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SYSTEM FOR PROCESSING GRAPHIC INFORMATION CONCERNING AIRCRAFT SPEEDS, ALTITUDES AND THE OVERLOAD FACTOR USING THE AELT-1 SCANNING DEVICE

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AELT-1 scanning device

The AELT-1 scanning device developed at the Joint Institute for Nuclear Research (JINR) [1] is designed to process information on 35 mm film. The device has been in operation since 1973 and is used for the bulk processing of pictures from the wide-gap spark chamber [2]. Sixty thousand events have been measured on the device and processed, and new physics results have been obtained.

In view of the importance of using devices developed at JINR in other areas of science and the economy, research began in 1974 into the use of the AELT-1 device for processing film containing flight information, and the corresponding software was developed.

The AELT-1 measures the information by means of a computer-controlled cathode-ray tube. A distinctive feature of the device is the interactive control system linking the operator and the computer. The system includes a display-monitor, a light pen, a circuit for controlling the signal discrimination level at the output of the measuring system, an optical screen for projecting the frame being processed and a functional keyboard. The above interactive techniques can be used to assist computer programming during both the taking and analysis of the measurements, thus making for a high level of efficiency and greatly assisting the automatic handling of film containing graphic flight information.

Another important feature of the AELT-1 device is that, where necessary, measurements can be stopped after each line has been scanned in order to process the information which has just been measured. This makes the measurement process more flexible and opens up additional possibilities for processing information (especially at the recognition stage) compared with the miniraster (slice) scanning technique which includes tens or even hundreds of lines. This capability is achieved by using a CRT control computer which is powerful enough to process the information after each scan line.

The measurements are carried out by means of lines, the position of which is defined by the computer. The resolution is 30 μm. The measurement accuracy for single measurement along the lines (across the film) is 15 μm and across one frame without special calibration - 25-50 μm. The frame size is 26 x 19 mm. The BESM-4 control computer has a 12K 45 bit internal store, a 64K magnetic drum store and is capable of performing 16 thousand operations per second.

Processing of flight information

The flight information (fig. 1) processed on the AELT-1 takes the form of speed, altitude and load factor graphs recorded in flight on 35 mm ciné film. All measurements are made in relation to a base line. The task of recognition is made easier by the fact that the graphs do not intersect. However, there are scratches across the graphs and other defects at points on the film, and there may also be breaks in the graphs caused by faulty operation of the recorder. A typical flight graph is 1-2 m long, and is processed in 19 mm sections which are then joined together. Each frame is measured every 0.3 mm in order to cover the main fluctuations in the overload factor line (the other graphs are smoother and do not require such a high measurement density). Defects of one type or another occur on practically every 1-2 m flight graph, and experience has shown that it is not advisable to process these automatically by means of computer programs (large and complicated recognition programs are required which slow down processing and demand an unduly large store). It is extremely difficult to remeasure these sections afterwards using semiautomatic devices, as is done for some pictures in experimental nuclear physics, particularly in view of the difficulty of pointing to the precise point rejected in such long graphs. The authors consider that the best approach in these circumstances is active participation by the operator in the measurement process. The operator can use the control system to communicate with the computer both in order to assist measurements (cyclic scanning of the section of film and extraction of the image on to the monitor, manual control of the discrimination level) and in order to recognize the graphs and filter out the useful information (display with a light pen, optical representation of the section of film which is being processed).

The operator also uses a functional keyboard to communicate with the computer. As in 2 , he can use the functional keyboard to select any particular set of programs and change the algorithm and the degree of automation depending on the problem under investigation and the quality of the section of film being processed.

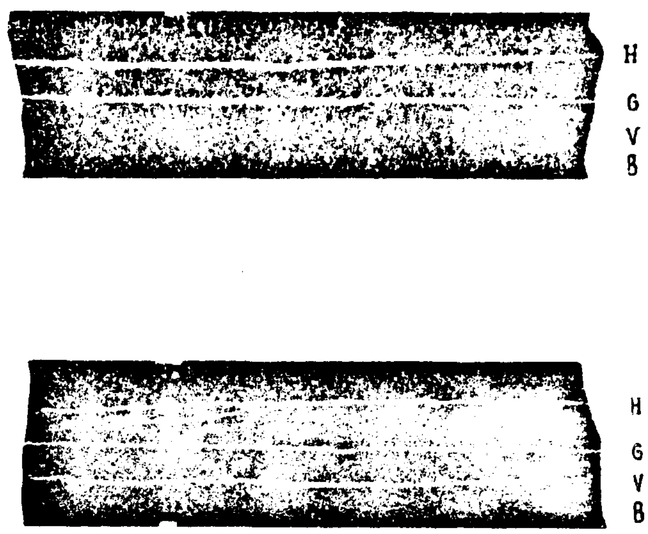

Fig. 1 Speed (V), altitude (H) and overload factor (G) graphs recorded in flight on film. The measurements are made in relation to the base line (B).
A scratch can be seen crossing the altitude plot (H) in the lower picture.

Programming

The flight information films are scanned before they are processed. A special mark is inserted at the end of each flight. The flight data (flight number, aircraft take-off and landing weights, etc.) are recorded on magnetic tape and then transferred to another magnetic tape before the measurements from each flight begin.

When he begins to process the graphic information from the next flight, the operator arranges the film so that the point corresponding to the moment of take-off is visible in the frame being processed. Having measured this frame, the operator uses the light pen to put a mark on the display at the beginning of each graph and to indicate the take-off point. He then gives the instruction to begin automatic processing.

Graph identification is based on the so-called 'string' method 4 . When the position of one point on the graph is known, the computer program plots the corridor (0.4 mm wide) within which the next point on the graph must fall. After taking a measurement 0.3 mm from the known point and discovering the position of the next point in the corridor, the program assumes that it belongs to the graph. The corridor is then plotted in relation to the new point, the next measurement is taken, and the processing is repeated.

Sometimes there are no points and sometimes there is more than one point in the corridor. If there are no points, the corridor is widened to 1.4 mm and the search is repeated. If no points are found in the corridor or if there is more than one point, the 'one and only one' principle is violated, the measurement is rejected and the program moves on to the measurement and processing of the information in the next line. The corridor is then plotted as before in relation to the last known point on the graph. If several lines are scanned for points without success, the automatic recognition process is stopped and the program turns to the operator for help. The frame in question is then scanned to the end and all the measured information is extracted on to the display. At the same time the measured frame is displayed on the optical screen. If the operator sees that outside interference (e.g. a scratch) caused the breakdown of the automatic recognition program, he can use a light pen to mark the points on the graph. If the breakdown was due to faulty tuning of the measurement mode (e.g. a wrong discrimination setting on the display produced too few points or, on the other hand, there were too many points because of the background information), the operator can issue the appropriate instruction in order to switch to the cyclic scanning mode and then establish the optimum read-out mode by referring to the image on the monitor screen. He then instructs the computer to repeat the measurement in the automatic mode.

If weak graph contrast is the cause of the breakdown (faulty operation of the recorder), the operator can use the monitor to tune the measurement process so that the graph points appear even if there is a large background. The automatic recognition mode is switched off in this case since it is highly probable that with this algorithm useful information would otherwise be lost. The operator then uses the light pen in order to indicate on the display screen the points which belong to the graph. This mode (the 'rescuing' mode) is used to process particularly soiled or scratched sections of film.

If a break in the graph is discovered during the automatic recognition process, the operator also uses the display and light pen to mark the points on the 'torn' part of the graph.

Incorrect tuning of the focus or video signal processing channel may be another reason for failure 1 . The program checks the operation of the readout channel by analysing the reference number of count pulses (Q) after each line has been scanned. If a fault occurs (Q fault) the line is remeasured up to 4 times. Short-lived outside interference (drops in voltage etc.) can thus be suppressed. If the number of lines in which a Q fault occurs exceeds a certain limit, the operator is informed (via the display) and makes the necessary adjustment to the operation of the automatic device by referring to the signal's modulation index on the oscilloscope screen (determined by the focussing quality). The frame in question is then measured again.

The most complicated process is the recognition of the overload factor. In addition to the above-mentioned measurement techniques, the operator also has to establish whether or not there is an overload factor. It is assumed that if there is no overload factor the graph falls within a comparatively narrow corridor and is represented by a rather broad line; if there is an overload factor, the corridor opens out sharply and the line becomes thin. A special program analyses the width of the overload factor line and determines whether it falls within a wide or narrow corridor. Identification of the line when there is an overload factor is made even more difficult when the graph is nonmonotonic and features sharp gradients. The search for points therefore has to be made over a comparatively wide corridor (up to 2 mm), and the probability of interference thus increases. Consequently, the operator has to intervene very frequently during the identification of the overload factor line.

All the graphs are identified on the basis of the results from the scanning and processing of each successive line. The flight time per length of processed film is counted at the same time as the graphs are processed: it is assumed that the film is drawn through the recorder sixty times more quickly when there is an overload factor than when there is not.

When the measurement and identification of the graphs on one frame have been completed, the computer program automatically advances the film and moves on to the processing of the next frame.

At the end of each flight a special mark is made on the film in the form of a group of parallel lines. If the program detects a sharp increase in the amount of information, the operator is summoned. When the operator is sure after looking at the optical image that the information on the particular flight has been fully processed, he uses the light pen to mark the point at which the aircraft lands and issues an instruction which confirms that the graphs for that flight have been fully processed and switches overto the next flight.

A flow diagram of the measuring sequence is shown in fig. 2.

Processing by means of analysis programs

The information from each flight, consisting of 10-20 000 digitizings representing the co-ordinates of the points on the graphs, is recorded on magnetic tape. It is then processed without using the automatic device by means of physical programs. An additional check of the information is carried out using special criteria (monotonicity, amount of information etc.), as a result of which the information from some flights is discarded. Up until now, 100 flights have been processed on the AELT-1, and the results from 60-70 of these have been successfully checked. This figure may be increased by directly processing the information by means of physical programs whilst the graphs are being measured and identified.

Accuracy. Efficiency.

Practical experience with the software, which has been in use since 1975, has shown that the technique of marking points on the display at the beginning of each graph and using these points as the initial speed, altitude and load factor readings yields good physical results in the case of the altitude graph (~ 0.1 km) but is lacking in accuracy (contains a systematic error) in the case of the speed and overload factor graphs. As a further development of the software, it is planned to eliminate these defects and increase the accuracy of the initial measurements on the speed and overload factor

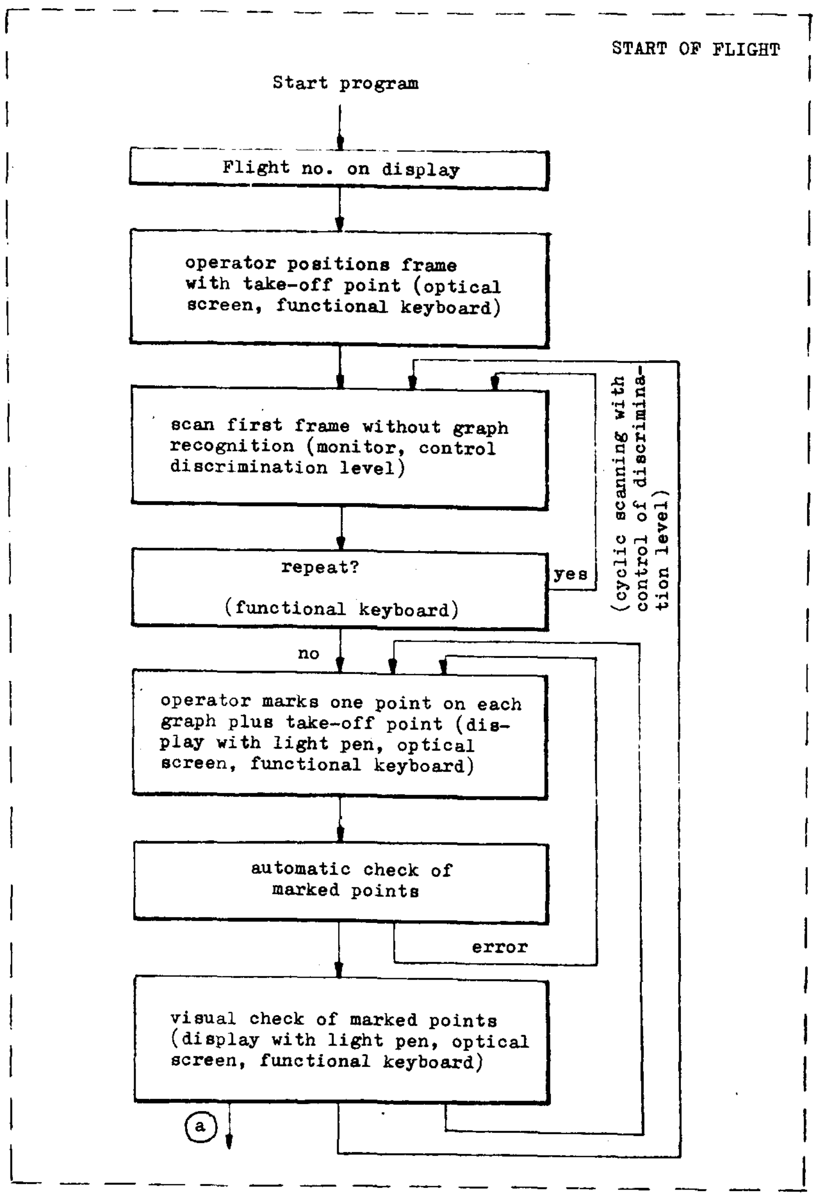

Fig. 2 Flow chart of the program

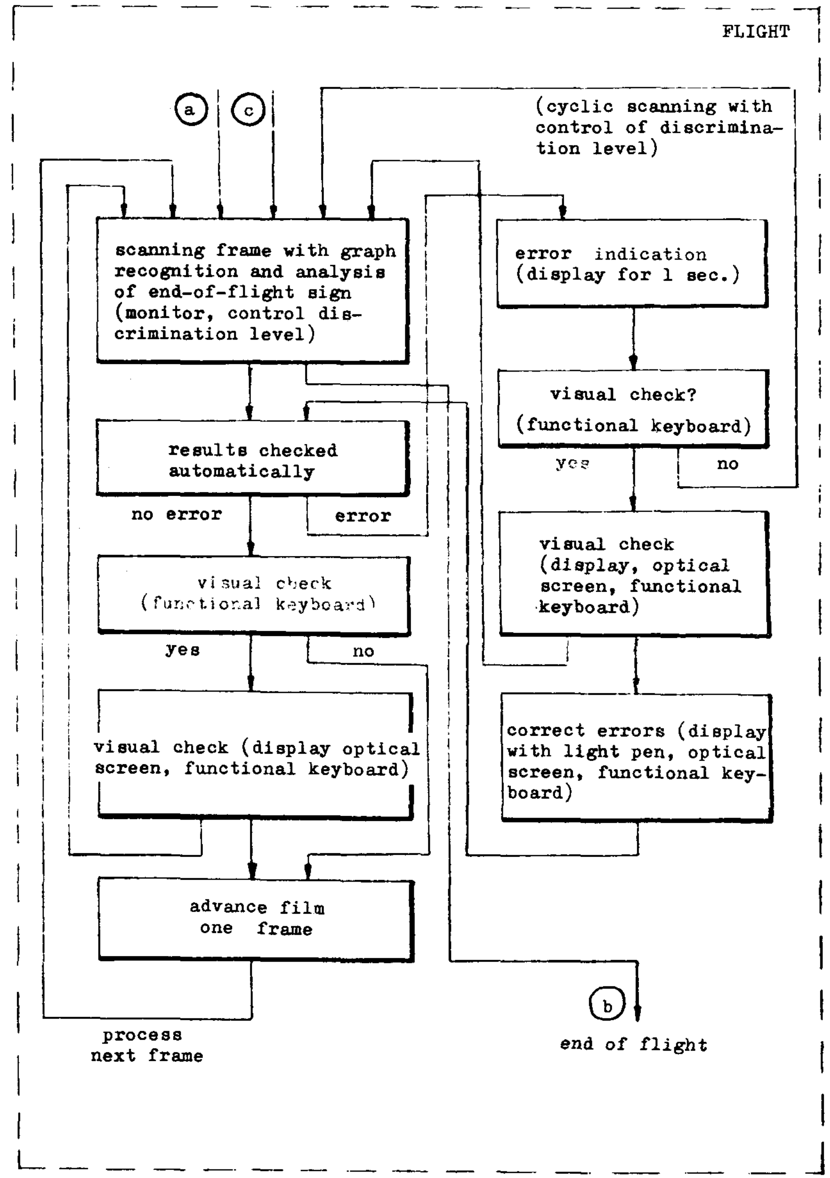

Fig. 2 (continued)

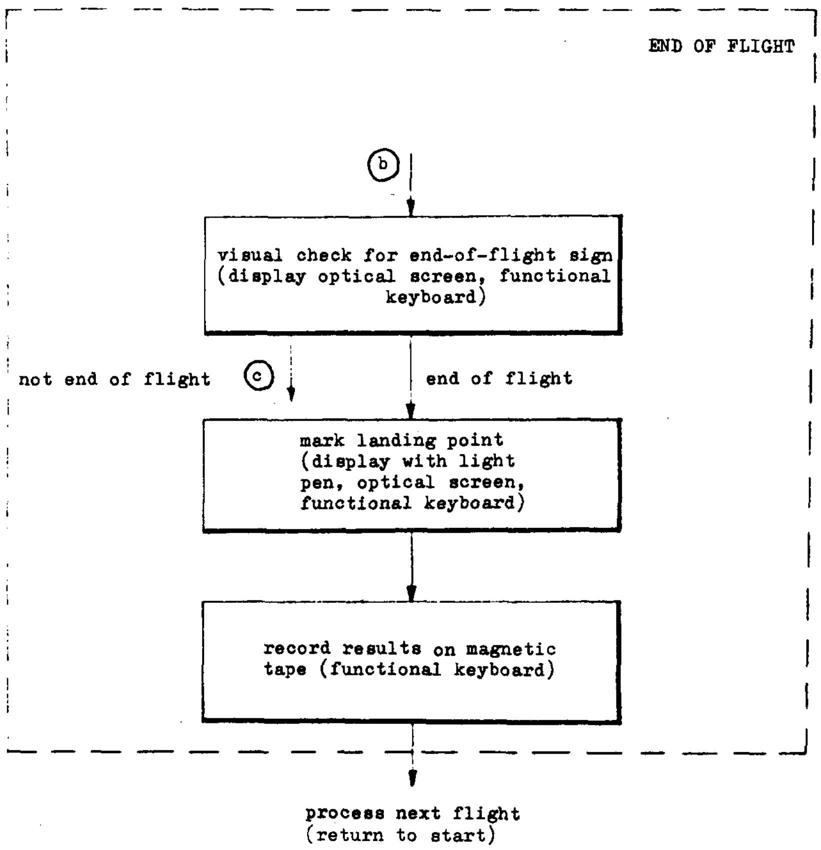

Fig. 2 (continued)

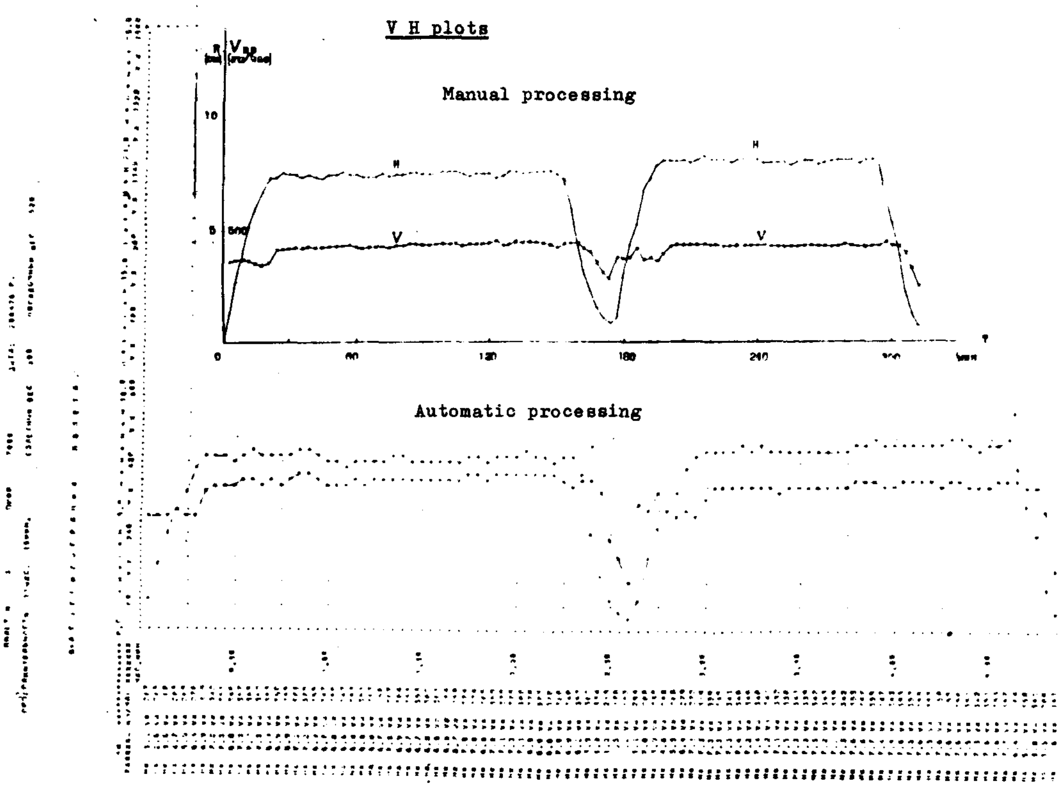

Fig. 3. VH plot for an IL-18 flight

graphs by using a special scanning technique.

It takes 1-2 hours (depending on the quality of the film) to process one film containing 5-10 flight records (a 12 m film), and 40 min if physical programs are used (the results appear on a print-out).

Results

Height and speed graphs (V H plots) for 359 flights by IL-18 aircraft have been processed (the barograms are used to obtain the absolute flight altitudes and the speedograms illustrate the relative variation in speed). By analysing the barograms the typical flight graph is plotted in which the holding areas, periods of acceleration, climbing, descent and level flight are distinguished. The probability of changes in flight level for meteorological or fuel economy reasons is calculated. The results from the large number of V H plots for separate flights (fig. 3) can be used by experts in aircraft stability, control systems and flight data to improve the technical characteristics of aircraft.

It is planned to use the processing system on the IL-62 and TU-144 in the future. The mass processing of the film will be carried out on the AELT-IM scanning device which is being developed jointly by JINR and TsAGI and which uses the same software as the AELT-1.

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