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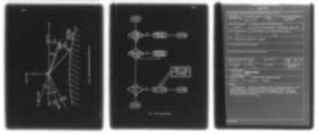

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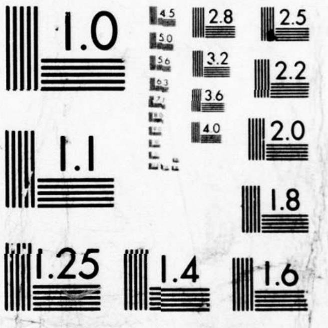

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ROYAL AIRCRAFT ESTABLISHMENT

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Technical Report 77071

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MIRANDA DATA PROCESSING -PROGRAMS

by

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SUMMARY

Miranda was a low-orbit technology satellite carrying a number of experimental packages. A comprehensive software system was developed for its operational support and the processing of experimental data. This Report outlines the various categories of data processing employed, and describes each program that was provided.

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1 INTRODUCTION

The UK technology satellite, Miranda[1] (1974-13A), was launched on 9 March 1974. It had an operational life of nine months and carried a number of scientific experiments. A previous Report[2] detailed the interfaces relevant to designing the software packages described in the present Report. The software fulfilled specific tasks which originated from the requirements for operational support[3], subsystem evaluation, and both the immediate performance evaluation for and long-term analysis of the experiments.

A decision was taken to carry out all data-processing and operations-support tasks on the Control Centre computer. It was in general ideal to provide one program per task rather than to combine the software for several tasks into one program, since most of the objectives which had large amounts of software in common required to process different sets of data; also, computer space was limited, magnetic tapes (for program storage) were plentiful, and there was a need to maintain simplicity wherever possible. An exception was with Quick Look requirements, where analysis for most of the subsystems and experiments was performed in the same program. The software for experimental analysis was largely written after launch, when the characteristics of certain parameters became clearly understood, in particular with respect to attitude modelling.

The programs which required Miranda telemetry data all obtained the data from magnetic tapes, written in standard format (as specified in Ref 2), and referred to* as 'digital tapes'.

2 CATEGORIES OF DATA PROCESSING

For scientific and technological satellites the data processing commitment of the operational Control Centre does not usually extend beyond data archiving and simple quick-look procedures. For Miranda, however, the amount of free computer time, during hours of manning, was considered to be adequate for all the necessary data-processing and operational-support activities. Also the computer was considered sufficiently powerful to perform all foreseeable tasks. Thus, at an early stage, a decision was taken to perform all Miranda software tasks on the Control Centre computer.

The time available for data processing during a group of morning or evening passes was limited by operational requirements, whereas considerable time was

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* The Miranda Control Centre used two kinds of magnetic tapes, containing Miranda telemetry data - referred to as 'analogue tapes' and 'digital tapes'. Analogue tapes contained complete sets of unprocessed telemetry data as received from the satellite. Digital tapes contained complete passes of formatted telemetry data, for direct use on the computer magnetic tape decks.

available between groups of passes. For most of the long-term experimental objectives, an assessment of in-orbit data was required before methods of analysis could be finalised. There was also a four- to six-week delay in obtaining the good orbital elements which most of the experimental data processing needed. Furthermore the effort available for system design and software production was limited - it being mainly available during the year before and the year after launch. Thus the various data processing activities had to be categorised, to allow essential aspects to be undertaken with minimum delay, while retaining sufficient flexibility to cope with anomalous situations and not incurring unnecessary delays in other data processing. When formalising the data-processing and operations-support requirements for the satellite controller, technical advisers and experimenters, the following categories were used.

2.1 Pre-pass

This category of processing was mainly related to the scheduling of passes and events which would influence the course of a pass.

2.2 Immediate post-pass

Assuming computer availability, as much routine data processing as possible is ideally done immediately after each pass. The program QLK was written for this purpose - it covered evaluation of the performance of most of the Miranda subsystems, as well as the initial processing for the satellite experiments, and included the routines which evaluated and summarised the operational status of the satellite for the Satellite Controller.

Also included in this category of processing were the programs used in the evaluation of attitude manoeuvres for earth and star acquisition. These programs required the latest information relating to the attitude of the satellite, in order to determine the necessary command sequences to be sent to the satellite on subsequent passes.

2.3 Other post-pass regular

From the outset it seemed likely that on occasions time would not permit all routine processing to be performed immediately after a pass; hence there was a category of processing which incorporated those requirements for which a delay of two to three hours would cause no inconvenience.

2.4 Long-term

Any data processing requirement which required good attitude and orbital data, and which did not affect the general operations plan, was considered to fall into this category. This covered the major part of the data processing for the experiments which were also dependent on an assessment of in-orbit data to finalise definition of methods of analysis.

During the periods of experimental interest, attitude manoeuvres were often performed; these were, however, confined to periods of direct data, so that during each period of recorded data the pitch rate was constant. Further it was possible to derive the satellite attitude accurately as a simple function of time from the data received during a pass. For the particular programs it was thus considered essential to provide automatic methods of attitude determination using only data from the pass under analysis.

The programs for the analysis of the experimental data are described in separate sections for Experiments A, B, C and D.

2.5 Available on request

Data processing experience on other satellites had shown that it was impossible, within reasonable bounds, for routinely used software to cover all contingencies. Furthermore, were it possible, the amount of computer output would be too great for assimilation. It was therefore considered necessary to make available a group of programs which could list any selected set of telemetry parameters.

There were also utility programs, which were built from modules of other software to meet minor but recurrent needs.

3 PRE-PASS PROGRAMS

3.1 Program for Look Angle Prediction (PLP)

Given the orbital elements of the satellite, the location of a ground station and an (extended) period of time, PLP searched for the periods of time during which the satellite was above the horizon. (For a more detailed description '6130PLAP' of Ref 4 should be consulted.)

Input was controlled by commands typed on the console. Though all the data could be input via the console, it was naturally more convenient to input the orbital elements via the tape reader since they arrived on 5-track paper tape. If periods of visibility were required for more than one station, the input of station co-ordinates was again via the tape reader.

Some output was generated on the console and some on the lineprinter. Console output occurred when the computer was waiting for a command or for data. Output on the lineprinter consisted of orbital elements as read from the tape reader, followed by the heading 'look angles from Lasham', day number, date, and a tabulation of time, elevation, and azimuth during the period the satellite was above the nominal horizon. The usual period of predictions was 14 days, so the program was run once a fortnight.

3.2 Program to produce Orbit Summary (PAL1)

PAL1 extended the orbital elements of the satellite read in from 5-track paper tape to a set of constants required by PAL2 and transferred them to a special storage area on a serial disc. When supplied with a day number via the console, an 'orbit summary' of various parameters including perigee height, apogee height and inclination, appeared on the lineprinter - an example is given in Fig 1.

The program was run whenever an orbit summary was required for a particular day, and whenever more recent elements became available, provided that this would not interfere with the continuity of gyro assessment analysis (as logged by PAL2 - see section 5.1).

3.3 Eclipse Angle Prediction

This program was used to monitor the onset of eclipse. It provided horizon depression-angle data over part of each orbit. This was used to predict two phenomena: (i) the times when the albedo or spectrally reflected light would enter the field of view of the fine sun sensor - as it was thought that this might cause an offset of the pitch axis; and (ii) the start of eclipse.

The program generated satellite position in one-minute steps, printing out the depression angle of the earth's horizon from the sun-direction whenever this was less than 30°.

The program used SDC orbital elements as input data and was run whenever new orbital elements were available. The lineprinter output consisted of the depression angles tabulated against time.

4 IMMEDIATE POST-PASS PROGRAMS

4.1 Quick Look (QLK)

QLK was used to provide the operations group, technical advisers and experimenters with partly analysed satellite data, as soon as possible after a pass.

The data-control software (see Appendix) was designed for processing digital tapes, and it enabled a number of mutually exclusive user requirements to be effectively met in parallel. Thus the QLK processing for one person in no way affected, or was affected by, the requirements of others.

The program was limited by the size of the computer, but this caused no problems as there was another program - RLK (see section 5.2) - for meeting routine requirements for which delays of a few hours would be tolerable. The QLK data processing covered the following:-

(i) the operations group;
(ii) the power subsystem;
(iii) the data handling subsystem;
(iv) all satellite temperature monitors;
(v) optimum gain evaluations for the IR sensor;
(vi) the initial and final frame counts for each batch of data;
(vii) Experiment B;
(viii) Experiment C;
(ix) Experiment E.

The program obtained satellite data from a digital tape and produced one lineprinter sheet for each of the above requirements, suitably annotated and automatically addressed for distribution. An example of the output for requirement (iv) is given in Fig 2.

4.2 Star Lock/Look (SLK)

(a) Operations plan

To give an adequate description of SLK, it is first necessary to refer to the operational sequence of events that were adopted to achieve star lock. This sequence, for a series of consecutive passes was as given in the table below.

Pass	Event	
E_3	Command: Mode 3 (inertial sun-lock) Command: 0°/h pitch rate	
M_1	Collect telemetry data Run SLK prior to next pass	
M_2	At T_1:	Command: alignment pitch rate
(M_3)	No action	
E_1	At T_2:	Command: Mode 5 (star acquisition and lock) Command: ±20°/h (as selected) Command: Pitch integrator to 0°/h
E_2	Assess lock	
(E_3)	Assess lock	

Note: M and E denote Morning and Evening passes; in principle the sequence could equally well have been started with an M_3 pass, but it was generally more practical to make the star-lock assessment phase in the evening.

The times T_1 and T_2 were selected by the Satellite Controller, before starting the star-lock procedure, as times which were convenient for command sending.

Setting the satellite to 0°/h pitch rate, at the start of the sequence, was considered to be necessary when the operational sequence and the program SLK were originally formulated. At that time, due to inadequate telemetry accuracy of the parameters from which the pitch rate was deduced, it was considered that a known particular pitch rate should be set and that this should be zero. Subsequent analysis of in-orbit data, however, showed how the telemetry could be used to determine the pitch rate uniquely, so that in principle the 0°/h command could have been omitted and the operational sequence started at M_1. These modifications were in fact incorporated during the late summer when it was found that it was necessary, because of the coldness of the South pole, to change the method of horizon detection (previously used by SLK) from fixed-threshold-IR sensing to rate-of-change-of-IR-signal sensing.

The ±20°/h drive rates (prime rate combinations of $+12^\circ$/h and $+8^\circ$/h or -12°/h and -8°/h) were selected to maximise the chance of observing the star with sufficient time for the ACS to update the pitch-integrator compensation loop, before the star signals were cut off by the earth-albedo-protection sensors.

For controlling the pitch rate the satellite contained a 12-bit register (known as the pitch integrator register) which biased the pitch gyro at any selected rate with magnitude up to 30°/h. This had to be used whenever an accurate pitch attitude was subsequently required at a given instant; also it was much more convenient if it could be used with 0°/h prime rate (rather than with any of the other rates) during an alignment manoeuvre. Since the operational requirement was to achieve star lock on the selected star, starting from any satellite pitch attitude, the times T_1 and T_2 had to be chosen at least six hours apart (and in practice about ten hours apart) so that an alignment manoeuvre was always possible by suitable choice of pitch alignment rate to be commanded at T_1. The satellite would then be in the correct orientation at T_2 for the selected 20°/h sweep rate to be commanded with the Mode 5 star-lock-initiate command.

The program could be used for a *star-look* exercise instead of a *star-lock* exercise, by simply omitting the Mode 5 command at T_2.

(b) Program description

The primary objective of SLK was to evaluate the alignment rate command tc be sent to the satellite at time T_1. Essentially two major items had to be evaluated - the attitude (ie pitch angle) that the satellite was expected to have at time T_1, and the attitude that it was required to have at time T_2.

From the telemetry data (usually received during the M_1 pass), horizon crossings (as indicated by the changing signals of the IR_1 detector) were analysed to provide horizon-position-reference times. Then, using the satellite and sun positions at those times, the attitudes were evaluated. A straight line was fitted through the attitude-time points at the known pitch rate (usually 0^o/h), from which the attitude at T_1 was extrapolated.

In order to evaluate the required satellite attitude at T_2, the characteristics of the star-sensor and attitude-control protection systems were employed. There was a glare detector, which operated automatically, and an infra-red detector (IR4) which could be brought into use by ground command. Since the characteristics of the glare detector were not fully determinable before launch it was initially decided to employ IR4. Its field of view was in the opposite direction to that of the star sensor and its principle of use was that only when it was sensing infra-red radiation from the earth did it allow the star-sensor signals into the attitude control system. This was over the part of the satellite's orbit which lay between the earth and the star. SLK evaluated the times, T_A and T_B, at which the satellite would, respectively, enter and leave this part of the orbit, subsequent to the time T_2. Then, if T_S was the time at which it was aimed to first observe the star, the period between T_S and T_B could be used by the ACS to update the pitch-integrator compensation of the pitch gyro drift. Thus ideally T_S should have been as close as possible to T_A. The predicted attitude at T_S was, however, subject to extrapolation errors over a period of ten to twelve hours, for which adequate allowance had to be made - so the most suitable estimate of T_S was taken to be given by:

$$T_S = 0.75T_A + 0.25T_B .$$

When in orbit, however, the glare detector (which operated automatically) was surprisingly restrictive. It allowed the sensor to operate between a pair of times, $T_A + \tau_A$ and $T_B + \tau_B$, say, where τ_A and τ_B were both positive and virtually constant. Thus in practice it was found that T_S was better given by $T_S = 0.43T_A + 0.57T_B$. Also in practice, it was found that the period between $T_A + \tau_A$ and T_B, allowed by the use of both protectors was inadequate, so IR_4 was not used for control-system protection. 71

From a knowledge of the star and sun directions, and the orientation of the star sensor in the satellite, the required attitude for observation of the star at T_S was determined, and using the selected drive rate the required attitude at T_2 was computed.

Knowing the times T_1 and T_2, and having determined the satellite attitude at those times, SLK determined the required alignment rate, which was converted to the actual command pattern that had to be sent to Miranda.

Finally, from a knowledge of the star and sun directions the angle between them, ie the elongation, was computed and hence the optimum setting of the star-sensor mirror was evaluated.

The program used a selected pass of data from a digital tape (usually the actual tape which was made in real-time; see APP - section 5.3) and required orbital elements. It also required information to be provided on a special form, an example of which is given in Fig 3.

The lineprinter output gave the alignment-rate command and the required star-sensor mirror-position number, together with annotated details of the major stages of computation, so ensuring that anomalous situations would be observed - such as when the radiance from the South pole was below the horizon-detection threshold. Fig 4 gives the output corresponding to the data of Fig 3.

4.3 Special Earth Lock

The program evaluated the pitch-attitude manoeuvres which would set the satellite at the required attitude for an earth-pointing exercise. This initially required 85 to 90 elements of the 100-element albedo array pointing below the horizon and the remainder looking out to space, so that the pitch-rate could be commanded to orbital rate at that time.

The procedures adopted were almost identical to the SLK procedures up to the selected time T_2. At that time the attitude had to be correct for the commanding of a pitch-rate equal to orbital rate.

The input data consisted of a digital tape and SDC orbital elements. In addition the times T_1 and T_2 were input via the console. The output consisted of a lineprinter sheet giving details of the attitude modelling, the attitude-time points, the alignment rate command and the pitch integrator value required to trim the nominal orbital rate into the actual orbital rate.

5 POST-PASS REGULAR PROGRAMS

5.1 Pitch Attitude Log (PAL2)

The main object of PAL2 was to produce a continuous log, on lineprinter paper, of all events significant to the ACS experiment (Experiment A) - Fig 5 gives a typical page of output. A subsidiary object was the updating of a Pitch Measurement File, held on magnetic tape. The relation between the Pitch Attitude Log and the Pitch Measurement File was that a measurement number was allocated to certain of the PAL 'significant events' and that information relating to the numbered events was stored in a record of the Pitch Measurement File, one record to each event. The events of principal interest were measurements of pitch attitude by sensors associated with Experiments A, B, C and D. For detail about the Pitch Attitude Log, beyond that given in this section, Ref 5 should be consulted.

The program was run after every pass and included data in chronological order. To achieve continuity, lineprinter output, corresponding to an incomplete lineprinter sheet, was held on a disc file in such a way that the output from the next PAL2 run would reproduce this sheet with extra material added.

The Pitch Measurement File was updated through a 'father-son' editing procedure with a 'grandfather' tape held in reserve as a precaution against tape damage. This file was required by other programs (see sections 7.1 and 7.2) in the assessment of the performance of the gyroscopes.

The log consisted of eight columns as follows:-

(i) Date.

(ii) Universal time.

(iii) Argument of latitude.

(iv) Measurement number: this was the serial number referred to for attitude measurements; it was generated whenever such a measurement was made unless the satellite was controlled by active pitch sensing. In addition, pseudo numbers were generated corresponding to any change in satellite status and to all crossings of the Lasham latitude, whether data was being collected at such times or not.

(v) Pitch angle relative to ecliptic north.

(vi) Pitch angle relative to the plane defined by the earth-sun line and the local vertical at the instant the satellite crossed the Lasham latitude.

(vii) A multiple column indicating ACS status; individual characters of this indicated the satellite mode, its pitch rate, the pitch integrator constant whenever applicable, gyro status and gas jet status.

(viii) A column containing codes which identified any ground commands sent and the type of sensor involved in an attitude measurement, etc. Entries in the log were in chronological order. Special entries indicated the beginning of data from a new pass (code NP) and the end of data (EP). The amount of gas present was evaluated at the start and end of a pass, thus enabling an estimate to be made of the gas consumed.

5.2 Routine Look (RLK)

This program was essentially an extension of QLK, covering requirements for which delays of a few hours would be tolerable. In fact most of the requirements which fell into this category were fitted into QLK, leaving only two requirements, each of which was relatively large. The first was to give complete images of the 100-element albedo sensor, for both recorded and direct data. The second was to provide an elementary star map - consisting of the active star-sensor outputs together with the great-circle sky track on which the sensor could observe. (The long-term data processing used other star mapping programs - see section 9.)

RLK obtained satellite data from digital tapes. In addition, SDC orbital elements were required. The output was to the lineprinter, suitably annotated and addressed.

5.3 Append (APP)

The basic system for generating Miranda digital tapes involved the transfer of data from a single pass - normally digitised real-time - to a scratch tape, storage being in a standard format[2], in which the end of data was recognised by a pair of consecutive tape-marks. To retain a separate tape for every pass would have been inconvenient and uneconomical, so APP was written to concatenate multi-pass data to a single tape, the individual passes each being terminated by *single* tape-marks. The term 'digital tape' then became applicable equally to the basic tapes and to concatenated tapes, the former being effectively special cases of the latter.

The operational requirement was to keep one tape for each day's data. Thus APP was normally run once per day. Any output tape was automatically valid as an input tape, however, so the concatenation could be performed in several stages.

Operation of the program was straightforward. APP was told, via the console, the number of input tapes and the serial number of the output tape. All information from each input tape, in the order loaded, was copied to the output tape, including header blocks and tape-marks, until a pair of consecutive tape-marks was located, of which only the first was copied. With the last tape, of course, the second tape-mark was copied as well, to indicate tape terminations.

5.4 Digital Tape Log (LOG)

LOG gave a brief summary of the information contained on a digital tape. It counted the number of direct and replay frames in each pass, noting the time of the initial and final frames. It also counted the number of frames that failed the checksum test[2], and computed the bit error rate.

Lineprinter output (identifiable by the tape serial number, copied from console input) consisted of the following items for each pass: (a) the tape number; (b) header block; (c) initial and final frame times and count numbers; (d) the number of direct and recorded frames that were good and bad; (e) the error bit rate.

The program was run every day, usually after APP (section 5.3), to provide a summary of the daily digital tape.

6 UTILITY PROGRAMS

6.1 Emergency Look (ELK)

Two versions of this program were available. The first, or standard ELK, could provide up to 14 columns of time-ordered sets of data on the lineprinter, using a selected pass of data. The alternative version, referred to as Extra Word Look (XLK), could provide up to 10 columns of time-ordered sets of data, together with the associated extra words (see Appendix of Ref 2). The standard ELK was used very extensively, some 2000 times during the life of the satellite, while XLK was rarely used.

The programs were designed around a special data form, see Fig 6, on which the analyst could fill in the syllable number and minor frame identity for each of the desired parameters. The minor frame identities were 0, 1, ..., 7 for distinct minor frames, or 'A' for all minor frames, while the syllable numbers were the standard octal values given in the Appendix of Ref 3. Each set of data could be output in octal (thus providing easy status recognition) or in decimal. A letter 'O' in the last column called for output of that set of data to be in octal - octal values being identifiable by a preceding asterisk. If known, the initial frame-counter value and the number of frames, for the data of interest, could be entered on the form, otherwise the complete pass of data was used. The special-data-form information was input line by line on the console. Each line that did not conform to the specified syntax was immediately rejected, thus minimising the effects of operator error.

The program scanned the selected pass of data from a digital tape and provided one line of output on the lineprinter for each minor frame within the specified range of frame counts for which data was required. Fig 7 gives the output corresponding to the input of Fig 6.

6.2 ACS Parameter Lists (WLK)

The program WLK was in many ways similar to ELK. It required a special data form, shown in Fig 8, and provided columns of time-ordered sets of data on the lineprinter from a selected pass of data on a standard digital tape.

Either or both of two data scans could be requested; the first produced up to 13 sets of data, modified according to specified calibrations, the second produced values of the roll, pitch and yaw integrators, together with up to 10 sets of data in octal. Since the ACS parameters were not sub-commutated, only syllable numbers were required to identify parameters. The initial and final counter values (of the band of interest) had to be entered on the form, and data was input in the same way as in ELK. The lineprinter output consisted of a line of data for each minor frame in the band of interest, for each of the selected scans.

6.3 Elongation Angle

The angle subtended at a satellite by any particular star and the sun is known as the elongation of the star. During the course of a year this angle varies, approximately sinusoidally. The Miranda attitude control system kept the satellite's pitch axis in the sun-pointing direction, and the star sensor contained a mirror which could be rotated to change the sensor's field of view. For purposes of experimental planning, it was necessary to know the times during the year when the sensor's field of view could accommodate a selected star.

The distance of the satellite from the centre of the earth being negligible in comparison with distance of the stars and sun from the centre of the earth, the program only needed to use sun and star data. The input to the program consisted of right ascension and declination of the selected star and the lineprinter output gave the elongation angle and best mirror position number 07
1200 GMT for each day of the year.

6.4 Attitude for Star Observation

Owing to the nature of the operations involving the star sensor, it was desirable to have available a simple and quick method of checking possible star observations. Satellite attitude information was readily available, so this program was formulated to compute the satellite attitude that would be necessary for observation of any particular star. Since the satellite's pitch axis always pointed at the sun, and its orbital position was close to the centre of the earth, relative to the positions of the sun and stars, the required attitude was only a function of the selected star and time of year. The input data consisted of the right ascension and declination of the selected star together with the day number. The lineprinter output gave the input data together with the necessary attitude as evaluated at the day. (The attitude angle was the angle between the yaw axis and the plane containing the sun direction and north-polar direction, see Fig 9.)

6.5 Oddities on a Digital tape (ODD)

ODD, analysed a selected pass of data from a digital tape and listed events that might be regarded as 'oddities'. It looked at four items for each frame of data: the checkword; the time indicated; the frame counter; and whether direct or replay. The initial frame time t_1 (say) and frame counter c_1 were stored, and a note made of whether the data was in direct or replay mode. The program predicted that the next frame time would be $t_1 + 0.5$ s (±0.1 s), that c_1 would be superseded by $c_1 + 1 \pmod{2^{12}}$, and that direct data would remain direct (and replay remain replay). If the prediction was not satisfied the 'oddity' (or oddities) would be listed and a prediction made for the next frame assuming the time etc to be as at the oddity frame. This process was repeated until the end-of-pass tape-mark was reached.

The detected oddities were listed on the lineprinter through messages such as: 'time not correct, predicted time ....., obtained time ....'; 'direct predicted, replay obtained', 'checkword not equal to 1', or 'count did not check, predicted count ......, obtained count ......'.

The program was run whenever there was a suspicion of faulty data.

7 PROGRAMS FOR EXPERIMENT A^5

7.1 Smoothing of Pitch Attitude Measurements (SPAM)

71 SPAM made a least-squares time-linear fit to the attitude measurements obtained from the IR1 detector. Observations with residuals exceeding three

standard deviations were excluded and the least-squares fit procedure repeated with the remaining observations. Examination of SPAM output has shown that rejections were all due to errors in the timing of recorded data, resulting from the fact that this timing was not fully automatic - see the comments in Ref 2. Finally, all attitude measurements (from the infra-red sensor, albedo sensors and star sensor) were examined and any which differed by more than 2° from the fit function eliminated (see Ref 5).

Input, via the console, consisted of the initial and final measurement numbers of the interval to be covered, together with the measurement numbers of any measurements to be rejected *ab initio*. Measurement numbers and pitch angles were read from the Pitch Measurement File produced by PAL2 (see section 5.1).

The following items were output to the lineprinter:-

(i) Reference date assuming an understood reference time at zero hours on that date.

(ii) The first measurement number specified in the program input (which might have been rejected in the processing), together with its time relative to the reference time.

(iii) The first three sub-columns of the status column in the Pitch Attitude Log, giving the ACS mode and the nominal pitch rate.

(iv) The number of observations employed in the final fit.

(v) The best estimate, B, of attitude at the reference time and the best estimate, W, of pitch rate.

(vi) All the attitude measurements not excluded by the above 2° rule, with asterisks indicating the observations used to derive the final fit.

(vii) The measurement number followed by the observed pitch angle, quoted relative to two different datums: first, relative to ecliptic north (as in the fifth column of the Pitch Attitude Log - see section 5.1); second, relative to the plane defined by the earth-sun line and the earth's polar axis (see Fig 9).

(viii) Miscellaneous items for use if sensor errors were investigated.

(ix) The assumed height of the horizon above sea level.

7.2 Gyro Rate of Drift (GROD)

GROD extracted the contents of the roll and yaw integrator registers for every frame of recorded data. Using the best fit for pitch attitude data, each sample was corrected to take account of the earth orbit rate around the sun. Time averages were then evaluated for all data obtained in the pass, and further 07 averages for all the passes obtained during each particular period of constant pitch rate.

The attitude of the satellite (as output by SPAM, ie B and W for a specified reference time) had to be input via the console, together with the index number of the pass to be analysed. Such input was required for all the passes to be analysed. Lineprinter output consisted of the mean of all the samples of yaw and drift rates, and the number of samples used.

The program was run whenever analysis was required for a number of passes satisfying the following conditions:-

(a) the nominal pitch rate was constant and did not exceed 30°/h;

(b) the pitch rate had been at a constant rate for not less than eight hours (usually data twelve hours later was the earliest used).

8 PROGRAMS FOR EXPERIMENT B^6

8.1 IR Detector Responsivities

The purpose of the program was to evaluate the comparative responsivity of each of the four detectors of the infra-red sensor using a selected pass of data, by analysis of data samples obtained when the detectors were observing space. For each detector, when viewing space, the transmitted signals were compared with pre-launch ground calibrations as functions of sensor in-orbit temperature. The comparisons were averaged over a large number of data samples to minimise quantisation errors, and standard deviations were provided to give checks on the validity of data and sensor performance.

In order to select only those data samples which were obtained when each of the detectors was observing space, the initial and final frames counts were input (via the console) for the period of observation of each detector, as obtained from standard QLK output. In principle this task could have been avoided by using the automatic attitude-determination procedures which were used in most of the long-term data processing. However, as these were still under development it was decided that the small amount of manual effort was worthwhile in order to obtain results rapidly. The program analysed data for selected passes from digital tapes and the results were output to the lineprinter.

8.2 Radiance Mapping

There were four programs; two were written to satisfy the initial requirements and the other two after further demands were made. Basically, all four programs were constructed and operated in the same way. The programs analysed

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data from each pass on a digital tape, scanning each pass of data twice. The first scan was to evaluate an attitude model (see Appendix, section A4) and the second to perform the required data processing.

The first three programs used the same type of attitude modelling. Horizon position fixing data was available from the IR1 detector, and the programs were used to analyse data corresponding to periods when the satellite was in Mode 3 (inertial sun-lock mode) and had a low pitch rate - usually $\pm 25^{\circ}$/h. The fourth program was used to analyse data received when the satellite was operating in Mode 2 (sun acquisition mode) during the last month of its life. Horizon position fixing data was obtained from the IR1 detector and, so long as at least two fixes were obtained, the pitch-gyro rate outputs could be integrated and scaled to provide an adequate attitude model.

From a knowledge of the satellite attitude and orbital position, it was determined, for the IR detector under consideration, whether or not the data samples were from observation of earth or space; only earth observation data was used, this being converted into radiance measurements using the pre-flight calibrations with in-orbit responsivity evaluations (see section 8.1). Using also a standard earth-shape the ground position of infra-red emission was determined and converted into latitude and longitude (to the nearest degree). In addition, for each sample the following items were computed and tabulated: sun-elevation relative to ground position (negative if below horizon); satellite elevation relative to ground position; and the condition of the sun with respect to the ground position - continuous dark, continuous light, rising or setting.

In addition to the digital tapes, orbital elements and values for responsivity were required for each program, and the output was produced on the lineprinter.

8.2.1 Radiance Mapping 1

This was the most important of the set of four programs. It analysed only data from the IR1 detector, which was the primary detector of the infra-red sensor. Full details of each radiance sample (as described above) were tabulated on the lineprinter.

Means and standard deviations of the radiance were computed corresponding to each of the latitudes 0°, 5°, 10°, ..., 85°. If desired, the analysis could be extended to a number of digital tapes. At the end of processing each digital tape, a paper tape of all carry-over quantities was made, and checked 071 (for punching errors) by reading it back in before program termination. This paper tape was then used as input for the processing of the next digital tape.

8.2.2 Radiance Mapping 2

This program provided radiance mapping information for all earth-observation data samples from detectors IR2, IR3 and IR4. There was no statistical analysis.

8.2.3 Radiance Mapping 3

This program was a modification of Radiance Mapping 1. It provided only the radiance mapping information of those earth-observed positions where the latitudes were 0°, 5°, 10°, ..., 85°. There was no statistical analysis.

8.2.4 Radiance Mapping 4

This program was used when the satellite was in Mode 2 to give: (i) the same radiance mapping information as described in Radiance Mapping 3, and (ii) the same statistical data as described in Radiance Mapping 1.

8.3 IR Horizon Characteristics

The purpose of the program was to evaluate the characteristic height of the IR horizon, using data obtained from the satellite when operating in star-lock mode.

When the satellite was in star-lock, two of the satellite axes were controlled with reference to the sun, and the third axis with reference to the selected star. Thus potentially the attitude of the satellite could be determined very accurately, subject to good orbital position determination which was itself dependent on the achievable timing accuracy. The most suitable detector of the infra-red sensor was IR1, as its data-sampling frequency was the highest. The direction of the centre-line of the IR1 field of view was almost constant, when the satellite was in star-lock, and during the course of an orbit it crossed the earth's horizon twice.

For each IR1 data sample in the region of an horizon crossing, the IR1 centre-line position was determined accurately from a knowledge of the star position, the satellite's orbital position and the relative orientation of the star sensor and the IR1 detector (see Appendix). The data sample was converted into a radiance measurement and the height of the centre-line above (or below) the earth was determined using a standard earth-shape.

The input to the program consisted of a digital tape, RAE orbital elements[2], and right ascension and declination of the star. In addition the initial and final frame counter values, for the data of interest, were input via the console; these were obtained from QLK output. The radiance measurements and horizon heights were output to the lineprinter, suitably annotated with time, etc.

9 PROGRAMS FOR EXPERIMENT C^7

The star sensor, when actively viewing space, gave two output signals, one giving a measure of light intensity and the other an error signal which was a difference signal from the split-image of the detector. A glare detector was used to ensure that the sensor was rendered inactive when observing relatively bright objects such as the earth (in practice for a given star direction the star could actively be observed for about one-third of the orbit). As a star crossed the field of view of the detector, the error signal passed through a null. The star-mapping programs could have used this principle for star detection, but there were not many star crossings and there were a number of occasions when the background light intensity was high - and so produced an error-signal bias in excess of the error signals from some of the fainter stars. Hence it was decided to produce programs which (for selected passes of data) output all the active sensor signals.

The output was in the form of a list on the lineprinter, giving each pair of sensor samples together with the time of the difference sample, and the right ascension (α) and declination (δ) of the centre-line field of view at that time. To provide α and δ, the attitude of the satellite had to be evaluated. Three methods of attitude determination were applicable and covered mutually exclusive periods. A complete star mapping program was provided for each method of attitude determination, the output being the same.

Each program used digital tapes as input and required orbital elements. The calibrations used for the pitch rates were those determined by the program SPAM (see section 7.1).

9.1 Star Mapping 1

This program scanned the data from each selected satellite pass twice, the first time to evaluate an attitude model and the second time to produce the star sensor data. The attitude model used horizon position fixing data from the 100-element albedo sensor, obtained when the satellite was rotating about the pitch axis at approximately orbit rate.

9.2 Star Mapping 2

This program scanned the data from each selected satellite pass just once, to produce the star sensor data. The attitude information was input in the form of two attitude-time points and an approximate pitch-rate, via the console. The program was used on data recorded when the satellite was rotating at orbit rate with the 100-element albedo sensor set to its lowest sensitivity, as in this configuration there was no horizon position fixing data available for attitude modelling.

9.3 Star Mapping 3

This program scanned the data from each selected satellite pass twice, the first time to evaluate an attitude model and the second time to produce the star sensor data. The attitude model used horizon position fixing data from the infra-red sensor, obtained when the satellite was rotating about the pitch axis at a rate less than 25°/h in magnitude.

10 PROGRAMS FOR EXPERIMENT D[8]

Three programs were used in the analysis of the distribution of albedo intensity near the terminator, known as DINT1, DINT2 and DINT3. The first two programs were used when the satellite was in the special earth-pointing mode, while the third covered periods when the pitch rate was held constant, in the numerical range 8°/h to 25°/h, for periods of two or three days. The albedo sensor had three integration times (known as sensitivity settings), viz 16 ms, 4 ms and 1 ms. With an integration time of either 16 ms or 4 ms, attitude could be determined from data collected by the 100-element array, but for 1 ms integration time this was not possible and a pair of independent attitude-time points had to be provided via the console.

The objective of the DINT programs was to analyse the response of the elements of the albedo sensor in relation to the variable intensity of illumination near the terminator, the results being expressed in terms of 'probability of albedo trigger'. For DINT1 and DINT2 this probability was tabulated, for each sensitivity, against a 'latitude angle', θ, relative to the nominal terminator. (The nominal terminator was defined by the geocentric plane perpendicular to the sun-line, θ being taken as positive for points on the sunlit side.) For DINT3 the tabulation was against local elevation angle, α, as well as θ.

A DINT survey consisted of the analysis of a number of passes, from one or more digital tapes. The programs asked, for each pass, whether or not the pass was required for the survey, so a list of the required passes had to be prepared in advance. If a survey could not be completed in a single session with the computer, a continuity facility was employed, involving a carry-over paper tape as with Radiance Mapping 1 (see section 8.2.1).

10.1 Illumination distribution (DINT1)

DINT1 was used only for sensitivities of 4 ms and 16 ms, when the program could determine its own attitude model for each pass. If, through lack of horizon crossings, this determination was not possible, the pass in question was rejected. The program scanned the data (for each pass) twice, the first scan to evaluate the attitude model and the second to analyse the sensor data in detail. From a knowledge of attitude and array orientation, the array elements pointing to earth and space were determined. For each element pointing towards the earth, the latitude angle θ of the ground position observed relative to the terminator was determined, the region of interest being from $\theta = -5.5^{\circ}$ to $\theta = 20.5^{\circ}$ divided into 26 1°-bands. The program reserved a pair of storage locations for each of the 26 bands, effectively an ON box and an OFF box, and for each element observing the earth, corresponding to one of the bands, the appropriate box was incremented.

The contents of the ON and OFF boxes for each of the 1° bands were listed on the lineprinter at the end of each pass, results from preceding passes of the survey being included. At the end of the survey the trigger probability table was output.

10.2 Illumination distribution (DINT2)

DINT2 differed from DINT1 in that it was used for the 1 ms sensitivity setting, when the attitude model had to be provided via the console. For the pair of attitude-time points required, one time had to be prior to the commencement of the first pass of the survey and the other subsequent to the termination of the last pass. It was essential that the pitch rate was not changed between these times.

10.3 Illumination distribution (DINT3)

DINT3 based its attitude model on horizon fixing from IR-sensor data, instead of from the albedo sensor. Analysis was similar to that for DINT1, but a second angle was required for the ground position observed by each array element, viz the elevation angle α of the satellite from that ground position. Thus the data in the ON and OFF boxes was accumulated for a range of α values as well as a set of θ bands. (However, only one sensitivity was covered, since data was only available for 16 ms sensitivity.) There were only 12 1°-bands for θ this time, covering the range -5.5° to 6.5°. The α subdivision was based 07 on rounding α to the nearest 5° and accumulation for 17 values, viz 10°, 15°, 20°, ..., 90°. The line printer table at the end of a survey was of trigger probabilities for the 204 (12 × 17) pairs of θ, α values.

11 OTHER EXPERIMENTS

For Experiment E no long-term data processing was required as all its data processing was incorporated in QLK.

There was, however, one unplanned experiment. After launch, when it was found that automatic processing of attitude data could be achieved, it was realised that Miranda offered a unique in-orbit test-platform for aerial polar diagram measurements.

11.1 Aerial

This was the program which evaluated the aerial polar-diagram angles, θ and ϕ. The program used the attitude model based on the IR1 detector. With a knowledge of the ground position and the satellite attitude, the orientation of the satellite relative to the ground-station antenna was evaluated in terms of θ and ϕ.

The program used digital tapes and orbital elements as input data, and produced lineprinter listings of θ and ϕ (as functions of time) to be used in conjunction with the AGC ground recordings made at Lasham, the ground station.

12 CONCLUDING REMARKS

The success of the Miranda data processing can be measured by the fact that all planned objectives, and indeed a number more, were met within a year of launch. This was largely a consequence of having structured the software in such a way as to allow easy modification of existing requirements and inclusion of further requirements. The structuring took full advantage of the fact that all the data for one day was on one magnetic tape, thus simplifying the operator interaction and increasing the reliability.

For data processing on similar satellites it is recommended that the same philosophy be used with small changes in detail, in particular:-

(i) ensure that the Quick Look and Routine Look programs cover all sub-systems thoroughly but concisely;

(ii) provide an abbreviated version of the pitch attitude log containing only the major operational and attitude events;

(iii) make the Emergency Look program more flexible, by allowing data to be requested in engineering units, as an alternative to decimal and octal.

Acknowledgments

The authors are indebted to R.H. Gooding for formulating the programs PAL1, PAL2 and GROD, and to A.W. Odell for providing the program PLP.

Appendix

SOFTWARE STRUCTURE

A.1 Philosophy

When work started on the design and implementation of the software system for support of Miranda non-real-time operations and data processing, only broad-line requirements were defined; certain requirements were not even definable before launch. The software system had to be sufficiently flexible to allow for this situation.

The format of data storage was, however, decided at an early stage, viz: one digital tape per day of data (with magnetic tape formats also specified at this stage, as given in Ref 2). It naturally followed that the data control routines should be made into one or more software packages. Furthermore, orbital-position and sun-direction software was available, and since not all users required orbital or sun data, these would naturally form independent packages. The attitude reconstruction required independent packages which could only be completed after in-orbit assessment of the pitch-rate monitors. Finally, the user requirements were built into independent packages, many of which were available before launch, while others were defined as a result of in-orbit experience.

A.2 Data control

The data-control software interfaced between the operator and computer, and controlled the flow of data from selected digital magnetic tapes. Data was processed serially from a pass or group of passes, and presented to the user routines frame-by-frame, suitably formatted, together with control flags and corrected times, appropriate to direct or recorded data. This software was integrated into six packages, two without attitude reconstruction and four with (see section A.4).

A.3 Satellite position and sun direction

Two sets of routines for determination of satellite position were in existence (as described in Ref 2), with corresponding routines for sun position. These sets of routines needed only minor modification to make them into modularised packages. The two packages were made to appear identical to the user and so were directly interchangeable. One package omitted some of the smaller orbit perturbations but was adequate for many requirements. However, it was necessary to use the more accurate package when, for example, the satellite was in star-lock.

A.4 Attitude reconstruction

Many of the data processing requirements for experiments B, C and D needed accurate attitude information. The attitude reconstruction was performed only during periods of constant pitch rate and was made available to the user via the controlling routines. Four versions were available - in three of these the data from a pass was scanned twice, the first scan to create an attitude model and the second to offer the data to the user. Since the pitch axis was kept in the sun-pointing direction the attitude of the satellite was fully defined by the pitch angle. The four versions of attitude model:-

(i) Attitude-time points were obtained from horizon crossings of infra-red detector IR1. The pitch rates were evaluated from the telemetry data and modified according to in-orbit calibrations. A best fit through the attitude-time points was taken at the evaluated pitch rate.

(ii) Attitude-time points were obtained from horizon indications of the 100-element array albedo sensor. Otherwise the attitude was reconstructed as in (i).

(iii) Two selected attitude-time points, plus an approximate inclusive pitch rate, were input via the console. The software evaluated the pitch rate to satisfy the given attitude-time points.

(iv) Attitude-time points were obtained from horizon crossings of the infra-red detector IR1. The pitch-gyro rate outputs were integrated and suitably scaled to fit these points.

Versions (i) to (iii) could be used to give extremely good attitude data when the satellite was in Mode 3 (inertial sun-lock with fine sun-sensing) but could also be used to give reasonable attitude data when the satellite was in Mode 3A (inertial sun-lock back-up using only the prime sun sensor - with resulting errors in sun-pointing caused by albedo contamination). Version (iv) could be used to give reasonable attitude data when the satellite was in Mode 2 (sun-acquisition mode - used when part of the satellite's orbit was eclipsed).

An independent attitude reconstruction was necessary for Experiment A because of these varying requirements:

(i) Experiment A required almost immediate data processing, while long-term processing was adequate for the other experiments.

(ii) Experiments B, C, D ideally required complete automatic processing of attitude data, while for Experiment A interactive processing was not only acceptable but desirable.

(iii) Experiment A used a different set of attitude reference axes from the other experiments.

Fig 9 shows the axis systems. For Experiment A the important feature was that the gyros gave a reference relative to inertial space. The axis system chosen incorporated the sun-line ($\hat{s}$) and the ecliptic north ($\hat{e}$). The satellite attitude was defined as the angle between the yaw axis and the ecliptic north (assuming the pitch axis to be sun-pointing).

For the other experiments, all observations were of items whose position was referenced in terms of earth axes. A vector $\hat{p}$ (pseudo-north) was defined such that $\hat{p}$ was in the plane containing the north polar direction ($\hat{n}$) and sun-line ($\hat{s}$), and perpendicular to the sun-line. The satellite attitude was defined as the angle between the yaw axis and the pseudo-north direction (assuming the pitch axis to be sun-pointing).

As can be seen from Fig 10, if the satellite position and the sun direction were known at the time of an horizon fix from one of the detectors, the satellite attitude could be obtained in either axis system.

The attitude reconstruction for experiment A was incorporated in the user routines for that experiment.

A.5 User software

Fig 11 shows how user routines dealt with the data. The controlling routines offered the data plus appropriate flags to the user routines (by way of common storage) after each data block had been read from the digital magnetic tape. The entry point, as shown in Fig 11, could be replaced in practice by a sequence of entry points to individual user routines. This allowed processing of several requirements to be performed in parallel on a serial data stream, while remaining mutually exclusive.

A.6 Program construction and use

Satellite-data-processing programs and operations-support programs consisted of one or more user routines and a controlling package, together with orbit and attitude packages as necessary.

All programs were stored in binary on disc or magnetic tape, with operating instructions available in a supplement to the Operations Manual. Each program was loaded into the computer by the operator according to the scheduled requirements.

07

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Some reports marked (to be issued) will have numbers allocated to them before this Report is issued. Reports quoted are not necessarily available to members of the public or to commercial organisations.

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               MIRANDA ORBIT SUMMARY
               ---------------------

DATE       DEC  4         (DAY NUMBER 338)

PARAMETER EPOCH      NOV 30

CEL. LONGITUDE OF SUN       251.4 DEG

ORBITAL INCLINATION        97.8 DEG

R.A. OF NODE       136.8 DEG

ARG. OF PERIGEE       122.5 DEG

PERIGEE HEIGHT        716 KM

APOGEE HEIGHT        933 KM

NODAL PERIOD       101.21 MIN      (= 1.6869 HOUR)

ORBITAL RATE       213.41 DEG/H

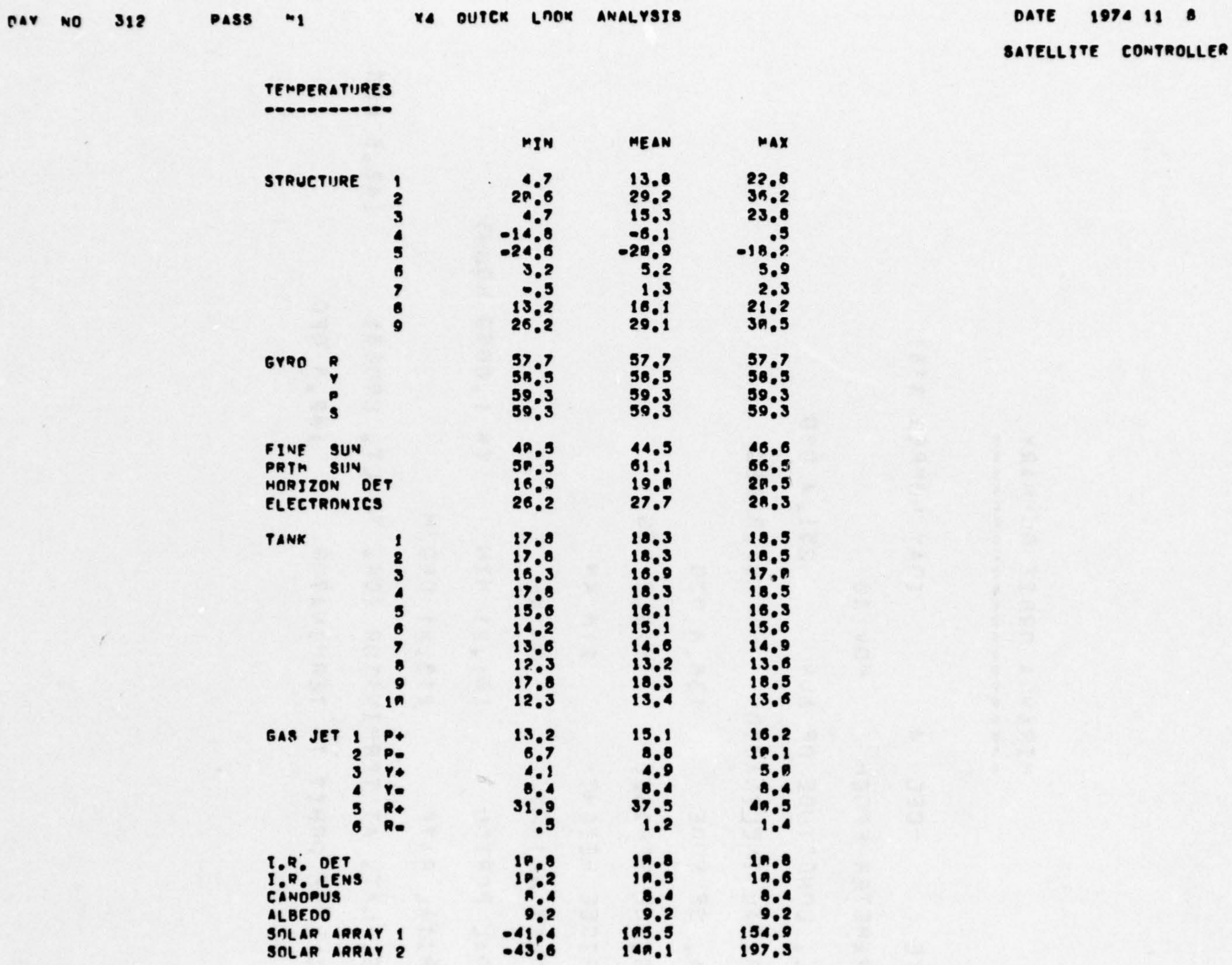
ARG. LAT. AT TERMINATOR (DK. TO LT. CROSS)       143.8 DEG

INCL. OF ORBIT TO TERMINATOR       142.6 DEG
```

Fig 1 PAL1 sample output

Fig 2

BEST AVAILABLE COPY



```
DAY  NO   312        PASS   01           X4  QUICK  LOOK  ANALYSIS                                DATE   1974 11  8
                                                                                                  SATELLITE  CONTROLLER

                      TEMPERATURES
                      ------------

                                          MIN          MEAN          MAX

                      STRUCTURE   1       4.7          13.8          22.8
                                  2      20.6          29.2          36.2
                                  3       4.7          15.3          23.8
                                  4     -14.8          -6.1            .5
                                  5     -24.6         -20.9         -18.2
                                  6       3.2           5.2           5.9
                                  7       -.5           1.3           2.3
                                  8      13.2          18.1          21.2
                                  9      26.2          29.1          30.5

                      GYRO  R            57.7          57.7          57.7
                            Y            58.5          58.5          58.5
                            P            59.3          59.3          59.3
                            S            59.3          59.3          59.3

                      FINE  SUN          40.5          44.5          46.6
                      PRIM  SUN          50.5          61.1          66.5
                      HORIZON  DET       16.9          19.0          20.5
                      ELECTRONICS        26.2          27.7          28.3

                      TANK        1      17.8          18.3          18.5
                                  2      17.8          18.3          18.5
                                  3      16.3          16.9          17.0
                                  4      17.8          18.3          18.5
                                  5      15.6          16.1          16.3
                                  6      14.2          15.1          15.6
                                  7      13.6          14.6          14.9
                                  8      12.3          13.2          13.6
                                  9      17.8          18.3          18.5
                                 10      12.3          13.4          13.6

                      GAS JET 1   P+     13.2          15.1          16.2
                              2   P-      6.7           8.8          10.1
                              3   Y+      4.1           4.9           5.0
                              4   Y-      8.4           8.4           8.4
                              5   R+     31.9          37.5          40.5
                              6   R-       .5           1.2           1.4

                      I.R. DET           10.8          10.8          10.8
                      I.R. LENS          10.2          10.5          10.6
                      CANOPUS             8.4           8.4           8.4
                      ALBEDO              9.2           9.2           9.2
                      SOLAR ARRAY 1     -41.4         105.5         154.9
                      SOLAR ARRAY 2     -43.6         140.1         197.3
```

Fig 2   QLK sample output

REQUESTING OFFICER	
DATE	
SERIAL NUMBER	

DETAILS OF STAR

NAME OF STAR

C	A	N	O	P	U	S													

RIGHT ASCENSION

H	H		M	M		S	S
0	6	△	2	3	△	2	3

DECLINATION

±	D	D		M	M
-	5	2	△	4	1

FINAL DRIVE RATE

±	X	X
-	2	0

PITCH INT. RATE CMD.

DAY No.

2	1	3

TIME (T_1)

H	H		M	M		S	S
0	5	△	4	4	△	0	0

STAR LOCK - LOOK CMD.

DAY No.

2	1	3

TIME (T_2)

H	H		M	M		S	S
1	6	△	1	5	△	0	0

Fig 3 SLK data sheet

Fig 4

```
DAY NO  213     PASS  M2          X4  STAR  LOCK  ASSESSMENT                         DATE   1974  8  1

                      STAR      CANOPUS

                      R.A.      06 23 23          DEC.      -52 41

                      FINAL  DRIVE  RATE     -20   DEG. / HR.

                      PITCH  INT.  CMD.            DAY  NO.  213      TIME   05 44 00

                      STAR  LOCK / LOOK  CMD.      DAY  NO.  213      TIME   16 15 00

                      ATTITUDE1     -130,8          TIME1      .23889
                      ATTITUDE2     -116,8          TIME2      .67708
                      ATTITUDE3     -131,2          TIME3      .70722

                      CALCULATED  ALIGNMENT  RATE            1,51

                      PITCH  INTEGRATOR  COMMAND  VALUE  +000317
                                                         -------


                      MIRROR  SETTING  IS    POSITION  10

                      REQUIRED  SETTING      POSITION  10
                                             -----------

                      ELONGATION  ANGLE  IS   77,12



                      ITP   TIME   ITO    ATT        AL        TH

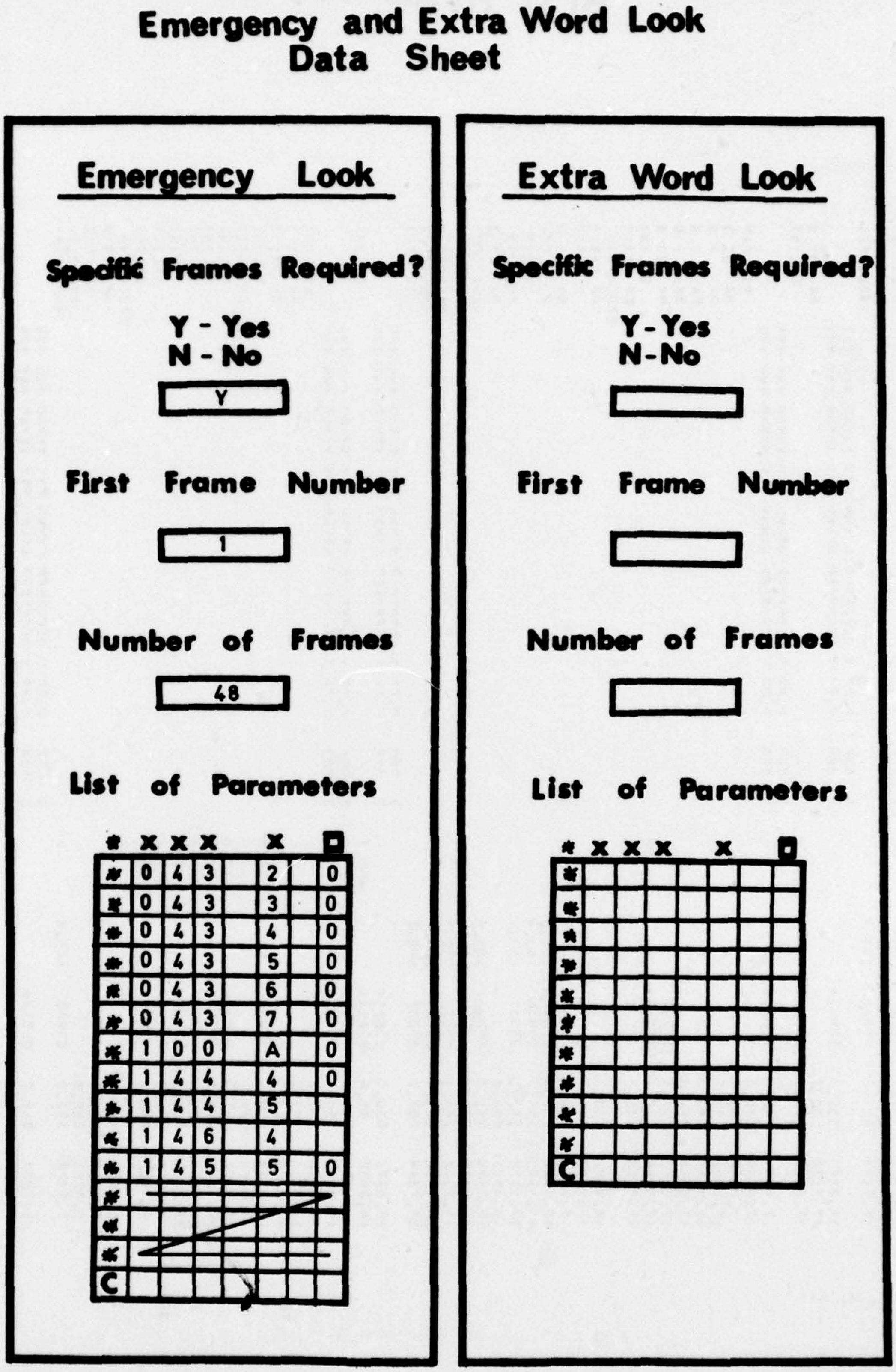
                       2   .1056    1   -130,80    63,68     -3,82
                       1   .1294    1   -130,75    63,17   -130,42
```

Fig 4 SLK sample output

```
                                                                                                     PAGE 750
SEP  5  16.4701  167.4   25835   183.2                                                                 ADL(ON)
        16.9945  276.5   25836   193.7                                                               SADL(OFF)
        17.0084  279.4   25837   183.5                                                               S  AS3
        17.0389  285.9   25838    59.4                                                               SADL(ON)
        17.0430  286.0   25839   183.1                                                                 IR(OFF)
        17.0478  287.0   25840   183.7                                                               SADL(OFF)
                                                  3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NN YYY
        17.2803  339.4   25841*                   3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NY YYY
        17.5150   29.1                                                                                 BK  31 S
        17.6100   51.9   25842*             -57.4                                                       GSL(N)
                                                  3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NY YYY
        17.6601   62.3   25843*                   3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NN YYY
        17.8499  102.3                                                                                  DIR DAT
        17.8499  102.3                                                                                 BK  21 S
        17.8562  103.7                                                                                 BK   2 S
        17.8587  104.2                                                                                 BK   1 S
        17.8603  104.5                                                                                 BK   1 S
        17.9655  127.1                                                                                 BK 234 S
        17.9706  128.1   25844*              16.6                                                       GSL(S)
        18.0515  145.3                                                                                 EP GAS11
                                                                                                  EPOCH 240
        18.0562  146.3                                                                                 NP GAS11
        18.0562  146.3                                                                                  REC DAT
        18.0562  146.3                                                                                 BK  16 S
        18.0568  146.4   25845   321.8                                                                ADL(OFF)
        18.1397  163.8   25846   183.9                                                                  IR(ON)
        18.1578  167.6   25847   183.1                                                                 ADL(ON)
        18.4517  228.6                                                                                 BK  48 S
        18.7089  282.3   25848   188.6                                                               SADL(OFF)
        18.6917  278.7   25849   183.3                                                               S  AS3
        18.7267  286.1   25850    59.3                                                               SADL(ON)
        18.7356  288.0   25851   183.6                                                               SADL(OFF)
        18.7314  287.1   25852   182.8                                                                 IR(OFF)
                                                  3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NN YYY
        18.9761  339.6   25853*                   3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NY YYY
        19.3057   51.9   25854*             -57.4                                                       GSL(N)
                                                  3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NY YYY
        19.3539   62.5   25855*                   3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NN YYY
        19.5316  101.2                                                                                  DIR DAT
        19.5316  101.2                                                                                 BK  31 S
        19.6423  124.9                                                                                 BK 241 S
        19.6575  128.1   25856*              16.6                                                       GSL(S)
        19.6598  128.7                                                                                 EP GAS12
        20.9927   51.9   25857*             -57.4                                                       GSL(N)
        21.3445  128.1   25858*              16.6                                                       GSL(S)
        22.6794   51.9   25859*             -57.4                                                       GSL(N)
        23.6314  128.1   25860*              16.6                                                       GSL(S)
SEP  6   0.3663   51.9   25861*             -57.4                                                       GSL(N)
         0.7182  128.1   25862*              16.6                                                       GSL(S)
                                                                                                  EPOCH 240
         1.6731  328.6                                                                                 NP GAS 0
         1.6731  328.6                                                                                  REC DAT
         1.6731  328.6                                                                                 BK  6.0H
         1.6740  328.8   25863   145.6                                                               SADL(OFF)
                                                  3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NN YYY
         1.7264  340.2   25864*                   3  000   0.00 Y OCPPPPPP NYNNN FYY YYYNO *NY YYY
         1.9220   23.1                                                                                 BK  31 S
```

Fig 5 PAL2 sample output

Fig 6



Emergency and Extra Word Look Data Sheet

Emergency Look

Specific Frames Required?

Y - Yes
N - No

Y

First Frame Number

1

Number of Frames

48

List of Parameters

*	X	X	X		X		■
*	0	4	3		2		0
*	0	4	3		3		0
*	0	4	3		4		0
*	0	4	3		5		0
*	0	4	3		6		0
*	0	4	3		7		0
*	1	0	0		A		0
*	1	4	4		4		0
*	1	4	4		5		
*	1	4	6		4		
*	1	4	5		5		0
*							
*							
*							
C							

Extra Word Look

Specific Frames Required?

Y - Yes
N - No

First Frame Number

Number of Frames

List of Parameters

*	X	X	X		X		■
*							
*							
*							
*							
*							
*							
*							
*							
*							
*							
C							

Fig 6 Emergency and extra word look data sheet

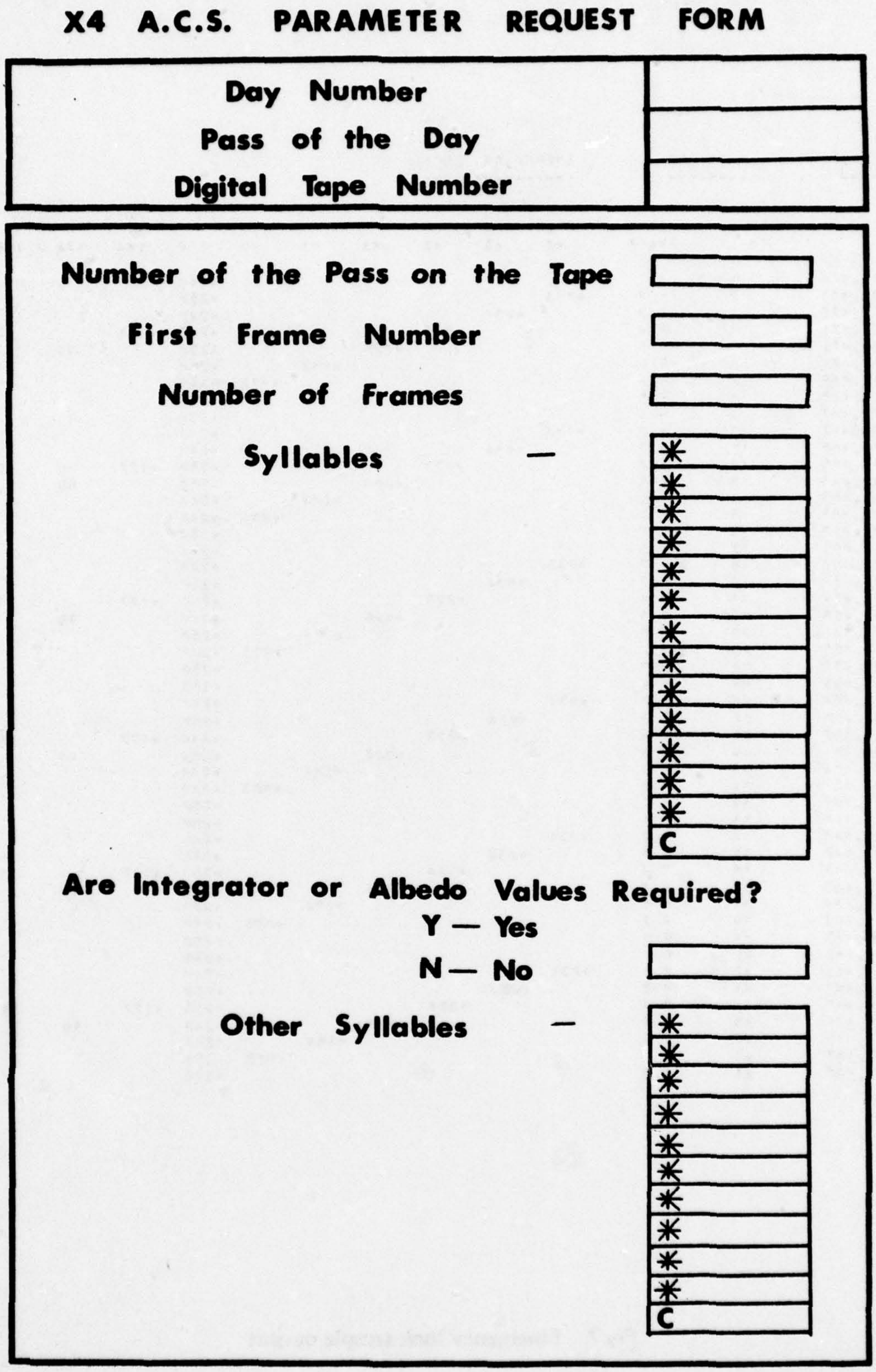
```
  DAY  69          PASS  82         EMERGENCY LOOK
 --------          --------        ---------------

                 FULL     MINOR     SYLLABLES
TIME             COUNT    FRAME       43    43    43    43    43    43   130   144   144   146   145

17 15 21.474         1     0 1                                          +240
17 15 37.473         2     0 2      +033                                +250
17 15 53.472         3     0 3            +034                          +240
17 16 09.471         4     0 4                  +025                    +240  +177          65
17 16 25.471         5     0 5                        +026              +250          99        +343
17 16 41.470         6     0 6                              +103        +250
17 16 57.469         7     0 7                                    +022  +240
17 17 13.468         8     0 0                                          +240
17 17 29.467         9     0 1                                          +250
17 17 45.467        10     0 2      +033                                +240
17 18 01.466        11     0 3            +034                          +240
17 18 17.465        12     0 4                  +025                    +250  +177          69
17 18 33.464        13     0 5                        +026              +250          99        +343
17 18 49.463        14     0 6                              +103        +240
17 19 05.463        15     0 7                                    +023  +240
17 19 21.462        16     0 0                                          +250
17 19 37.461        17     0 1                                          +240
17 19 53.460        18   * 0 2      +033                                +240
17 20 09.459        19     0 3            +034                          +250
17 20 25.459        20     0 4                  +025                    +250  +177          73
17 20 41.458        21     0 5                        +026              +240          99        +343
17 20 57.457        22     0 6                              +104        +250
17 21 13.456        23     0 7                                    +023  +240
17 21 29.455        24     0 0                                          +250
17 21 45.455        25     0 1                                          +250
17 22 01.454        26     0 2      +034                                +240
17 22 17.453        27     0 3            +034                          +250
17 22 33.452        28     0 4                  +025                    +240  +177          78
17 22 49.451        29     0 5                        +026              +250          99        +343
17 23 05.451        30     0 6                              +104        +240
17 23 21.450        31     0 7                                    +023  +240
17 23 37.449        32     0 0                                          +250
17 23 53.448        33     0 1                                          +250
17 24 09.448        34     0 2      +034                                +240
17 24 25.447        35     0 3            +034                          +240
17 24 41.446        36     0 4                  +024                    +250  +177          79
17 24 57.445        37     0 5                        +026              +250          99        +343
17 25 13.444        38     0 6                              +104        +240
17 25 29.444        39     0 7                                    +023  +240
17 25 45.443        40     0 0                                          +250
17 26 01.442        41     0 1                                          +240
17 26 17.441        42     0 2      +034                                +240
17 26 33.440        43     0 3            +034                          +250
17 26 49.440        44     0 4                  +024                    +250  +177          81
17 27 05.439        45     0 5                        +026              +240          99        +343
17 27 21.438        46     0 6                              +104        +240
17 27 37.437        47     0 7                                    +023  +250
17 27 53.436        48     0 0                                          +240
```

Fig 7 Emergency look sample output

Fig 8



X4 A.C.S. PARAMETER REQUEST FORM

Day Number
Pass of the Day
Digital Tape Number

Number of the Pass on the Tape

First Frame Number

Number of Frames

Syllables —

*
*
*
*
*
*
*
*
*
*
*
*
*
C

Are Integrator or Albedo Values Required?
Y — Yes
N — No

Other Syllables —

*
*
*
*
*
*
*
*
*
*
C

Fig 8 X4 ACS parameter request form

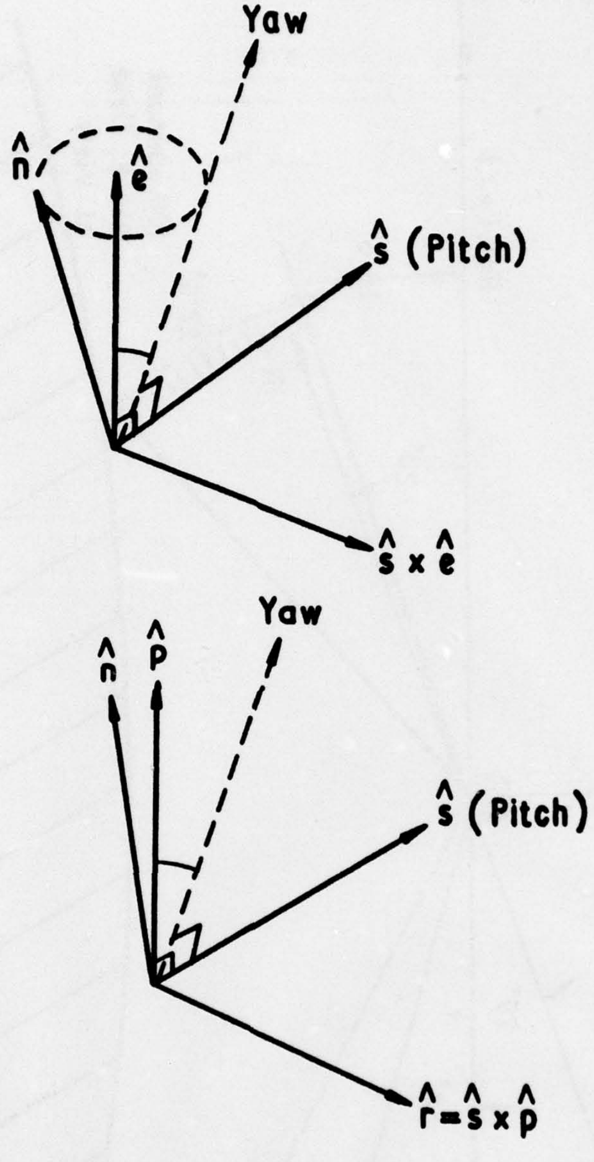


Fig 9 Attitude reference axes

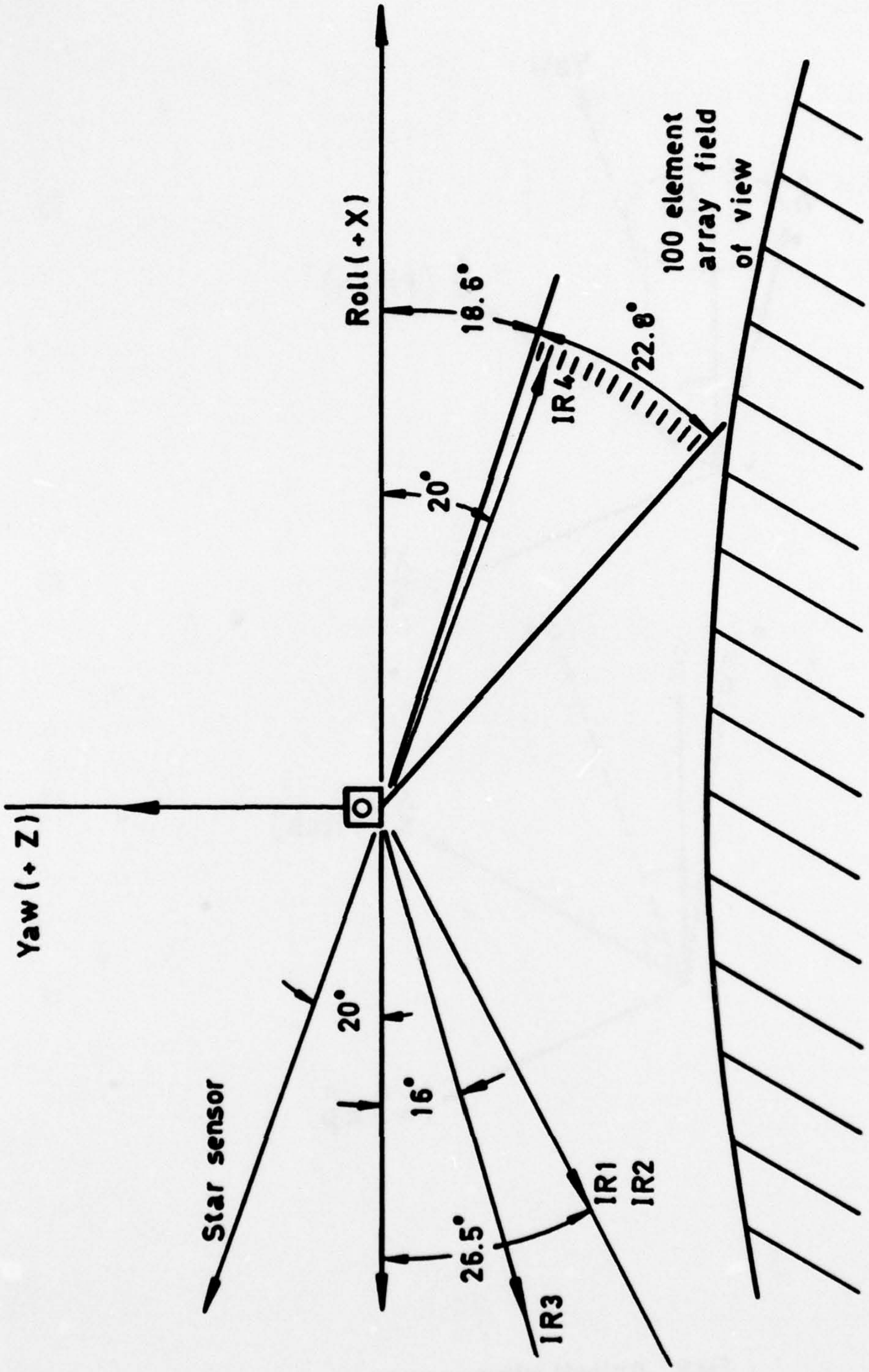


Fig 10 Miranda experimental sensors fields of view

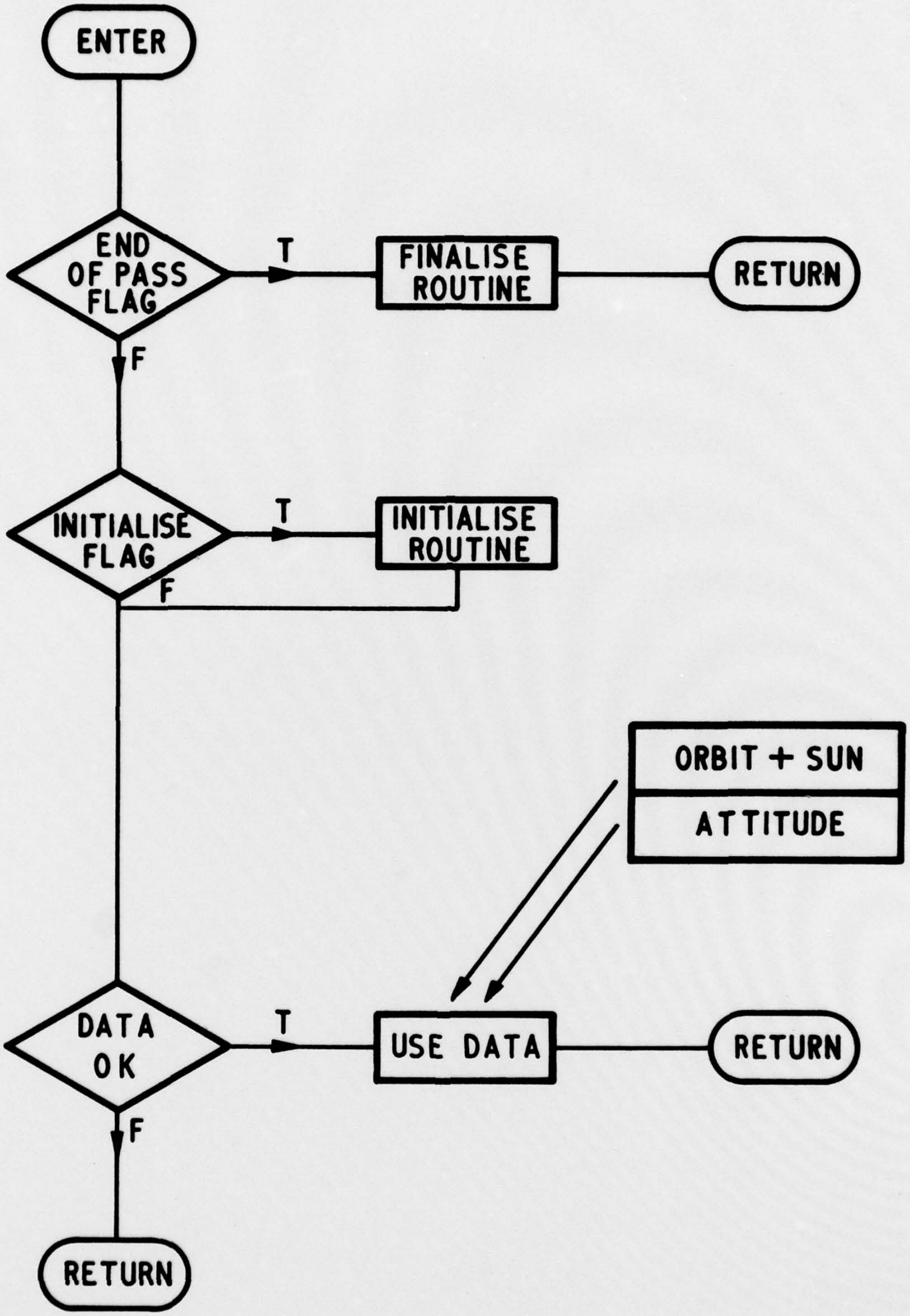


Fig 11 User routine flowchart

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17. Abstract

Miranda was a low-orbit technology satellite carrying a number of experimental packages. A comprehensive software system was developed for its operational support and the processing of experimental data. This Report outlines the various categories of data processing employed, and describes each program that was provided.

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