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16. Abstract  Physical experiments using tracking cameras resulted in hundreds of thousands of stereo-photographs of events being received. To process such a large volume of information, automatic and semi-automatic measuring systems are required.  At the Institute of Space Research of the Academy of Sciences of the USSR, a system for processing film information from the spark gamma-telescope has been developed. The system is based on a BPS-75 projector in line with the mini-computer Elektronika 1001.  The report describes this system. The various computer pro- grams available to the operators are discussed. 25 pages, 10 figures,					
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In the conduct of contemporary physical experiments with the use of tracking cameras, hundreds of thousands of stereo-photographs of events are received. For the processing of such a great volume of information in a compressed time period, automatic and semi-automatic measuring systems are used in all large-scale physics centers in our country as well as abroad (1).

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Human participation is determined by the characteristics of the processing and by the capabilities of the system itself. The range of action of the operator in different systems extends from the recognition and identification of the events and the participation in the process of measurement in all its stages to the use of an electronic computer ECM (system) in critical situations only.

In semi-automatic systems a group of measuring instruments is joined to one ECM which controls the process of measurement in all the instruments. For measuring compound events with photos of any quality, such systems are economically more advantageous and are more available in small physics centers. In semi-automatic systems, the operator is in constant dialog with the ECM. The substance of the dialog is determined by the operator tracking program. The construction of a general purpose tracking algorithm is practically impossible; therefore, as a rule, such algorithms are created for the processing of photos received in a wide variety of uniform experiments.

In the Institute of Space Research of the Academy of Sciences of the USSR, the gamma-astronomy section, in conjunction with the MIFI<sup>\*\*</sup>, has created a system for processing film information from the spark gamma-telescope on the measuring projectors BPS-75 in line with the mini-computer Elektronika 1001. At the present time such a system is based on one BPS-75 projector.

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The measuring system provides:

- a transfer of information from the projectors to the ECM;
- the preliminary processing and control of input information;

\*Numbers in the margin indicate pagination of original foreign text.

\*\*Translators Note: MIFI = Moscow Engineering Physics Institute.

- message display to the operators via the light panel of the data transceiver consoles or teletype (for the ECM operator);
- storage on magnetic tape of information obtained through measurement for further processing.

The ECM system, in addition to the minimum configuration, is made up of supplementary operating memory, a real-time clock and accumulators on magnetic tape.

The projector consists of a large viewing-measuring table onto which the image of the photograph is projected. The operator measures the coordinates of the points of the photograph by matching a special mark transferred by means of the control handle with the points of the film. The reader can familiarize himself with the details of the BPS-75 device in the work [2].

The console of the data transceiver contains an input unit of operator commands to the ECM and auxiliary data, an output unit and visual representation of information from the ECM, a unit of coordinate registers, and a link with the ECM (controller). Functional units are used in the standard KAMAK. The console is described in the work [3].

Program support of the measurement system includes the operating system, a system of program modules, and a system of functional control. The operating system is designed for the control of two projectors and does not depend upon the characteristics of the photographs being measured. /5

The operating system handles:

- system start-up;
- the establishment of request fulfillment order at an interrupt and the organization of request servicing by priority;
- control in the dialog mode by the measurement process in accordance with a defined sequence of stages;
- the conduct of the dialog with the ECM operator;
- the accumulation of measurement information on magnetic tape.

The structural diagram of the operating system is shown in Fig. 1; this system is described in detail in the work [4].

The functional control system is designed for:

- the control of input information;
- the control of the work of the measuring devices and the localization of errors.

If the operating system and the functional control system fulfill the functions necessary for the measurement of photographs independently of the form of the experiment, then the program module system reflects the characteristics of the experiment. In current work the system of program modules is intended for the measurement of photographs from the gamma-telescope "Gamma 1"; it serves the separate stages of the measurement process. In the work the structure of the programs is described, the function of each program of the system; the organization of masses of measurement data, and the work of the operators.

#### Structure of the Programs

The measurement process of each event is divided into separate stages. Each stage is serviced by the functional program corresponding to it (Table 1). The program dispatcher of the operating system (Fig. 1,2) controls the sequence of the stages of photograph measurement. Before returning to the functional program, the operating system sets up the status buffer (status) and then analyzes the results of the running of the programs and directs the further work of the measurement system.

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The work of the programs is arranged in the following sequence:

- 1) Receipt of information from the data transceiver console (PPD);
- 2) control and processing of this information;
- 3) preparation of the status region for the next stage and the setting up of the "Projection" region (accumulation of data);

TABLE 1

Program Title	Stages Served by the Program	Stages	Purpose of Program	Input Information	Length of Program in 12 digit Words
1	2	3	4	5	6
Start	Start	01	Receipt of aux. information according to last event in previous series of measurements	Film number, frame number, re-measurement number, experiment number	358
Frame	Frame	02	Receipt of aux. information on new frame	Frame number, operator number, type of event, number of tracks	189
Track	Track	03	Receipt of aux. information by track	Track number, number of sparks, first and last gap numbers	128
Ref. mark	Ref. mark	04	Measurement of ref. mark crosses	Coordinates x and y	250
Point	Coordinate	05	Measurement of the coordinates of the track points	Coordinates x and y	417
Write	Write	06	Output of the accumulated area to magnetic tape, complete magnetic tape label	--	173
Stop	All stages	01- 06	End of job, fill in tape label	--	49
Delete	All stages	01- 06	Deletion of input information	--	204
Dummy frame	Frame	02	Override control of sequential frame processing	--	16
Dummy ref. mark	Ref. mark	04	Omit measurement of next reference mark crosses	--	85
Dummy gap	Coordinate	05	Omit empty gap	--	48
Program tracking	Coordinate & ref.mark		Speed-up of operator effort	Coordinates x and y	256

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- 4) preparation of messages for the operator (for error, the error flag is set and the error code is entered into the status cell). These messages are displayed by the program dispatcher of the operating system on the light panel of the console while a continuous audio signal is turned on.

In Table 2 are enumerated the program-controlled errors of the operator and of the measuring system, and the messages which are displayed on the light panel for error explanation.

TABLE 2

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Stage	Error	Numerical Identification	Message
1	2	3	4
Start	Wrong film remeasurement number entered	Remeasurement number of last film measurement (zero if film was not measured)	Remeasure number
Start	Magnetic tape end of film		Change tape
Start	Frame number different from zero, and film number not in tape label		Film number
Start	Input frame number different from that written in tape label	Number of the last measurement frame of the given film (written in tape label)	Frame number
Frame	Out-of-sequence processing of film frames	Number of the preceding measurement frame	Frame number
Frame & track	Null aux. information input from console		Null console
Track	Number of track exceeds allowable		Track number
Ref. mark	Reference mark cross badly measured		Remeasure reference mark
Coordinate	Inadmissible value of point coordinates		Coordinate error
Coordinate	Spark gap too small		Increase gap



TABLE 2 (continued)

1	2	3	4
Coordinate	Spark gap too large		Decrease gap
Coordinate	[Foreign text unreadable]		Gap number /9
Write	Repeated measurement of ref. mark cross does not coincide with the initial one		Remeasure ref. mark cross
Write	Number of words in the storage region exceeds the maximum possible.		Reduce data
All stages	Stages out of sequence		Error
All stages	Conflict between console "read" and "write" commands		Test console

### The Operator's Task

The linking of the operator with the measurement system is accomplished through the console (Fig. 3). The operator accumulates the auxiliary data on the switches of the auxiliary data units (BSD). The ECM reads the coordinates of the points from the counters of the coordinate recording units (BRK) under pressure on the button "Reading."

Messages to the operator are displayed on the light panel (BST). Numerical information is output to the indicators of the numeric indicators unit (BTsI)-6 decimal digits-and on the indicators of the BST unit-4 decimal digits.

The calling of the program to service the next stage is effected by pressing a lighted button of the command buttons unit (BKK). The buttons in turn are illuminated by the ECM in a sequence defined for the given experiment.

For measuring the coordinates of the reference mark crosses or of the points of the track, the operator calls the corresponding

programs (the programs "Reference mark" and "Point") by pressing the "Read" button of the coordinate recording unit. The ECM passes information about the stages "Reference mark" and "Point" through the light panel.

The buttons "Dummy frame," "Test," "Delete," "Release," "End," are not illuminated on the console. By pressing the "Dummy frame" button, a program is called which overrides control of the frame sequence. This enables the operator to pass over a certain quantity of frames on the film and start measuring events that interest him.

An analogous system of programs allows one to skip the measurement of a certain number of reference mark crosses or sparks in the gaps at the stages "Reference mark" and "Point" (the programs "Dummy reference mark" and "Dummy gap"). The "Delete" button calls a program to erase the input data at the present stage and, if required, allows a return to the preceding stage of measurement.

The "End" button calls a program which writes in the label of the magnetic tape the numbers of the last measured frames of both projections. By pressing this button, the operator may terminate the measurements at any time that is convenient for him.

Each error-free execution of the program servicing a sequential stage is accompanied by a short audio signal.

A long signal attests to an error. In this case the operator must press the "Clear" button and, depending on the nature of the error, change the auxiliary information on the switches of the auxiliary data unit, accurately measure the coordinates of the points or reference mark cross or set the coordinate recording unit counters at the origin of coordinates on the viewing screen. As required, by pressing the "Test" button he calls the diagnostic program [5] and with its help he checks the efficiency of the units. After he presses the "Clear" button the ECM, by lighting the command button or putting out a message to the light panel, prompts the operator from which stage to begin measurement.

The number of measured tracks, sparks and points of the current spark (or reference mark crosses) is constantly displayed on the digital indicators. /11

To facilitate and speed up the operator's task, the program tracking mode is employed, which is inferred in the removal of the measuring mark to the zone being measured under the control of the ECM.

The smoothness of the track makes it possible to extrapolate the curved track (curved for Gamma-1) and find the coordinates of the next points with respect to the 2 or 3 already measured. Program tracking is made use of also for the measurement of the reference mark crosses, since approximate values of their coordinates are first given by the coordinates of the standard reference crosses.

#### Description of the Functional Programs

1. The program "Start," whose block diagram is shown in Fig. 4, serves Stage 01.

With the aid of this program the operator determines if the given film has been measured, which was the last frame on it that was measured, on which projection was the work stopped.

The program takes from the switches of the auxiliary data units the input information - the film number (with the remeasure number for the first projection), the number of the last measured frame on this film. It is stipulated that if the operator begins the processing of a new film he inputs at Stage 01 a frame number different from zero; the correct number of the frame of the new film being measured is input to the stage "Frame." We shall consider two branches of the program.

1) The frame number is different from zero. In this case the film number must be in the tape label. If the program does not find the film number with the given remeasure number in the tape label, the error is stated (farther on in this section we shall assume the

setting of an error flag and the entry of the corresponding error code into a defined status cell). After exit from the program, the dispatcher turns on a continuous audio signal and displays the message "Film number" on the light panel. /12

If the film number is detected in the tape label, then the frame number read from the console and the number of the last measured frame of the film written in the tape label are compared. If there is no match, the frame number from the tape label is entered into the indicators of the BTsI unit. After exit from the program, the dispatcher indicates the error "Frame number."

2) The frame number equals zero. Then if the film number is in the tape label, the remeasure number must be one greater than the remeasure number of the given film written in the tape label; if the film number is not in the label, then in this case the remeasure number must be zero.

For the error, there is the message "Remeasure number."

If a new roll of film is started but the tape is already full, then the operator is informed of end of tape via the light panel unit by the message "Change tape." From the teletype, it is possible to write the tape end date in the tape label.

The program determines, according to the data written in the tape label, for which projection of the event the operator finished the task in the previous series of measurements. At the end of the program, the film numbers of the first and second projections are written into the storage area "Projection."

We note that in all the functional programs after the command to read the registers of the console unit is verified, the unit generates a response signal. In the absence of such a signal, an error code is set (message - "Test console"). Later on in the description of the program, this form of control will not be mentioned.

2. The "Frame" program whose block diagram is shown in Fig. 5 serves Stage 02.

The program controls the sequence of frame measurements on the film and accepts auxiliary information with respect to the frame. At /13 the start of the program the number of the frame being measured is read, along with the operator number, the type of event, and the number of tracks on the frame, from the switches of the auxiliary data unit.

The input information is checked for zero (for an error, there is a message on the light panel -- "Zero console").

Then the program verifies whether the incoming frame number from the auxiliary data unit is one greater than the number of the previous measured frame. In case of error, the message "Frame number" appears. The number of the previous measured frame is output on the numeric indicator unit. This control is overridden by pressing the "Dummy frame" button of the command buttons unit. The writing of input information into the storage area "Projection" is a result of the program's action.

3. The "Track" program whose block diagram is shown in Fig. 6 serves Stage 03. The program takes from the auxiliary data unit the auxiliary information by track (track number, quantity of sparks, the number of the first gap in which there is a spark) and writes it into the storage area "Projection."

The input information is checked for zero (for lack of information, the message "Zero console" appears on the light panel).

Before the measurement of the first track, the measuring mark is tracked by the program to the reference mark cross of that gap from which the track begins; for this, the coordinates of the reference mark crosses of the status are used.

For the measurement of the second track, the stage "Reference

mark" is omitted and control is given to the "Point" stage.

4. The "Reference mark" program, whose block diagram is shown in Fig. 7, serves Stage 04. The program is designed for the measurement of the coordinates of the reference mark crosses and writes them into the storage area "Projection."

At the beginning of the program, the quantity of reference mark crosses is determined. When the first reference mark cross is measured, the program, by having in status the location of the reference mark crosses, determines the coordinates of the crosses of the frame being measured. 14

For the measurement of the remaining crosses, a check of the coincidence of the measured and calculated coordinates is made. If the coordinates do not agree within the limits of the allowable precision, the error code is set and the message "Remeasure cross" appears. If, while measuring a cross, the operator gets -- after exit from the program -- the message "Remeasure cross," he may try once more to measure this reference cross. After a second error message, the operator remeasures all crosses, starting from the first, since there is the danger that the very first reference cross was badly measured and hence the coordinates of the rest of the crosses were calculated incorrectly. The number of crosses measured is displayed on the indicators of the light panel unit.

At the end of the program, the measurement mark is tracked by the program to the following reference cross. After the measurement of the last cross, a flag is set for end of stage.

5. The program "Point," whose block diagram is shown in Figs. 8a and 8b, services Stage 05. The purpose of the program is the measurement of the coordinates of the track points, the checking of the quality of this measurement, and the writing of the coordinates into the storage area "Projection."

As was pointed out above, the program tracking mode is utilized

for the measurements. The first two points are measured manually, then the manual measurement flag is reset and the measurement mark is program-tracked to the rest of the track points.

All the coordinates are compared to the maximum and minimum allowed values recorded in the status. In case of error, the message "Coordinate error" appears, the program resets the contents of the status and the "Projection" area for a repeated measurement of the first point of the track. /15

The program controls the size of the spark spacing (the message "Increase spacing" or "Decrease spacing"), which is selected so that the number of points taken from each spark is the same.

The gap number, which on transfer to a new spark is increased by one, is controlled in the program. If the gap number exceeds the maximum possible (message -- "Gap number"), then this means that the operator incorrectly determined the number of the first gap at the "Track" stage. The status and the storage area "Projection" are reset for transfer to the "Track" stage.

After a successful measurement of the last point of a track, the end of stage flag is set and a transfer is made to the "Track" stage for the measurement of the next track. After the measurement of the last track on the frame, the number of words in the storage area is written into the "Projection" area. (In case of area overflow, the message "Decrease data" appears on the panel.) Before transfer to the following "Write" stage, the measurement mark is tracked by the program to the first measured reference cross for a comparison measurement.

6. The program "Write" whose block diagram is shown in Fig. 9 serves Stage 06. The purpose of the program is to write the formatted area "Projection" onto magnetic tape and to write in the tape label data concerning the new roll of film.

The control measurement of the first reference cross is carried

out at the beginning of the program. Its coordinate must coincide within the established limits with those written in the area "Projection." If this coincidence is lacking -- that is, if disagreement resulted through the work of the counters of the coordinate recording units -- the operator is informed of the error by the message "Remeasure reference mark."

If at Stage 01 (program "Start") a flag was set at the start of a new film then in the label are written the film number, and as the number of the first frame measured on it -- the number of the current frame.

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The number of the projection is written into the storage area and the whole area is transferred to magnetic tape. At the end of the program, the number of the measured frame from the status cell and the number of the current frame are transcribed into the cell "number of the previously measured frame."

A simplified (without error calculation and interruptions) diagram of the measurement sequence of a photograph for the Gamma-1 experiment is shown in Fig. 10. As was indicated above, the sequence of stages is set up by the operating system.

The programs described above for the electronic computer Electronica 100I were compiled on the ECM BESM-6 by means of the program translator by a co-worker of the LVTA OIYaI,\*V. V. Galaktionov.

The authors offer their sincere thanks to V. V. Galaktionov for the kind permission to use this program and thereby to speed up the development of the mathematical support.

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\*Translators Note: OIYaI = Joint Institute of Nuclear Research



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5. A. Ya. Astakhov, G. V. Navasardyan, OIYaI, 10-10274, Dubna, 1976.

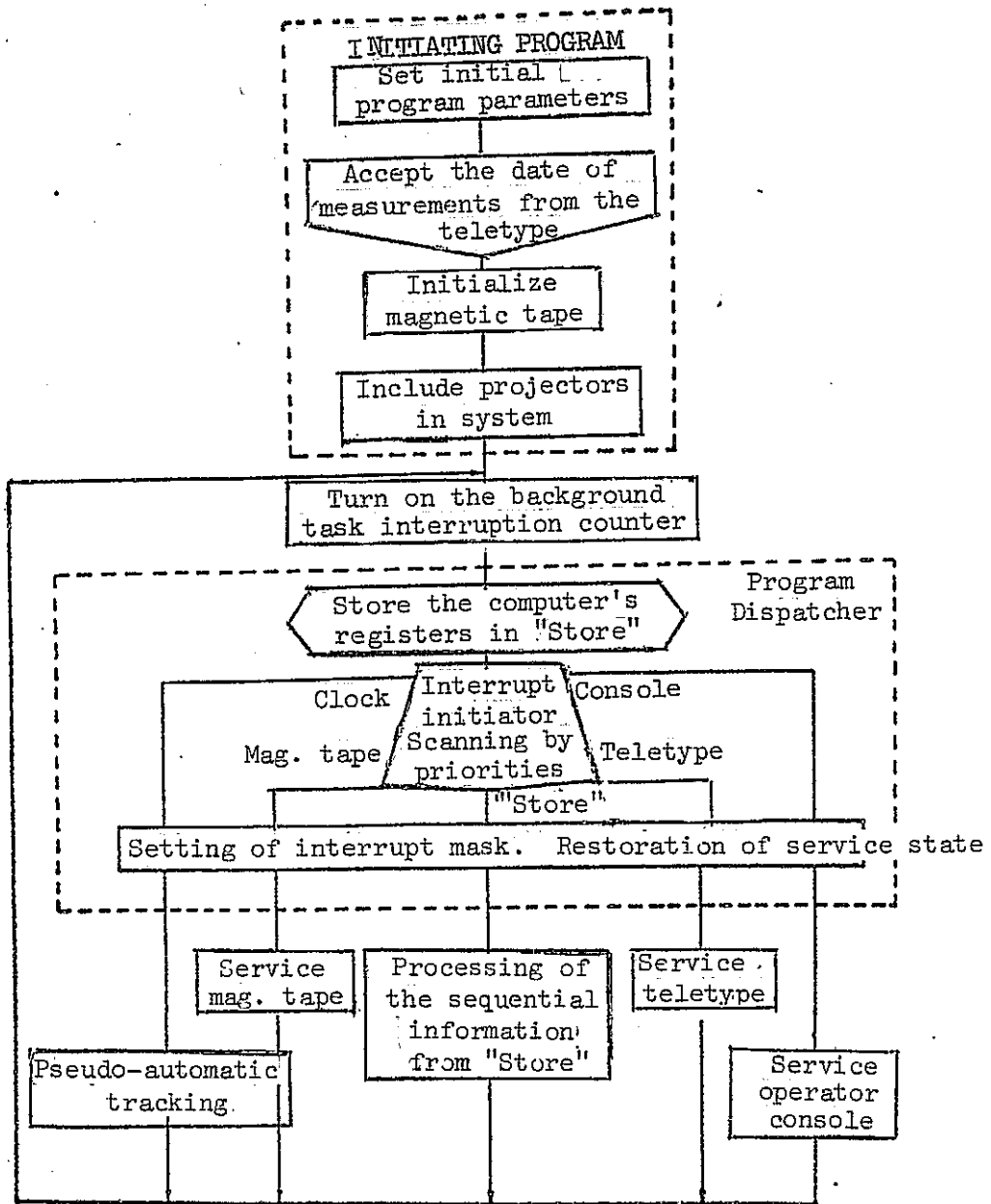


Fig. 1. Structural design of the operating system.

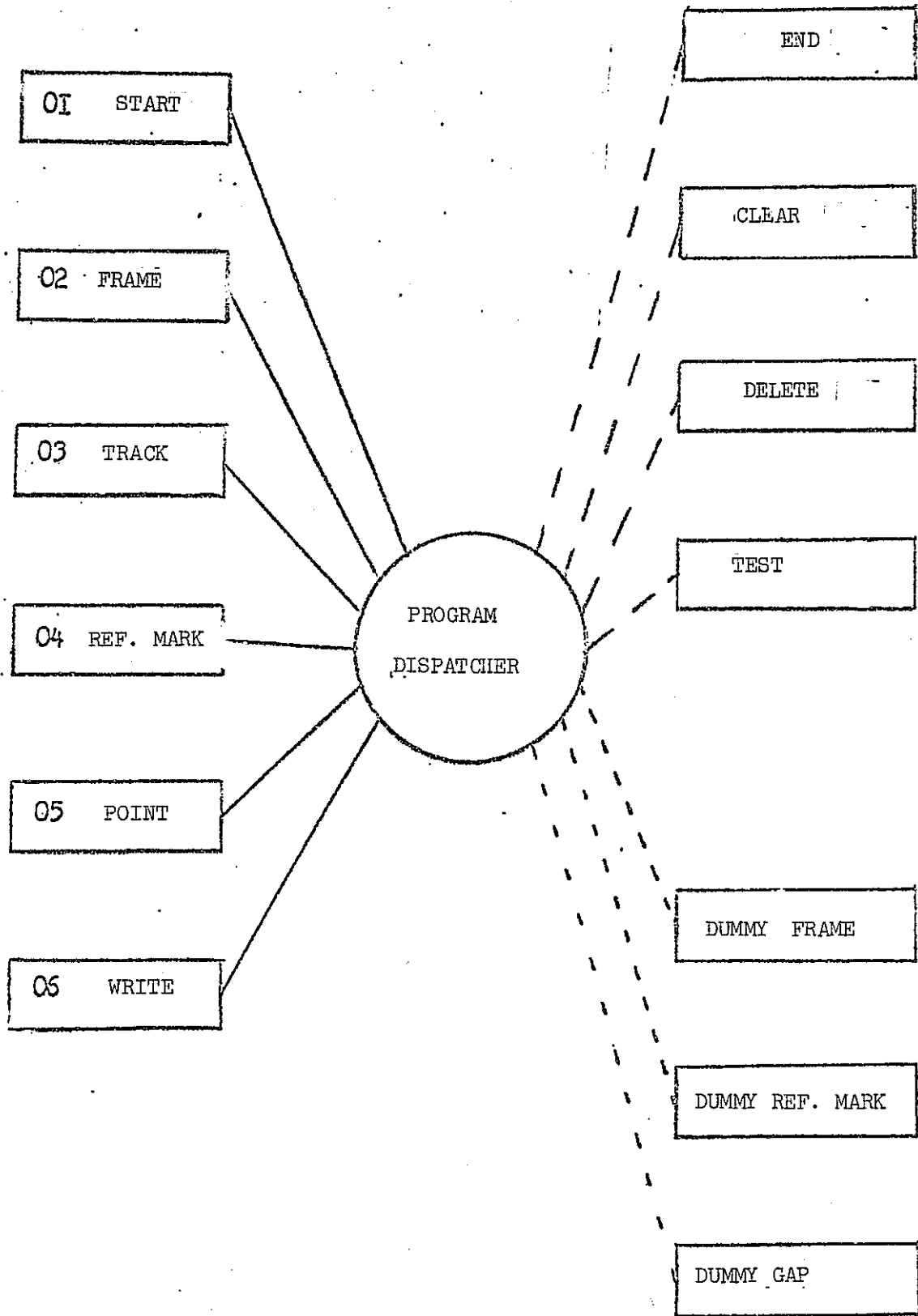


Fig. 2. Functional programs controlled by the dispatcher of the operating system

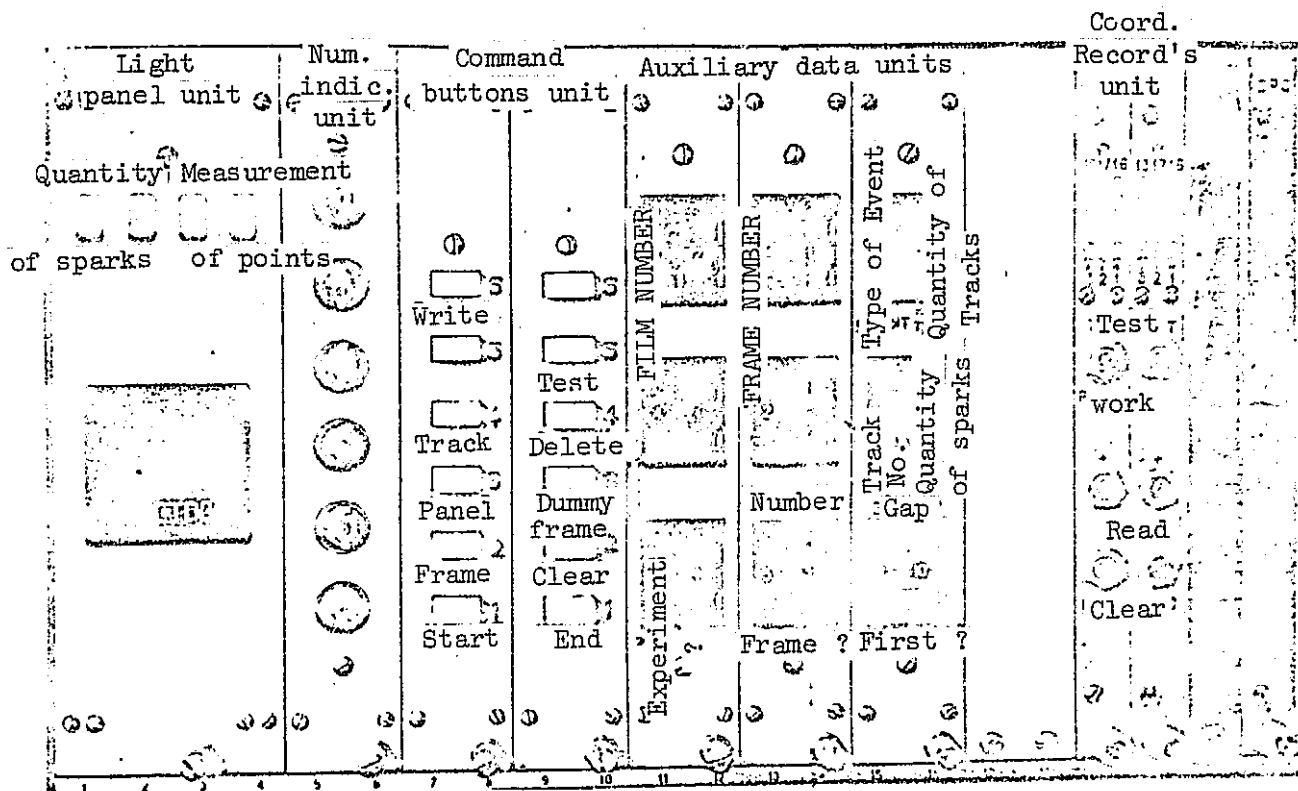


Fig. 3. Data transceiver console

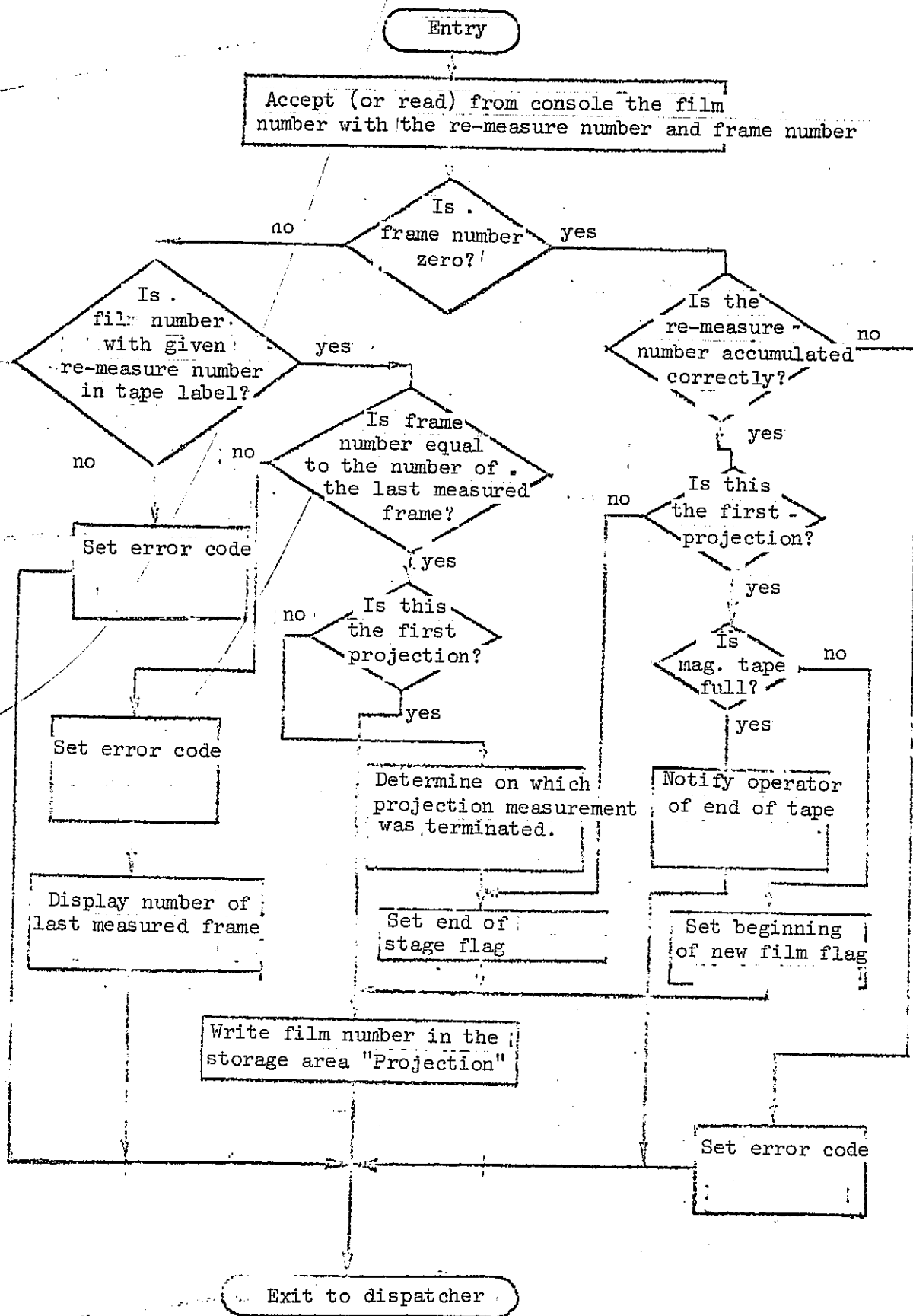


Fig. 4. Block diagram of "Start" program

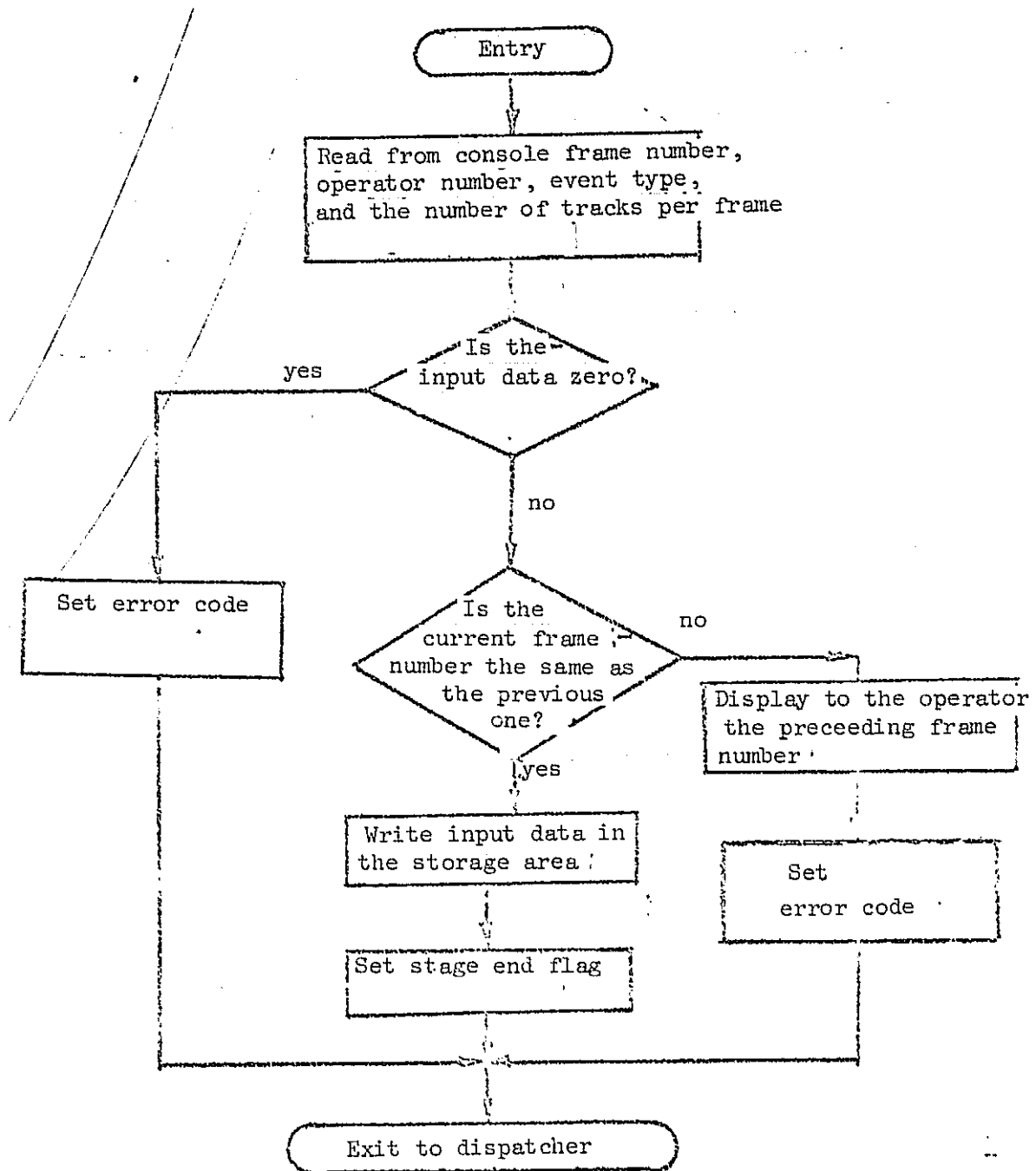


Fig. 5. Block diagram of the "Frame" program

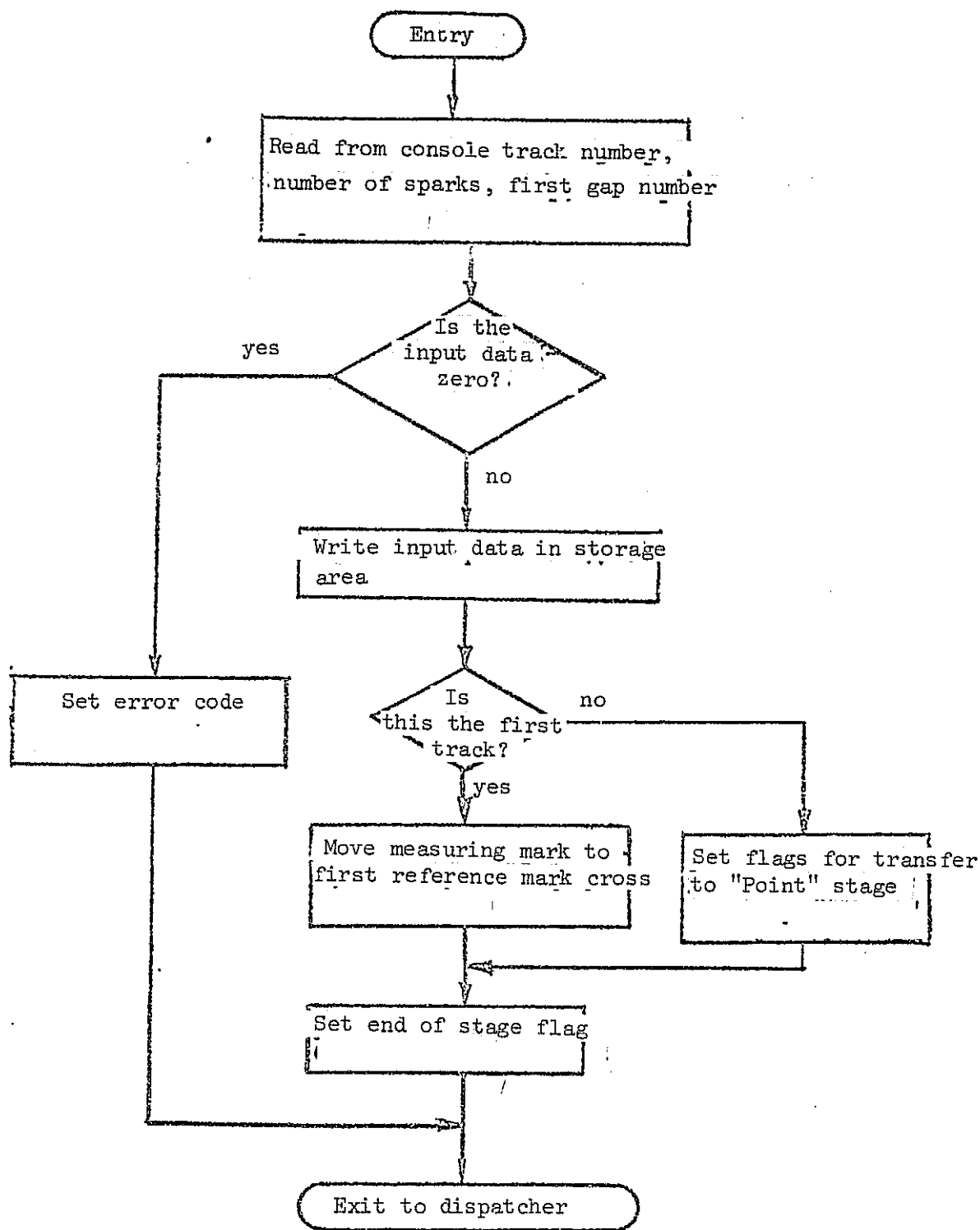


Fig. 6. Block diagram of the "Track" program

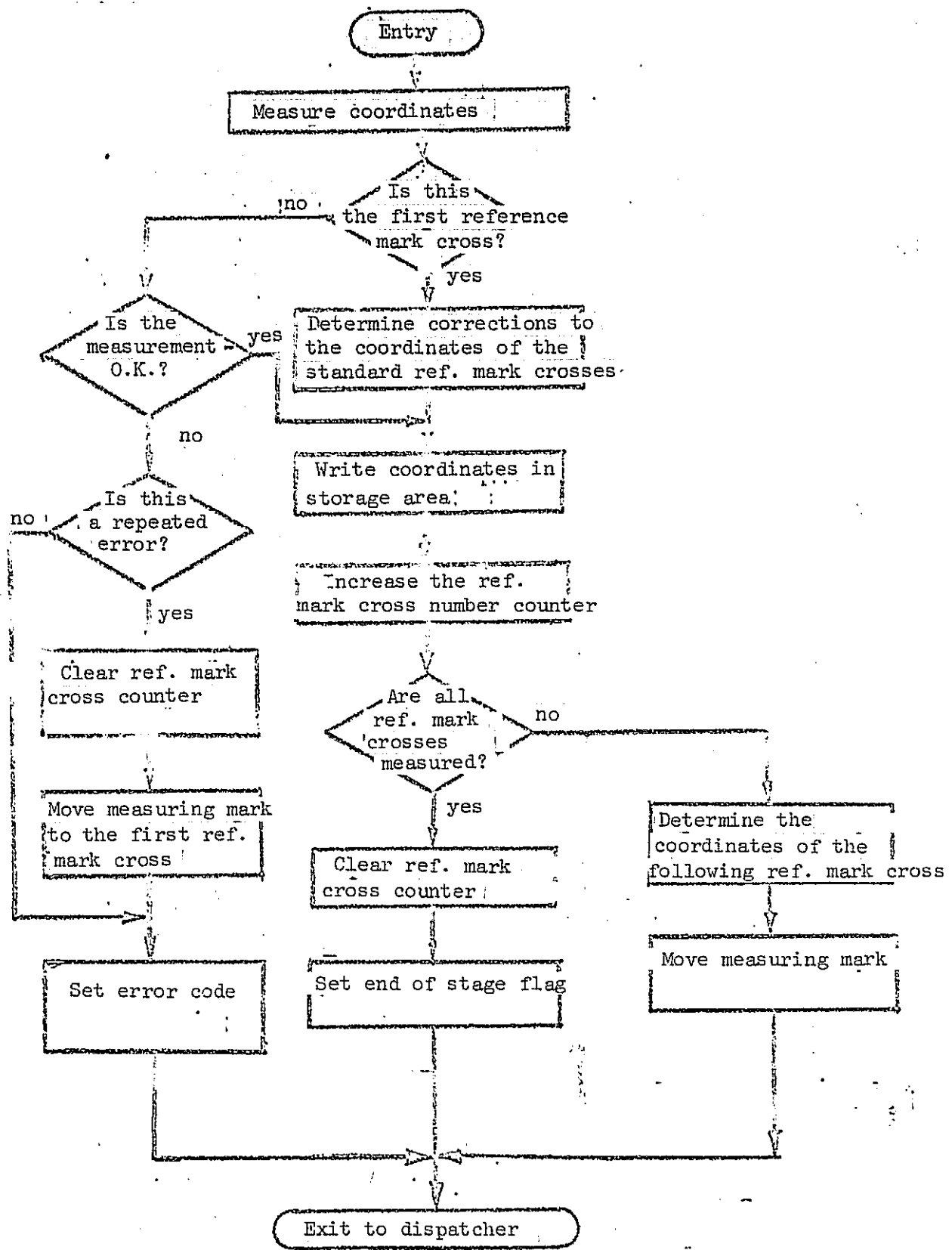


Fig. 7. Block diagram of the "Reference mark" program



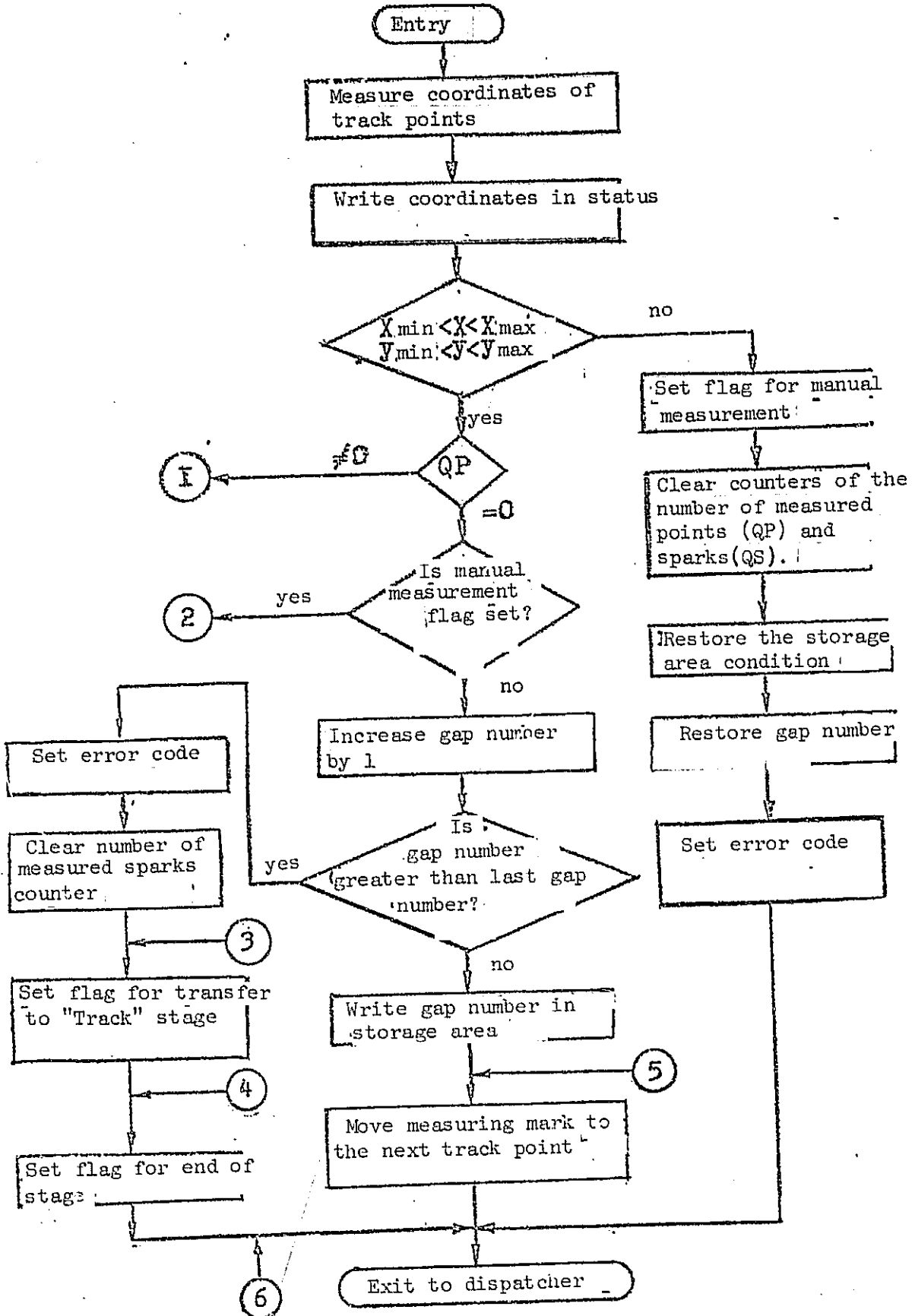


Fig. 8a. Block diagram of the "Point" program

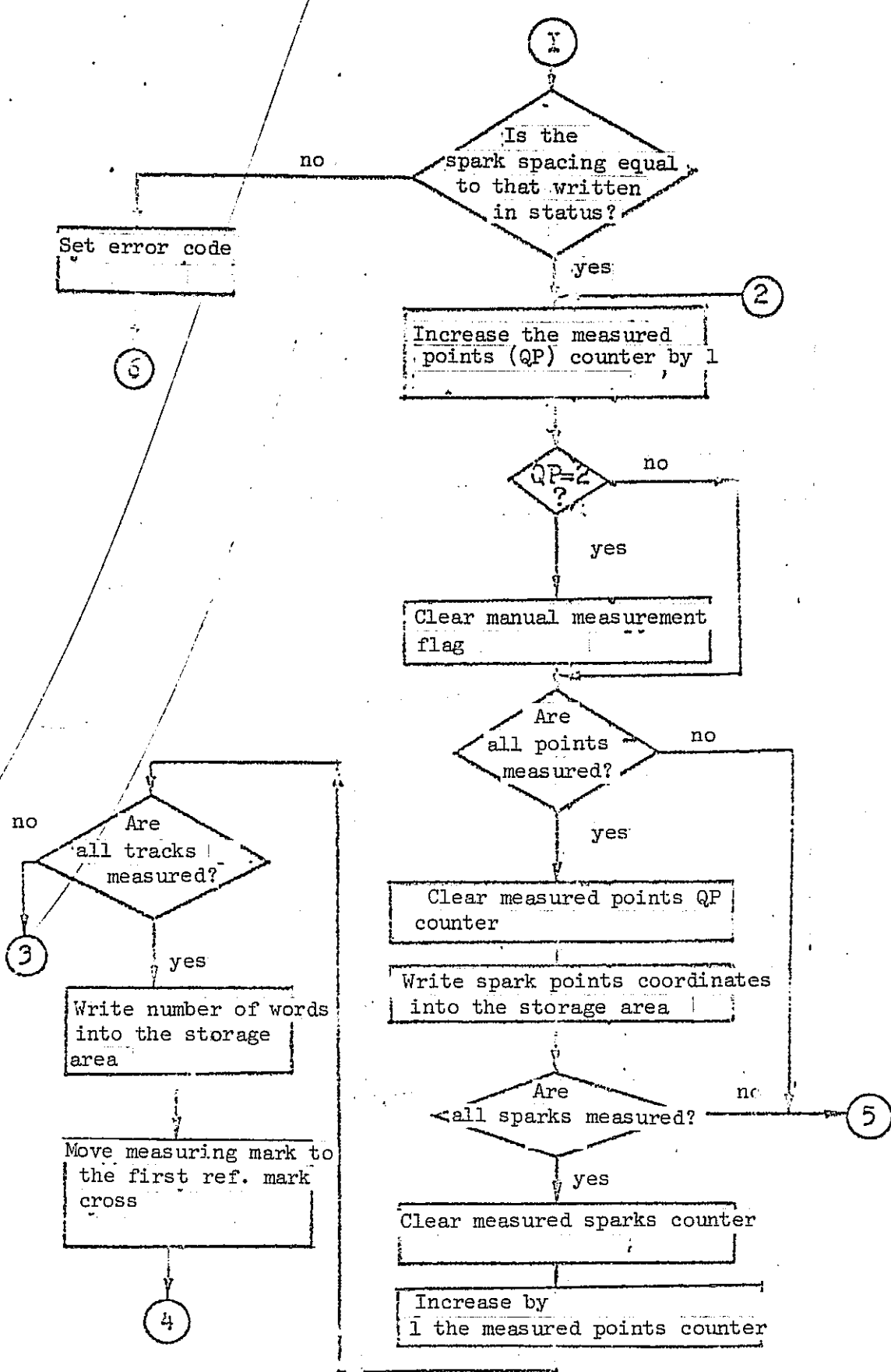


Fig. 8b. Block diagram of the "Point" program (cont'd.)

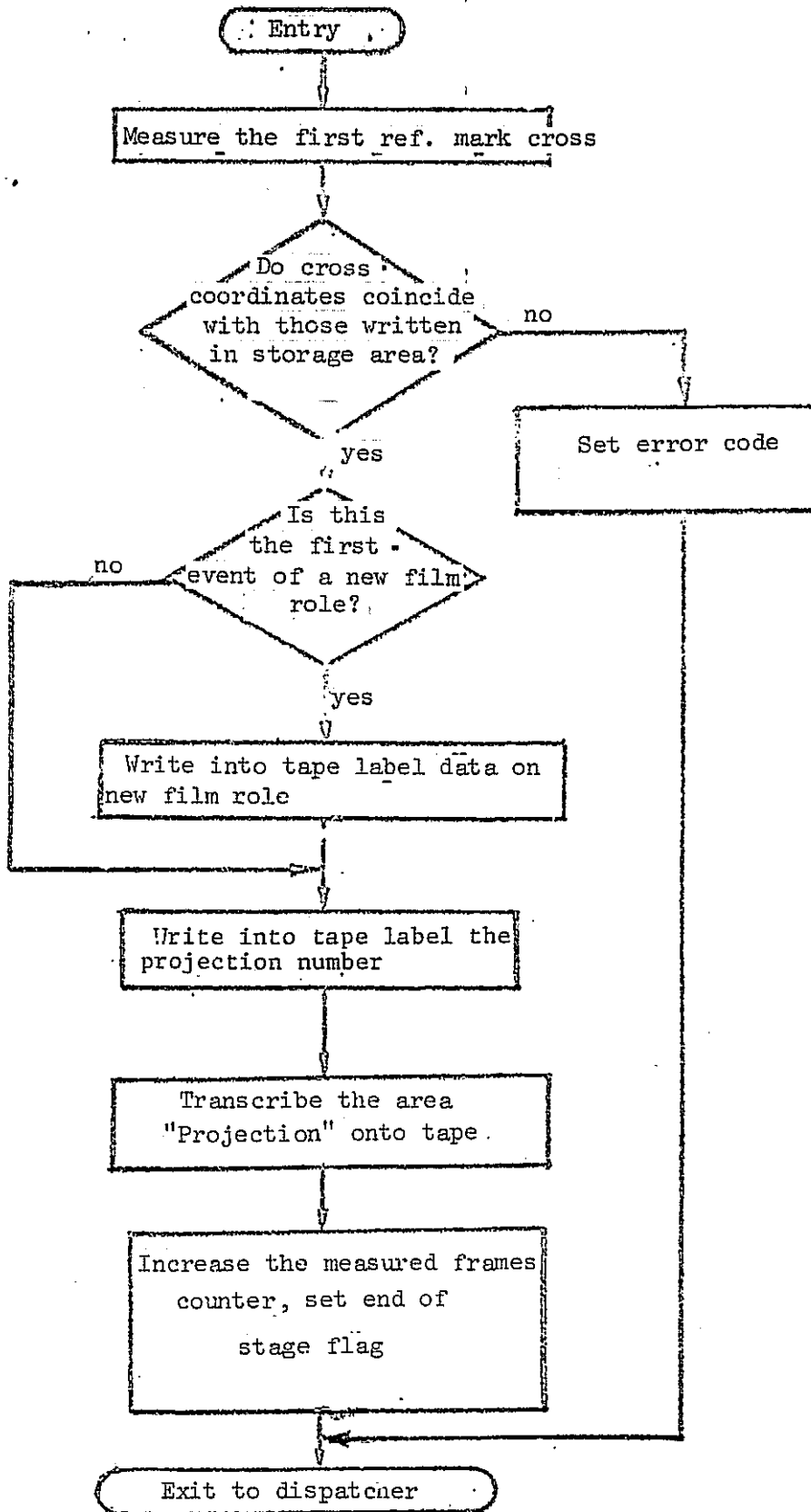


Fig. 9. Block diagram of the "Write" program

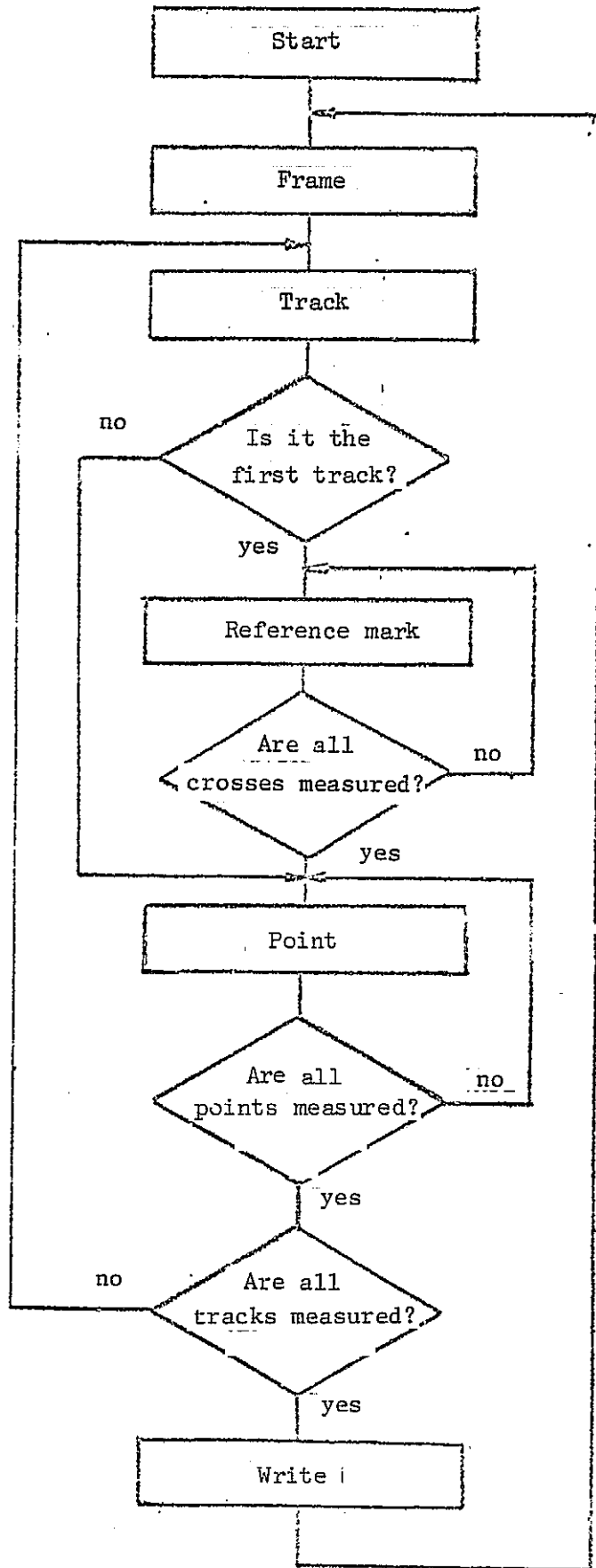


Fig. 10. Sequence of photograph measurement