithmic and programmatic facilities needed by the user. Therefore in order to make this work possible subsequently, we at first discuss here the basic principles for assembling the system, and then we describe in detail "the control programs" and we display the "exchange format" within whose framework the cataloging of any programs recommended for the system of processing will be activated in the future.			
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TABLE OF CONTENTS

Introduction	1
I. The functional purpose and basic tasks of the complex of programs "SOFI".	2
II. Organization of the complex	9
1. Interaction of the modules of the complex	9
2. Storage and transmission of control files	13
3. The subprogram for calling modules	14
4. Cataloging absolute modules	15
5. Cataloging object modules	16
6. Information about the makeup of the complex	16
III. Exchange format	18
Appendices	24
References	25

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A DESCRIPTION OF A SYSTEM OF PROGRAMS FOR MATHEMATICALLY
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INTRODUCTION

24*

The intensive development of aerospace facilities for studying the natural resources of the Earth results in the need to construct a system of data processing for the purpose of obtaining the maximum benefit. Since in the first stages of the operation basic attention was focussed on the creation of technical means for obtaining information the solution of the problem of its use has been relegated to a secondary position.

Now the situation is changing -- an ever increasing circle of users is involved in analyzing and interpreting the data. A real danger arises here: the development of similar methods and the creation of program facilities for solving the same problems due to a failure to provide for successive exchange of information and to construct processing systems on the modular principle.

With the present paper the Institute of Space Research steps forth as initiator to create a system which is convenient for the majority of users, and which has a potential for development through the contributions made by users with various interests. The basis of the system is a well-developed

* Numbers in margins indicate foreign pagination.

exchange format of programs and data, a control program, and also a set of preliminary processing programs included in the system.

I. The functional purpose and basic tasks of the complex of programs "SOFI". With the present paper, the publication of a series of articles is initiated which are devoted to the creation of a complex of programs for an automated system of processing, on computers of the Unified Series (YeS), information received from spacecraft while studying the surface of the earth. The need to create such a complex has been repeatedly discussed by the authors in conferences attracting a wide circle of specialists occupied with questions of image processing, as well as the subsequent use of video information obtained from spacecraft. The problem cited has special urgency in connection with the great progress which has been made in the development of means for obtaining photo images of high resolution associated with the creation of the photo camera MKF-6 for the orbiting space vehicle "Soyuz-22". This space flight has made available to researchers voluminous and essentially unique material which requires operational processing on a computer and, moreover, the development of the corresponding mathematical and programmatic facilities.

As domestic and foreign experience shows [1], the absence of coordination in the development of such systems inevitably leads to explicit and implicit parallelism of operations in various laboratories and organizations. This is also fostered in no small measure by the fact that the earth's surface is diffuse in character, and the fact that it lacks a regular structure complicates the application here of the methods of mathematical modelling and often forces the researcher to resort to empirical methods. During the solution of the same problems, this gives rise to a great variety of approaches which are hard to compare. Therefore here, in or-

der to avoid the necessity for repeated programming when implementing each new type of image processing, the authors have worked out an automated system on computers specially adapted for performing certain complex operations which make it possible without any difficulty to introduce into the makeup of the system any new programs within the framework of the adopted exchange format. The basic objective of the first edition of the system considered below is, in the opinion of the authors, to present to investigators the simplest programming instrument for working with images of the earth's surface on a computer. In order to complete the scientific developments of the research plan associated with optimizing the methods for automatic classification of objects, as well as solving other practical problems. The integration of a large number of programs into the system makes it possible during operation to identify the most effective programs and to store them in the succeeding generations of a higher level system.

Let us turn to a brief analysis of the basic functional modules determining the structure and certain tasks of the complex.

At the present time in various laboratories of the Institute of Space Research of the USSR Academy of Sciences while solving certain particular problems concerning the processing of images on the computer YeS-1040 a number of programs were developed. In turn these programs served as the basic framework during the development of the complex "SOFI" with its subsequent orientation toward preliminary processing of six-zone photographs using the photo camera MKF-6. The first stage in the processing consists in the equivalent transformations of the pictures, storing the information contained in them, i.e., 1) copying the pictures on magnetic tape; 2) combining the pictures obtained in different spectral ranges;

3) correcting the linear and non-linear distortions; 4) superposing the geographical coordinate network. Then /7 color processing is carried out, i.e., the six-zonal gamma is translated into two-color, three-color, etc., images, and finally, the color photograph is produced on photo film.

At this stage progress depends to a significant degree on the efficiency and quality of the technical means of visualization. At present two visualization devices are used for this purpose: a digital printing device of the computer (an alphanumeric printer (AIIIY) and the photo output of the minicomputer "L-16". The undoubted advantage of the AIIIY is its accessibility and the ability to use it in the burst mode of computer operation. The disadvantages are obvious, and consist, as is well-known, in a lack of clarity and a low degree of spatial resolution regarding the results of visualization. Nevertheless for a definite class of test problems, visualization by means of AIIIY seems advisable so that the development of a universal program of visualization on a AIIIY is included among the top-priority tasks for the compilers of processing systems.

It is well known that the most effective means of processing images on computers is the output of information for display. Since in the future it is proposed to equip the computer YeS-1040 with terminals which will include displays, the automated complex of programs under development must also include modules for visualizing on a display images undergoing processing.

Finally, a most complete and precise representation of information can be achieved by means of the photo devices of the computer "L-16". Since this computer is simultaneously capable of making designs, it in turn can be useful in certain

standard input-output procedures for inscribing drawings, for read-outs on tape in a definite format and other service operations. Note that here the resort to the computer 1 can be accomplished in two ways: either by equipping the complex with special modules responsible for visualization of information on the computer 2, or in the case of the use of single exchange formats this problem is solved by a specialized program supplied on the computer 3, which ensures the given deciphering and visualization of the information previously recorded on magnetic tape in the approved format. Since at the present time the 4 computer has no communication circuits with the YeS-1040, the latter alternative is preferable in the opinion of the authors.

We shall now pass on to a brief description of the modules for the equivalent transformations of information. Among them the most important and the most complicated is the problem of combining multizone photographs involving the superposition of two different images of the same portion of the surface so that all elements of the superimposed images coincide. The problem of superposition arises when the constituent colored images are prepared from the color-separated images obtained simultaneously by means of cameras mounted on a platform, as occurs with the photo camera MKF-6. In order to facilitate the subsequent solution of this problem, a total of 9 crosses is applied in advance to the objective of each MKF-6 camera as coordinate reference markers. Thus in mathematical terms the combination problem involves identifying on each photograph a preassigned triple of non-collinear reference crosses, and then reducing in the computer all remaining photographs to the coordinate system of one of the photographs, chosen as a reference, using the operations of translation and rotation. At the present time in the Institute of Space Research in the USSR Academy of Sciences such

a program has been created and included in the composition of the complex "SOFI" [2]. After being combined, the six-zone photographs are recorded in the unified exchange format and become suitable for superposition on their coordinate network.

Here the problem is to combine the photographs with the standard portions of the Earth's surface whose coordinates in turn are well known. Thus mathematically this problem is identical with that considered above and can be solved by the same method. However, in this case the most efficient procedure may be to use the Fourier transform, making it possible to combine the photographs according to the degree of correlation of the images. At present this method is under development.

The correct solution of the problem of finding the coordinate network is also closely related to the problem of correcting linear and non-linear distortions arising on the photographs in comparison to the standard images as a result of variations in the properties of the atmosphere and other effects. Thus to make the appropriate corrections, the photographs must be subjected to special linear and non-linear transformations. For the first step of the operations the authors propose the development of a program module for linear transformations of the photographs in a computer.

The modules of the processing system described above complete the initial processing of images of the earth's surface. The subsequent processing of the images can be extremely varied and is determined basically by the practical problems of investigators in each of the interested branches of the domestic economy and the appropriate earth sciences. Next we shall dwell briefly on only those problems of subsequent processing toward whose solution some project has al-

ready been started or can be provided in a short time by the approximate programs of the "SOFI" complex. Here the most familiar problem is the development of a method for automatic classification of objects when processing images. /10 The basic difficulty when introducing such a classification is that the images under observation in each class studied may assume an infinite variety of forms, due in part to the variability of the earth's surface, and also to the variations in the properties of the atmosphere and in the intensity of illumination. All this makes it extremely difficult to define satisfactorily the representatives of the training set which may then be used for a sufficiently reliable solution of the classification problem. One of the planned ways to solve this problem is, as is well known, to develop an effective system of spectrozonal signs for the reliable recognition and classification of objects. This in turn gives rise to the need to create for the computer libraries of special characteristics of objects under study. These libraries would be augmented and brought up to date systematically through widening the classes of objects themselves, as well as by extending the spectral boundaries, including the infrared region of radiation.

Moreover, for certain practically important applications the simplest problem of classification may also be solved effectively by establishing the auto-correlation of various objects pictured on a photograph. Here if a photograph is identified with what is found on the earth's surface (for example, plant cover, cultivated areas, etc.), then this information often is sufficient for constructing a training system. At the present time in the Institute of Space Research in the USSR Academy of Sciences a program module has been written, defining the degree of autocorrelation of image elements [4], which is included in the complex "SOFI."

Note also that the development of the automatic classification methods includes as a constituent the solution of the problem of isolating or accentuating contours delimiting various homogeneous regions or encompassing nominally homogeneous regions of natural formations within the limits of admissible precision for describing them by the accepted classification of objects. In the Institute of Space Research in the USSR Academy of Sciences, on the basis of gradient approaches and regression analysis, a program has been written for isolating contours [3], which is also included in the system of image processing.

Next, the authors consider it necessary to introduce into the makeup of the complex "SOFI" a program for determining the parameters of theoretical models through the results of measurements [5]. The program in question has shown a high degree of effectiveness in different physical applications and can be useful in the conduct of many researches, in particular, when classifying objects to be identified in the non-linear space copying their signs.

At the present time in the Institute of Space Research in the USSR Academy of Sciences effective programs of one- and two-dimensional Fourier transforms (FT) have been developed. As noted above, the FT can be a reliable means of solving a number of problems involving the processing of images. In particular the FT can be used successfully to synthesize complex optical filters on computers modelling holographic methods for processing images. Thus equipping the complex "SOFI" with FT programs, followed by the development of special program modules for the algebra of rapid Fourier transforms will provide a reliable program base for creating new, effective methods for processing images on computers.

Finally, to conclude the present section, let us note that combining programs for processing images within the frame-

work of the single automated system "SOFI" solves a whole series of problems, the most important of which are the /12 following.

1. Subsequent work to extend the mathematical and program facilities applicable to the study of the earth's natural resources can be efficiently planned.
2. Duplication in the creation of programs and algorithms is eliminated.
3. The input and output information recorded on computer media is unified, and this in turn facilitates the exchange of data between various organizations.
4. Natural conditions for a comparative analysis of the effectiveness of different approaches are created as the result of solving the problems of processing images on a computer.
5. Setting up the program complex "SOFI" on the YeS-1040 computer facilitates the exchange of programs between different groups of developers.

II. Organization of the complex

/13

1. Interaction of the modules of the complex

Control program

The structure of the complex is modular. Each module is a set of programs located in the absolute module library of the system **IOC.EC.** [DOS YeS]. Each module solves a particular problem; for example, translation of incoming information from one format into another, visualization of images, gradient transformation, etc. In case of a concrete calculation,

the order of call of modules must be defined. The given order of processing the modules is provided by the control program of the complex.

Each module of the complex is cataloged under a definite number which must not exceed 9,999,999. Usually a programmer working on a supplement to "SOFI" receives an interval of numbers for cataloging his programs.

A calculation via the complex is always initiated by calling the module "job loader." For this purpose, a job management command is used: **// EXEC V0000000**

The module "job loader" reads information from a punched card input device. This information determines the order in which modules are processed, and also controls the work of each module. The punched cards (pk) are made up as follows:

- 1 pk. -- the number of the first module called (format I7)
- 2 pk. -- the control for operating the first module called (format 32 II)
- 3 pk. -- the number of the second module called (format I 7)
- 4 pk. -- the control for operating the second called module (format 32 II). etc. but in a job there can be defined a list of at most 20 modules.

/14

/* - the sign of the end of the information defining the order of operation of the modules.

The structure and dedication of the punched cards controlling the operation of the modules is explained below. The loader module is numbered 0 in the library of absolute modules in the complex. The module is written in FORTRAN IV. This listing is given in Appendix I.

The module "job loader," which introduces the informa-

tion for operating the modules, prints the formulated job, for example:

[OPERATES THE COMPLEX FOR PROCESSING VIDEOIMAGES VIDEO
*]

[CONTROL FOR OPERATING THE COMPLEX]

[ORDER]	[NUMBER OF MODULE]	[CONTROL]
1	3000003	00111110000001100000000000000000
2	2002	00010101110001100000000000000000
3	3000003	11101101010100000000000000000000

and calls the control module of the complex. The control module of the complex calls the first module shown in the list and feeds into its control file:

[MODULE CALLED] 2002

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	0	0	1	0	1	0	1	1	1	0	0	0	1	1	0	0	0	0	0
21	22	23	24	25	26	27	28	29	30	31	32								
0	0	0	0	0	0	0	0	0	0	0	0								

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Each module whose work has been completed normally, again calls the control module:

[MODULE FINISHED] 2002 [MESSAGE ARRIVED] /15

[MODULE CALLED]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0
21	22	23	24	25	26	27	28	29	30	31	32								
0	0	0	0	0	0	0	0	0	0	0	0								

*illegible in foreign text.

The control module calls the next module (in accordance with the list of jobs) and feeds into it the control file, etc., and reports

[MODULE FINISHED]

[MESSAGE ARRIVED]

[CALCULATION VIA COMPLEX ENDED]

and the calculation by means of the complex is terminated.

The file of controls for operating a current module is transmitted by the control module via the unlabelled COMMON block. The control file is the complete file IABC(32) in each four byte element of which the number 0 or 1 is contained, depending on whether 0 or 1 was printed on a punched card in the corresponding digit for controlling the work of the given module (Recall that the format of the record on a control punched card is 32 I I). The presence or absence of a unit in a particular element i of the control file $IABC(i)$ serves as an indication by means of which the programmer can supervise the order of processing blocks in the module. For example, suppose the fifth element controls the print mode. Then the print operators will have the form /16

```
if(IABC(5). EQ. 1) WRITE(3, )
```

print will be carried out if IABC(5) equals 1.

The number of the control module in the library of absolute modules in the complex is i .

The module is written in FORTRAN IV.

The listing is given in Appendix 2.

2. Storage and transmission of control files.

During a calculation by means of the complex the files controlling the operation of the complex are stored in the main storage. This is achieved because all the main programs of the modules are obliged to have an unlabelled COMMON block. Clearly this block must have all the subprograms of the module which pertain to the unlabelled COMMON block. The COMMON block must have one of the following three forms:

Complete description

DIMENSION INTEGER*2 PRIK(20,32)

COMMON IABC(32),IS,K,IZAD(20),PRIK,ISOOB(20)

and further, if necessary, the module's own file.

Incomplete description

COMMON IABC(32),IS,FICT(361)

and further, if necessary, the module's own file.

"Blind" description

COMMON FICT(394)

/17

and further, if necessary, the module's own file.

The files in a complete description have the following content

IABC(32) -- the control file

IS -- the identifier of a message in a module any number may be assigned to this identifier. After returning to the control module this number is printed. Moreover, it will be placed in the file **IS OOB** () at the Kth place. If in

a given module no value is assigned to **IS** then the control module prints that the message 0 has arrived.

Messages can be used for information about any results in the module. And since they are placed in the file **IS00B** and stored, they may also be used as information transmitted from module to module. It should be noted that this capability of the complex is rarely used by programmers. **K** is the ordinal number of the given module in the list of jobs for calling modules.

- IZAD (20)** - is the file in which the list of modules is stored which the control module must call.
- PPIK (20,32)** - is a file of the type *integer x2*; in it is stored the file of controls for the operation of the modules.
- IS00B (20)** - is the file in which messages of the modules are stored.

Usually the incomplete description of the COMMON block is used which makes it possible to obtain the control IABC and to transmit the message **IS** .

3. The subprogram for calling modules

/18

To call modules of the complex, a special subprogram is used. It is stored in the library of object modules of the complex and can be called as a subprogram.

CALL NEXTV(N)

N - is an integer variable or integer.

The control module of the complex is called by the operator **CALL NEXTV(1)** . The subprogram **NEXTV** can call any module of the complex without reference to the control program.

From the viewpoint of the control module, the entire supermodule has the number of the first module called from the supermodule. The subprogram **NEXTV** is stored in the library of object modules of the complex. The subprogram is written in the ASSEMBLER language. The listing is given in Appendix 3.

4. Cataloging absolute modules

The basic structural unit of the complex is the module located in the library of absolute modules. The job for cataloging a module in the library of absolute modules is organized as follows:

/19

```
// JOB      NAME
// ASSGN SYSCLB,X'190'DISK I02
// ASSGN SYSRLB,X'190'DISK I02
```

(According to this command the operator places disk No. 102 with the complex and assigns to it the cataloging of the absolute and object modules. The number of the disk may differ from that shown in the present example).

```
// OPTION CATAL
```

```
  ACTION RL
```

```
  PHASE V N1N2N3N4N5N6N7*
```

($N_1 N_2 N_3 N_4 N_5 N_6 N_7$ is the number of the module; for example 0011000 or 0000005, etc.).

The usual job for translation is, for example:

```
// EXEC PPORTRAN
```

```
text of basic program
text of subprogram
```

/*

// EXEC LINKEDT

5. Cataloging object modules

As a result of the transformation of the system *DOS EC V.M 2.0*, cataloging object modules has been complicated. The job for cataloging a subprogram in the library of object modules is organized as follows:

```
// JOB
// PAUSE ASSGN SYSPCH,X'190'[DISK]102
// PAUSE ASSGN SYSRLB,X'190'[DISK]102
// OPTION DECK
// EXEC HELPCAT
  CATALR [NAME]
// EXEC ASSEMBL [OR] // EXEC PPORTRAN
  [PROGRAM]
/*
...
CLOSE SYSPCH,X'OOD'
// PAUSE ASSGN SYSIPT,X'190'
// EXEC MAINT
CLOSE SYSIPT,UA
// PAUSE [RECLAIM ASSIGNMENT FOR] SYSIPT
// OPTION NODECK
// EXEC DSERV
  DSPLY ALL
```

/20

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Note: the number of the library disk can be changed.

6. Information about the makeup of the complex.

For successful functioning of the complex, in whose synthesis a large number of programmers has participated, it is necessary to provide operational access to information about augmentations and changes in the complex. To this end, each module included in the complex is equipped with a description.

The number of the description of a module is one million greater than the number of the corresponding operating module. For example, if the operating module has the number 321, then the module in which the description of the module 321 is contained has the number $1000000 + 321 = 1000321$.

/21

Only when a module has been provided with a description is it considered to be included in the library of absolute modules of the complex.

$$1.000000 + 321 = 1000321.$$

The description of an absolute module can be called by the command

`// EXEC V N2 - N7`

or through the complex, after the call of the corresponding module in the list of jobs for the calculation

`1N2 N3 N4 N5 N6 N7`

is placed, where `N2 N3 N4 N5 N6 N7` - is the number of the operating module, e.g., 000321.

The description of an object module is placed in the library of absolute modules under the assignment `V1 A1 A2 A3 A4 A5 A6` where `A1 A2 A3 A4 A5 A6` consists of the first six symbols in the assignment of the object module under which it is called in the programs. For example, to the subprogram `NEXTV` corresponds the assignment `V1NEXTV` in the description placed in the library of absolute modules. The module of the description of an object module can be called from the library of absolute modules only by the command `EXEC`.

For example:

`// EXEC V1NEXTV`

The description of a module or subprogram must contain

the following divisions:

1. The assignment of the module.
2. The decoding of the controls of the module.
3. The format and the means of input of external data for a calculation by means of the module.
4. The format and the means of output of the results of a calculation by means of the module.

An example of a description is given in [6].

III. Exchange format

22

Video information subject to processing on a YeS computer is usually made ready on a standard medium--a magnetic tape, accepting up to 10^8 bytes of information placed on one reel. To make possible a broad exchange of original material as well as the results of processing, there must be a uniform standard for the format of placement of information on magnetic tape.

The different sources of video information (scanners, multispectral photo recorders, etc.) determine their intrinsic natural form of placement of data. The specifics of scanner information are such that the intensities of reflected light in various spectral channels corresponding to an element of resolution on the earth's surface succeed each other and during transcription from specialized to standard magnetic tape, blocks of n groups of K bytes (of color vectors) each are formed [4] (K is the number of spectral channels in which recording occurs and n is the number of elements per image line). This organization of video information is natural for scanner information.

The materials from multispectral photo cameras arrives in the form of negative or positive color or black and white images. The input of information is accomplished separately in each spectral region of the entire material. To receive information on magnetic tape in a form like that received during transcription of scanner images, it is necessary to perform a quite large operation involving the combining of color-separated information. The difficulties arising during combination can be overcome and the information can be presented in just such a standard.

The programs of visualization and/or statistical processing which have been developed may be necessary not only for original information, but also for any processed information (e.g., differentiated or filtered). Consequently it is desirable to represent the results of processing in such a form that no problem of describing new programs, e. g., of visualization, arises. In the majority of cases this is possible.

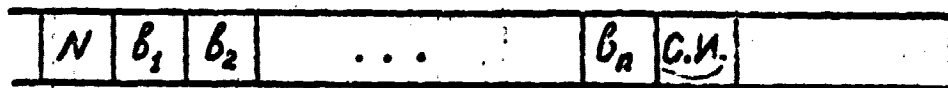
The number of reels of magnetic tape with video information is quite large, even when processing the results of a modelling experiment. To make it possible to identify the contents and to avoid operator errors, in the **AOC** system [Disk Operating System] a method has been worked out whereby special header and tail labels are placed at the beginning and end of each reel [7]. The presence of standard labels makes it possible to process data on magnetic tape by means of programs written in different programming languages, FORTRAN, ASSEMBLER, etc.

Two basic formats for original information are possible: scanner and spectrally divided.

In the scanner format a line consists of n color vectors of k components and contains service and auxiliary information,

/23

recorded at the time of the reverse travel of the scanning device which is not strictly video information. At the present time this auxiliary information is not used as a rule; however, in the future many of its parameters, such as, for example, the magnitude of the noise, the amplification factor, the time, the direction of flight, etc., may provide substantial help in deciphering images. The physical unit of a record of scanner information is a line of an image or its part. The arrangement of the material in a line has the following form:



/24

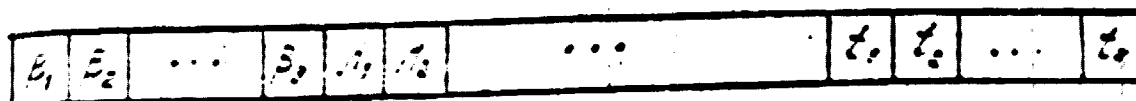
here N is the number of lines during repackaging of information and is either the ordinal number of the line, or is obtained from the number of the line, determined at the moment of photography and recorded instrumentally at the time of reverse travel. N is placed in the first four bytes of the record. b_1, b_2, \dots, b_n are the color vectors, each of which occupies k bytes, where k is the number of spectral ranges. $C.M.$ is the service information recorded instrumentally on telemetric tape.

The existing scanner provides 2048 bytes per line, of which only 1536 represent video information. The scanning devices which have been developed can have lines of length 4096, 8192 and more bytes each. In this case it is proposed that properly speaking a line of an image breaks down into blocks of 2048 or 4096 bytes each, and the presence in two or more lines of the same number in a line is evidence that blocks with the same numbers correspond to a single line and are distributed on an image from left to right one after the other.

During recording, blocks are separated from each other by interblock intervals. The set of information blocks forms a file with standard header and tail labels. The first block

after the header labels of the file **VOL1** and **HDR1** [7] can be an information block of length 512 bytes. This block contains information about the organization of the material and parameters of the recording apparatus; test characteristics, commenting data, the number of spectral ranges, wavelengths, etc. The presence of such a standard block makes it possible to construct programs adjusted to a given concrete organization of data and to have verbal commentaries about the material on a given reel.

The arrangement of information in an informational line is



The line contains 512 bytes. The words of the recording $\beta_1, \beta_2 \dots \beta_9, \alpha_1, \alpha_2 \dots$ contain 4 bytes each; the words t_1, \dots, t_r 64 bytes each; β_1 is the number 0. β_2 is the type of recording. If $\beta_2 = 0$, the information in a line of the image is recorded in a sequence $\alpha_1, \alpha_2 \dots \alpha_k$, i.e., for an element of the image, all k spectral intensities are recorded; then we have $\alpha_1, \alpha_2 \dots \alpha_k$ for a second element of the image, etc. /25

If $\beta_2 = 1$, the information in a line of the image is recorded in a sequence $\alpha_1^1, \alpha_1^2 \dots \alpha_1^n, \alpha_2^1, \alpha_2^2 \dots \alpha_2^n$, i.e., at the beginning for the entire line of the image is the spectral intensity of the first channel, then for the same line, the spectral intensity of the second spectral channel, etc.

β_3 - is the length of the physical recording

β_4 - is the number of elements in a line of the image (for a single spectral channel).

β_5 - is the number of spectral channels.

β_0 is the approximate number of lines in the image

β_1 is the aperture

β_2 is the raster

β_3 is the scale

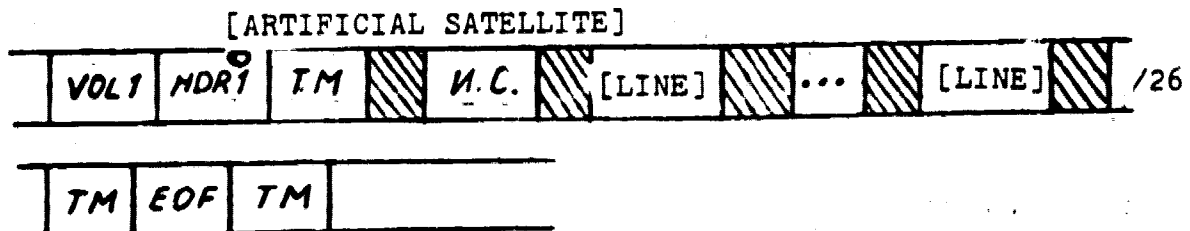
λ_1 is the wave length of the first spectral channel

λ_2 is the wave length of the second spectral channel

λ_k is the wave length of the k th spectral channel.

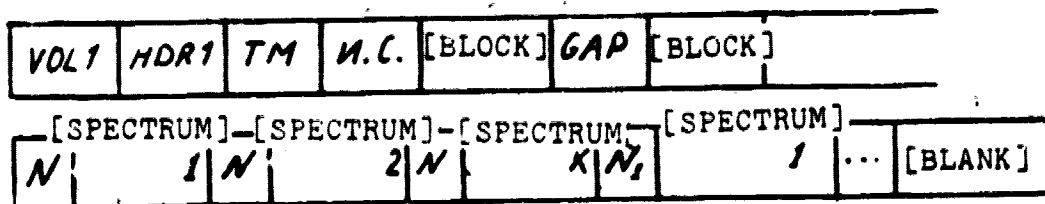
In the words t_1, t_2, \dots, t_p any alphanumeric information about the photograph is recorded.

Thus the format of scanner video information has the form:



The spectral format is naturally obtained during the introduction of the negatives from various spectral ranges. In this case (after carrying out geometrical correction and combination) the lines of the image consist of K blocks, each corresponding to a separate spectral range. Since the length of a line (the number of elements in the line) is determined not only by the dimensions of the negative, but also by the aperture of the reader, and also by the desire of the user to study an individual fragment of the image, it seems reasonable not to fix the length of a line rigidly.

It is desirable to have the length a multiple of 2048 bytes, placing in one block or several spectral ranges, corresponding to one line (when there are small fragments), or placing in several standing blocks in succession, data characterizing a single line in the corresponding spectral ranges: in such a case the presence of an informational line is necessary in order to work with such material.



The block for a small fragment (several lines in one block).



a group of blocks for a large fragment -- one line per several blocks.

/27

It is obvious that it is also possible to represent scanner information in a spectrally separated format. When developing programs it is necessary either to prepare self-adjusting programs relative to the N.C., or to provide for the possibility of an easy program change for their work with data in various formats.

In conclusion the authors consider it their duty to mention the participation of Comrade L. S. Chesalin touching on the questions in this article.

/28

Appendix 1. Job loader module.

```

DIMENSION IZAD(20), ISOOB(20)
INTEGER*2 PRK(20,32)
COMMON IABC(32), IS, K, IZAD, PRK, ISOOB
WRITE(3,101)
I=1
2 READ(1,200,END=10) IZ
  READ(1,100) (PRK(I,J),J=1,32)
  ISOOB(I)=0
  WRITE(3,102) I, IZ, (PRK(I,J),J=1,32)
  IZAD(I)=IZ
  I=I+1
  GO TO 2
11 IZAD(I)=0
  WRITE(3,107)
  K=0
  CALL NEXTV(1)
100 FORMAT(2I1)
101 FORMAT(//,0X, [operates complex for processing video images]
• [video-77], [controls for operating the complex]
• 'U4FPRB', ['order,' 'module number,' 'control']
• 27X,32(1H.))
102 FORMAT(1X,15,7X,17,7X,32I1)
200 FORMAT(I7)
107 FORMAT(/1X)
END

```

Appendix 2. Control program for the complex

```

103 FORMAT(//, ['operation of module concluded,'] [message arrived.])
104 FORMAT(1X, ['module called'],'.18)
105 FORMAT(/1X,32I3/' ')
106 FORMAT(1X, ['calculation by means of module ended'])
DIMENSION IZAD(20), ISOOB(20), IARC(32), L(32)
INTEGER*2 PRK(20,32)
COMMON IABC, IS, IZAD, PRK, ISOOB
IK(K) = 0, 8, 9
NMOD=IZAD(K)
WRITE(3,103) NMOD, IK
ISOOB(K)=IS
K=K+1
NMOD=IZAD(K)
IF(NMOD)4,4,3
DO 3 J=1,32
  IABC(J)=PRK(K, J)
  WRITE(3,104) NMOD
DO 7 I=1,32
  L(I)=I
  WRITE(3,105) (L(I),I=1,32)
  WRITE(3,105) (IARC(I),I=1,32)
  IS=0
  CALL NEXTV(NMOD)
4  WRITE(3,106)
  STOP
END

```

Appendix 3. Subprogram for calling modules from the library of absolute modules.

```

1          PUNCH ' CATALR NEXTV'
2 NEXTV   START
3          PALR 3,0
4          USING 0,3
5          L 4,0(1)
6          L 4,0(4)
7          CVD 4,0
8          INPK N,D
9          NI N#6,X'F0'
10         LA S,A
11         FETCH (S)
12 DOS,ES  FETCH V.M 2.0
13         DC 0H'0'
14         IR 1,5
15         CR 0,0
16         SVC 1
17 D      NS D
18 A      NS CL1 'V'
19 N      NS CL7
20       END

```

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