CRES REMOTE SENSING LABORATORY

AAFE RADSCAT DATA REDUCTION PROGRAMS USER'S GUIDE

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16. Abstract

The theory, design and operation of the computer programs which automate the reduction of joint radiometer and scatterometer observations conducted by the AAFE RADSCAT instrument is presented. The programs reduce scatterometer measurements to the normalized scattering coefficient; whereas the radiometer measurements are converted into antenna temperatures. The programs are both investigator and user oriented. Supplementary parameters are provided to aid in the interpretation of the observations. A hierarchy of diagnostics is available to evalute the operation of the instrument, the conduct of the experiments and the quality of the records.

General descriptions of the programs and their data products are also presented. This document therefore serves as a user's guide to the programs and is therefore intended to serve both the experimenter and the program operator.

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FOREWORD

The value of microwave scatterometers and radiometers as remote sea wind sensors has been independently demonstrated by a number of investigators. However, near-simultaneous observations by a composite radiometer and scatterometer (RADSCAT) instrument have been proposed as a method of making improved wind estimates. The improvement is derived from the complementary as well as supplementary features of the sensors. To demonstrate this potential a joint effort among New York University, General Electric Space Division, the University of Kansas and NASA Langley Research Center was undertaken through the Advanced Application Flight Experiment program of NASA. This document is submitted in support of these efforts.

Specifically, this document was prepared by the Remote Sensing Laboratory of the University of Kansas Center For Research, Inc. under NASA Contract NAS 1-10048. The principal investigator under the contract is Dr. R. K. Moore and project engineer is Dr. A. K. Fung. Several individuals rendered valuable assistance in the development of the computer programs. The control and integration of the routines were partially achieved by Glen E. Elliott of the University of Kansas. John L. Mitchell of LTV operated the programs repeatedly on the CDC-6600 while they were under final scrutiny by the author.

ABSTRACT

The theory, design and operation of the computer programs which automate the reduction of joint radiometer and scatterometer observations conducted by the AAFE RADSCAT instrument is presented. The programs reduce scatterometer measurements to the normalized scattering coefficient; whereas the radiometer measurements are converted into antenna temperatures. The programs are both investigator and user oriented. Supplementary parameters are provided to aid in the interpretation of the observations. A hierarchy of diagnostics is available to evaluate the operation of the instrument, the conduct of the experiments and the quality of the records.

General description of the programs and their data products are also presented. This document therefore serves as a user's guide to the programs and is therefore intended to serve both the experimenter and the program operator.

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I. INTRODUCTION

The AAFE RADSCAT* Data Reduction Package, as prepared by the University of Kansas, is a family of computer programs** which together form a basis for automated reduction and presentation of scatterometer and radiometer measurements taken by the RADSCAT instrument. The primary member in the family validates the raw RADSCAT data records and uses instrument and aircraft parameters to yield emission and scattering characteristics of the scene represented by the data. The scatterometer data is reduced to the normalized scattering coefficient whereas the radiometer data is reduced to the antenna temperature. Other programs in the family are employed to maintain a file of instrument characteristics, list the output (reduced data), and prepare duplicate output tapes for use on other computing machines. Two engineering routines are also provided to compute certain antenna parameters essential to the reduction of the microwave data; these routines are not employed regularly. The programs were written in FORTRAN IV, developed on a HW 635 system and then modified and demonstrated on a CDC-6600.

The program outputs provide a comprehensive basis from which to interpret the results of RADSCAT experiments. The basic output parameters have been augmented with others to reconstruct the influence of the aircraft attitude on the experiment, to validate the measurements, and to reflect the status of the RADSCAT instrument. Full evaluation of the data is accomplished by examining contents of an activity report as well as the output records. A fuller data base from which to analyze RADSCAT data is only provided when these outputs are augmented with sea/ground truth and certain aircraft parameters available from other sources. The programs are therefore largely experimenter oriented.

Attempts have been made to generalize the reduction algorithms so as to easily adapt the programs for changes in the character or operation of the instrument. In doing so the user is expected to provide many more of the calibration and

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*A composite radiometer and scatterometer sensor.

**The family of programs does not include a merge and edit routine which prepares the raw input data. This routine was developed by the Flight Instrumentation Division of NASA Langley Research Center.

data parameters than would otherwise by required. For this reason a historical file is maintained on the instrument parameters. It is also provided to trace the development, modifications and aging of the instrument.

No attempts have been made to develop efficient coding; rather extensive efforts have been made to develop programs which will, to some degree, document themselves. Self documentation is provided by a liberal insertion of comment cards. This approach had been instituted with the full realization that the programs are likely to undergo changes as experience or changes in the instrument dictate them. It is hopeful that this approach together with this document will ease the insertion of program modifications. However, the authors can assume no responsibility for changes made without their knowledge. It is strongly recommended that changes to the reduction algorithms be made only with the approval of an engineer who is thoroughly familiar with the operation of the instrument, the theory behind the algorithms and the needs of the investigators.

Some strides have been made to design production type programs. External directives give the users the ability to select the files to be processed or the service function to be executed. Unrecognized directives will halt the execution of the program. Data entries are also validated and when too many bad files are encountered the job is aborted. Activity reports and termination statements are provided so that the user can trace the progress of the job.

The details on the use, theory and design of these programs are presented in the remainder of this document. To place these programs in context with RADSCAT experiments the technical background is briefly described in Section II. The experimenter and programmer will find Section III helpful in understanding the general features and data products of the programs. He may wish to refer to Section IV and the Appendices for more specific information. The program operator will find Section IV essential to the operation of the programs. Again he may wish to consult the appendices for specific help. The cognizant engineer will want to become familiar with all aspects of this document to develop a thorough understanding of the program content. To a large extent this document assumes some knowledge of the operation of the RADSCAT instrument*. The programmer and cognizant

*A description of the instrument may be found in "Field Service Procedure Handbook," vol. 1, prepared by General Electric Space Division, Philadelphia, Pennsylvania under NASA Contract NAS 1-10161.

engineer will also want to consult the document which describes the merge and edit routine which prepares the raw data records. This document is in preparation at NASA Langley Research Center. Those wishing to learn the details on the theory and design of the various routines in the family of programs will find the appendices helpful.

II. TECHNICAL BACKGROUND

A. Introduction

This section is primarily written for the investigator or programmer not familiar with scatterometric or radiometric measurements. The motivation for joint measurements is presented and the elementary theory behind the measurements is discussed. The instrument and its relation to the C-130 aircraft is also briefly described. It is hoped that this section will place the AAFE RADSCAT Data Reduction Programs in context of experiments.

B. Motivation for Joint Measurements

In recent years a strong interest has developed in interpreting the microwave signatures of natural surfaces. In these efforts a number of potential earth resources and scientific applications have been demonstrated by measuring the emission or scattering properties of various scenes. The scatterometer is employed to measure the scattering characteristic whereas the radiometer is used to measure the emission properties. To date the investigations have been largely conducted with one instrument or the other. However, several investigators have proposed that joint scattering and emission measurements would form a stronger interpretational basis, because each sensor measures a different aspect of the bi-static scattering characteristic of the surface. From an entirely different viewpoint the sensors are complementary in nature. It is known that the radiometer is very sensitive to clouds and rain whereas the scatterometer is relatively insensitive to clouds and rain. Over the ocean this property has potential in correcting the scatterometer measurements for small attenuations caused by clouds.

C. Description of the RADSCAT Sensor

The AAFE RADSCAT instrument is a composite sensor consisting of a pencil-beam microwave scatterometer and radiometer. It was designed to conduct measurements from an aircraft and is capable of operating at either of two frequencies, 9.3 GHz or 13.9 GHz. In three of its four modes of operation it makes scatterometer and radiometer measurements on a near-simultaneous basis. In the fourth mode it makes radiometer measurements only. Observations can be conducted at any one of six adjustable angles covering the sector between nadir and 60 degrees.

The AAFE RADSCAT instrument was primarily designed to perform experiments over the ocean to verify the remote anemometric capability of the composite sensor. Although primarily designed for oceanographic work, the extension to observations of agrarian or urban scenes is straightforward. The instrument is capable of conducting experiments at one of four altitudes, viz, 2000, 5000, 10,000 and 20,000 feet.* The wide range of altitudes is provided to study atmospheric effects such as humidity, temperature, clouds and rains. To avoid difficulties introduced by operating from behind a radome, the RADSCAT instrument mounts on the tail gate of the NASA/MSC C-130 aircraft. The Litton Navigator LTN-51 aboard the C-130 aircraft is extremely useful to the interpretation and reduction of the RADSCAT observations. It provides aircraft attitude and location information from which the point of observation on the surface may be established. The attitude parameters are especially useful when measurements are performed from a roll maneuver, since these parameters enable one to compute the incident angle. The radar altimeter information provided by the aircraft is essential to the inversion of the scatterometer measurements.

D. Estimating the Scattering and Emission Properties from Measurements

The scatterometer is a radar which is capable of accurately measuring the backscatter properties of a rough surface. The backscatter ability of the surface is denoted by the normalized scattering coefficient σ^o which is given in terms of the scattering cross-section per unit area. In general it is dependent upon the point of observation, the incident angle, frequency, polarization, etc. It is well known that the radar return is predicted by (see Figure 1).

$$P_r = \frac{\lambda^2}{(4\pi)^3} P_t \iint_{4\pi} \frac{g^2(\theta,\phi)\ \sigma^o(\theta',\phi')}{R^4} \, dA \qquad (1)$$

where σ^o = normalized scattering coefficient

P_r = received power

P_t = transmitted power

λ = wavelength

g = antenna gain function

R = radar range to elemental area dA

*The radiometer by itself can operate at any altitude.

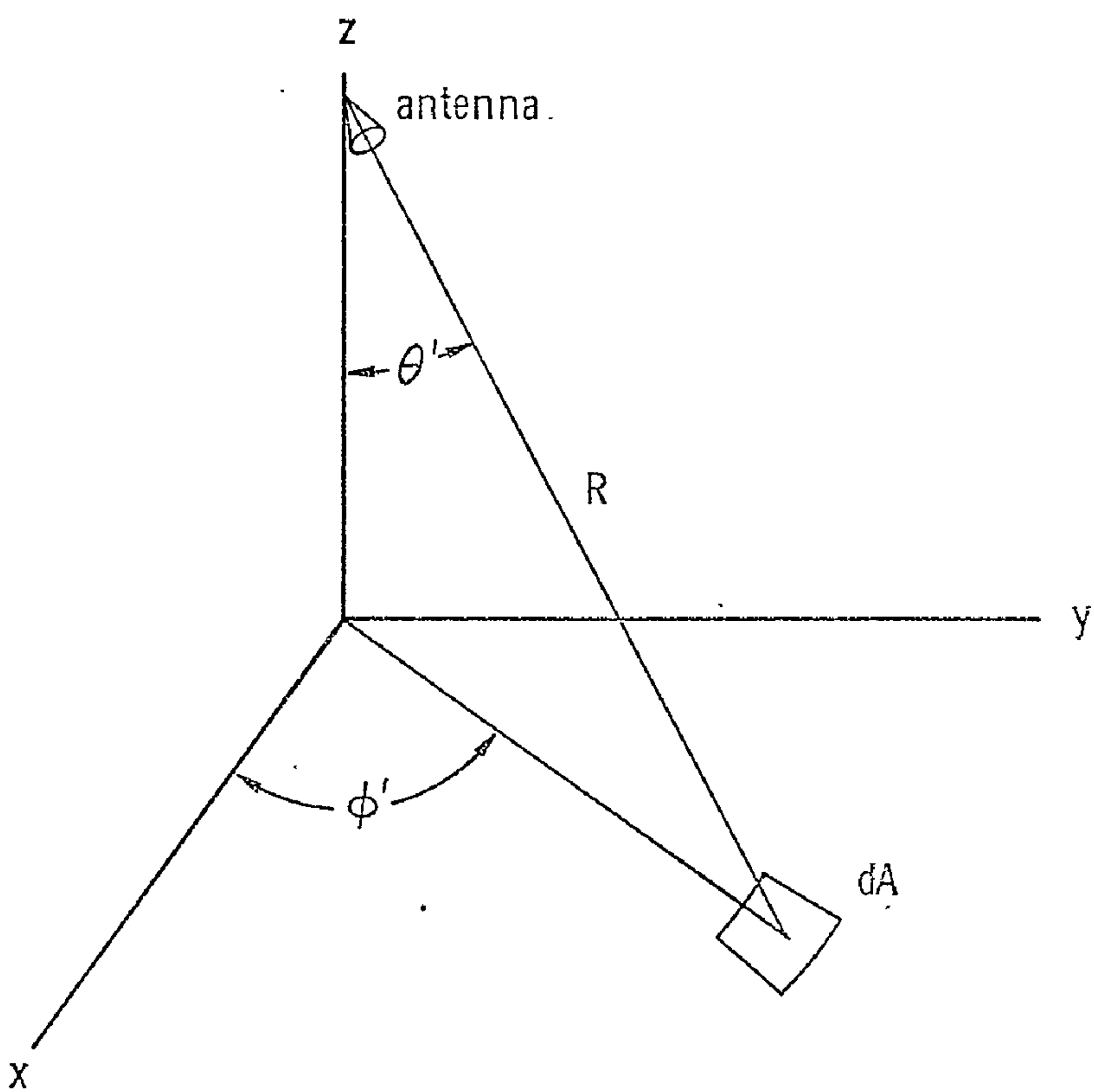

FIGURE 1. RADAR GEOMETRY

For narrow (or equivalently narrow) beam scatterometers the above integral expression may be inverted rather simply for σ^o. As a consequence the problem of accurately determining σ^o reduces to the problem of accurately measuring the transmitted and receiver powers, the pattern function, look angle, and radar range. The area of illumination may be shown to be related to the pattern function, look angle, and radar range. The scatterometer provides outputs which are measures of P_r and P_t. The power transfer function of scatterometer completes the association between the outputs to yield P_r and P_t *. A member of the family of programs actually employs the scatterometer transfer function and an algebraic approximation of equation (1) to estimate σ^o.

The radiometer, on the other hand, is a very sensitive receiver capable of measuring very low level emissions which emanate naturally from objects. In the microwave region the natural emission is governed by the Jeans-Rayleigh law which states that the power emitted is proportional to the physical temperature T of the body. In actuality, however, different objects at different temperatures emit different powers depending until their relative ability to absorb energy. Better absorbers emit more efficiently than poor ones. The relative ability to emit is described in terms of a parameter called emissivity ϵ. The emitted power per unit bandwidth in direction θ is given by **

$$P(\theta) = \frac{4\pi k \epsilon(\theta) T}{\lambda^2} \tag{2}$$

where k is Boltzmann's constant.

We may now suppose that the surface emits in accord with this relation. Then a radiometer whose antenna gain function is given by $g(\theta,\phi)$ will measure (ignoring atmospheric contributions) a total power per unit bandwidth given by ***

$$P_a = \frac{1}{\Omega} \iint_{4\pi} g(\theta,\phi)\, k\, T_B(\theta)\, d\Omega \tag{3}$$

* Actually only the ratio P_r/P_t is needed.

** For one polarization.

*** This relation is only representative of the nature of the problem. See Claassen, J. P. and A. K. Fung, "An Efficient Method for Inverting Antenna Temperatures for the Apparent Temperature Distribution" University of Kansas Center For Research, Inc., TR 186-8, January 1973, for a precise relationship.

where

$$\Omega = \iint_{4\pi} g(\theta, \phi)\, d\Omega \tag{4}$$

and

$$T_B = \epsilon(\theta)\, T \tag{5}$$

The antenna power may be related to antenna temperature by $P_a = kT_a$. For narrow beam efficient antennas the antenna temperature is an approximate measure of the brightness temperature T_B in the look direction. The radiometer therefore must accurately measure the antenna power. The RADSCAT data reduction programs use the calibration data and radiometer transfer function to estimate T_a for each polarization.

III. GENERAL DESCRIPTION

A. Introduction

This section is primarily written to familiarize the investigator or programmer with the family of RADSCAT data reduction programs. The functions of the particular programs and the relationships between the programs are presented. Input and output data products are described to various degrees.

B. Summary of Programs

The AAFE RADSCAT Data Reduction Package consists of a family of six programs:

1. Conversion Program (CONVERT)
2. Output Program (OUTPUT)
3. Program for the Storage and Retrieval of Instrument Characteristics (ICHAR)
4. Output Translation and Duplication Program (TDUPE)
5. Equivalent Beamwidth Program (WIDTH)
6. Antenna Gain and Efficiency Program (GAIN)

The actual reduction of data is accomplished in CONVERT. The input data for CONVERT is prepared by an edit and merge routine developed by NASA Langley Research Center. The merged tape oonsists of RADSCAT and aircraft data. To assist in the computations, program ICHAR prepares a historical file of instrument characteristics. CONVERT selects a particular set of characteristics from the file and applies them to the input data. The computed results are stored on an output tape. Program OUTPUT will list the contents of the output tape. To prepare duplicate output tapes for use on other computing machines program TDUPE may be employed.

WIDTH and GAIN are special routines which compute several antenna parameters. The parameters are employed as elements of the instrument characteristics. Both programs require antenna pattern information to compute the parameters. Their use will seldom be required unless the antenna pattern changes.

Of the six programs the initial four programs are production types and the last two are engineering application programs.

C. Conversion Program

The reduction of RADSCAT data is performed entirely in CONVERT. By means of external directives, physical files of a specified type are processed with a designated set of instrument characteristics withdrawn from a separate file source. External directives permit the user to initiate processing of input files by type or sequentially regardless of type. The files are organized by flight runs and are labeled in accord with a procedure instituted by the Flight Operations Division of NASA/MSC.

Directive options are given by MISFLT, FLTLIN, SPECIF, or ALL. When the first directive is appended with mission and flight numbers, all files from that mission and flight are processed in the order that they appear on the tape. Mission, flight and line numbers must appear with the second directive option. Files of the designated line type will thus be processed. Consecutive directives which exhaust the line types will order the output files by line type. This feature is helpful to the interpreter who often associates an experiment condition with a line type. The third directive is employed when a specific file designated by mission, flight, line and run is to be processed. This directive is appropriate for a quick or selective look at the experiment results. The last directive (ALL) will initiate processing of all files regardless of type. Combinations of directives may be employed; however, indiscriminant use of the processing types is cautioned against since duplicate processing of files may occur. For each directive the file search is effectively conducted from the beginning of the tape.

Each of the above directives must include a designator which selects a set of instrument characteristics from a historical file of characteristics or which permits them to be read from cards. It is likely that the most current characteristics will be chosen; however, any set on the file may be selected. Alternatively, characteristics may be entered from the card reader. However, operation under this latter option is restricted to one data file per directive. Entry through the card reader is mainly reserved for testing a set of instrument characteristics before storage on the historical file. Also as a part of the same directive the number of files to be processed of the indicated type and the line density of the activity report must be designated on the control card. The latter parameter can be used to limit the number of data records on which reports are given.

During processing CONVERT generates a conversion report. The report routinely issues statements on the calibration parameters and critical receiver temperatures as they are computed from the input file. It will also routinely state that a record had been reduced. The reports are appended with record numbers. Other special statements are generated whenever critical situations are encountered in the records. When these special situations occur, the record is normally processed regardless; however, that record is flagged by an interpretational code which becomes a part of the output record. In some cases, such as invalid data, the record is bypassed and an appropriate error message is generated. When an excessive number of bad records is encountered, the file is bypassed and an appropriate message printed. These messages are primarily intended to reflect the status of the processing, the condition of the instrument, the conduct of the experiment, and the quality of the data. A sample listing of the conversion report is illustrated in Figure 2.

As processing progresses output records are accumulated in blocks (arrays) and the blocks are written to the output tape. A description of the contents of the output tape appears in the following subsection.

D. Output Program

Program OUTPUT will list the processed records produced in the conversion program. External directives similar to those in CONVERT permit listing files of designated types or all files regardless of type. Again general directives are given by MISFLT, FLTLIN, SPECIF or ALL. The appropriate mission, flight, line and run designators must accompany the directives.

A sample listing produced by OUTPUT is shown in Figure 3. A double page of output consists of the file label, column headings, 80 records and a key. The set of instrument characteristics which produced the results is identified by set number and date in the last entry of the file label. Each measurement record occupies one line on the listing. A record number is appended to each line and should agree with the number assigned in the conversion report. The time of measurement in mean Greenwich time is presented in the second column. It is to be read in hours, minutes, seconds and 1/10th seconds. The measurement can therefore be associated with data from other sources. The mode from which the instrument conducted the measurement is reflected in column 3. The incident and cross-tracks angles appear in the next two columns. They were computed from aircraft attitude parameters and the RADSCAT view angle with respect to the aircraft platform. The cross-track angle is that angle

CONVERSION REPORT

MISSION-207 FLIGHT- 12 DATE- 7 25 1972 FLT LINE- 2 RUN- 3 FREQUENCY- 13.9 FEED- WG SW IPAR= 1 2 1 73

RECORD NO.*	MESSAGE *	PARAMETERS
	* CALIBRATION DATA *	CHAN 1= .270 CHAN 2= .410 CHAN 3= 1.190 CHAN 4= 1.285
	*	RCAL= 2.406 RBASE= .160 NCAL= 6 NBCAL= 6
1	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
1	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 288.0 GDE= 312.7
1	* EXCESSIVE DEPOLARIZATION *	DEPOL= .021
1	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 246.6 SCATTERING COEF=7.720364E+00 CHANNEL= 2 DOP BAND= 7
2	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
2	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 288.0 GDE= 312.7
2	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 248.6 SCATTERING COEF=6.311449E+00 CHANNEL= 2 DOP BAND= 7
3	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
3	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 288.0 GDE= 312.7
3	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 248.4 SCATTERING COEF=5.924877E+00 CHANNEL= 2 DOP BAND= 7
4	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
4	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 288.0 GDE= 312.7
4	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 249.8 SCATTERING COEF=7.028195E+00 CHANNEL= 2 DOP BAND= 7
5	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
5	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 287.9 GDE= 312.7
5	* EXCESSIVE DEPOLARIZATION *	DEPOL= .021
5	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 249.4 SCATTERING COEF=6.206822E+00 CHANNEL= 2 DOP BAND= 7
6	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
6	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 287.6 GDE= 312.7
6	* EXCESSIVE DEPOLARIZATION *	DEPOL= .022
6	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 249.1 SCATTERING COEF=5.944944E+00 CHANNEL= 2 DOP BAND= 7
7	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
7	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.2 SW= 311.3 AIR= 287.9 GDE= 312.7
7	* EXCESSIVE DEPOLARIZATION *	DEPOL= .020
7	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 248.2 SCATTERING COEF=7.507535E+00 CHANNEL= 2 DOP BAND= 7
8	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
8	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.2 SW= 311.3 AIR= 288.0 GDE= 312.7
8	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 249.0 SCATTERING COEF=7.141959E+00 CHANNEL= 2 DOP BAND= 7
9	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.8 KELVIN
9	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 288.0 GDE= 312.7
9	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 249.2 SCATTERING COEF=8.071941E+00 CHANNEL= 2 DOP BAND= 7
10	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =337.6 KELVIN
10	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 288.0 GDE= 312.7
10	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 248.6 SCATTERING COEF=7.185143E+00 CHANNEL= 2 DOP BAND= 7
11	* RECVR TEMP NOT WITHIN OPERATING RANGE *	LOCATION NO. 1 TEMPERATURE =338.0 KELVIN
11	* CRITICAL TEMPERATURES *	WARM= 311.8 HCT= 415.0 OMT= 312.1 SW= 311.3 AIR= 288.1 GDE= 312.9
11	** COMPLETED RECORD COMPUTATIONS **	ANTENNA TEMP= 243.5 SCATTERING COEF=5.522865E+00 CHANNEL= 2 DOP BAND= 7

FIGURE 2. SAMPLE OF THE CONVERSION REPORT

MICROWAVE DATA

MISSION-207 FLIGHT- 12 DATE- 7 25 1972 FLT LINE- 2 RUN- 3 FREQUENCY- 13.9 FEED- NO SW IPAR= 1 2 1 73

RECORD NO.	TIME	MODE	INCID ANGLE (DEG)	CROSS ANGLE (DEG)	XMIT POL	REC POL	S INT TIME (SEC)	SCAT	SCAT DB	RAD (DEG K)	DEPOL FACTOR	S/R CODE	ALTITUDE (FEET)	FLT DIRECT (DEG)
1	151746.7	F.A.	13.7	-11.4	H	H	.595	7.7204E+00	8.9	246.8	.021	110000	9966	2.5
2	151748.2	F.A.	13.8	-10.3	H	H	.595	6.3114E+00	8.0	248.6	0.000	100000	9959	2.7
3	151750.4	F.A.	13.8	-9.0	H	H	.595	5.9249E+00	7.7	248.4	0.000	100000	9957	2.6
4	151751.1	F.A.	13.7	-9.9	H	H	.595	7.0282E+00	8.5	249.8	0.000	100000	9956	2.3
5	151751.9	F.A.	13.6	-10.7	H	H	.595	6.2068E+00	7.9	249.4	.021	110000	9956	2.0
6	151752.6	F.A.	13.6	-10.8	H	H	.595	5.9449E+00	7.7	249.1	.022	110000	9959	1.9
7	151753.3	F.A.	13.5	-10.5	H	H	.595	7.5075E+00	8.8	248.2	.020	110000	9958	1.8
8	151754.1	F.A.	13.5	-9.7	H	H	.595	7.1420E+00	8.5	249.0	0.000	100000	9955	1.8
9	151754.8	F.A.	13.3	-6.9	H	H	.595	8.0719E+00	9.1	249.2	0.000	100000	9953	1.8
10	151756.3	F.A.	13.4	-8.6	H	H	.595	7.1891E+00	8.6	2 8.6	0.000	100000	9956	1.6
11	151757.8	F.A.	13.5	-9.5	V	V	.595	5.5229E+00	7.4	243.5	0.000	100000	9956	1.3
12	151758.5	F.A.	13.6	-9.3	V	V	.595	5.5486E+00	7.4	244.0	0.000	100000	9954	1.2
13	151759.2	F.A.	13.5	-6.9	V	V	.595	5.3070E+00	7.3	242.9	0.000	100000	9955	1.2
14	151800.0	F.A.	13.4	-6.2	V	V	.595	5.6865E+00	7.5	244.0	0.000	100000	9955	1.1
15	151800.7	F.A.	13.4	-7.4	V	V	.595	5.7777E+00	7.6	243.8	0.000	100000	9955	1.1
16	151802.2	F.A.	13.3	-7.2	V	V	.595	5.7537E+00	7.6	243.2	0.000	100000	9953	.9
17	151804.4	F.A.	13.3	-7.8	V	V	.595	7.1411E+00	8.5	244.4	0.000	100000	9951	.6
18	151805.1	F.A.	13.4	-7.6	V	V	.595	5.3751E+00	7.3	242.7	0.000	100000	9952	.6
19	151805.9	F.A.	13.3	-7.1	V	V	.595	7.2444E+00	8.6	243.7	0.000	100000	9956	.6
20	151806.6	F.A.	13.2	-6.7	V	V	.595	7.6415E+00	8.8	244.4	0.000	100000	9956	.6
21	151815.8	F.A.	43.0	-2.5	V	V	.595	3.2273E-01	-4.9	250.1	0.000	100000	9951	103.4
22	151816.7	F.A.	43.0	-2.8	V	V	.802	2.4405E-01	-6.1	250.1	0.000	100000	9953	359.8
23	151818.6	F.A.	42.9	-2.6	V	V	.802	2.4335E-01	-6.1	250.4	0.000	100000	9952	359.9
24	151820.5	F.A.	42.7	-2.2	V	V	.802	2.4358E-01	-6.1	249.7	0.000	100000	9952	359.8
25	151821.4	F.A.	42.8	-2.2	V	V	.802	2.4347E-01	-6.1	249.3	0.000	100000	9953	359.7
26	151822.4	F.A.	42.7	-2.4	V	V	.802	2.0886E-01	-6.8	250.5	0.000	100000	9952	359.7
27	151823.3	F.A.	42.8	-2.5	V	V	.802	2.0911E-01	-6.8	250.5	0.000	100000	9953	359.6
28	151824.3	F.A.	42.7	-2.5	V	V	.802	2.0958E-01	-6.8	250.1	0.000	100000	9957	359.6
29	151825.2	F.A.	42.8	-2.2	V	V	.802	2.0990E-01	-6.8	250.1	0.000	100000	9957	359.7
30	151827.1	F.A.	42.7	-1.9	V	V	.802	2.0854E-01	-6.8	249.3	0.000	100000	9961	359.6
31	151828.0	F.A.	42.8	-1.9	V	V	.802	2.0997E-01	-6.8	249.5	0.000	100000	9960	359.6
32	151829.9	F.A.	43.0	-1.9	V	V	.802	2.4451E-01	-6.1	249.3	0.000	100000	9963	359.4
33	151830.9	F.A.	43.0	-2.0	V	V	.802	2.4449E-01	-6.1	249.3	0.000	100000	9963	359.4
34	151831.8	F.A.	43.0	-1.9	V	V	.802	2.4402E-01	-6.1	250.1	0.000	100000	9961	359.4
35	151832.8	F.A.	42.9	-1.8	V	V	.802	2.4336E-01	-6.1	250.5	0.000	100000	9962	359.5
36	151833.7	F.A.	42.9	-1.6	V	V	.802	2.4434E-01	-6.1	249.7	0.000	100000	9958	359.5
37	151835.6	F.A.	42.8	-1.2	H	H	.802	8.2189E-04	-30.9	247.0	0.000	100000	9959	359.4
38	151836.5	F.A.	42.8	-1.2	H	H	.802	7.5444E-04	-31.0	246.0	0.000	100000	9957	359.3
39	151837.5	F.A.	42.8	-1.3	H	H	.802	7.4506E-04	-31.3	246.8	0.000	100000	9960	359.3
40	151838.4	F.A.	42.8	-1.3	H	H	.802	6.5443E-04	-31.8	246.2	0.000	100000	9960	359.3
41	151839.4	F.A.	42.8	-1.4	H	H	.802	7.7676E-04	-31.1	246.4	0.000	100000	9960	359.4
42	151840.3	F.A.	42.7	-1.3	H	H	.802	7.2953E-04	-31.4	245.0	0.000	100000	9960	359.5
43	151842.2	F.A.	42.9	-1.0	H	H	.802	8.5995E-04	-30.7	246.0	0.000	100000	9960	359.4
44	151844.1	F.A.	42.9	-1.1	H	H	.802	6.8271E-04	-31.7	247.0	0.000	100000	9960	359.4
45	151846.0	F.A.	42.9	-1.3	H	H	.802	6.8509E-04	-31.6	245.2	0.000	100000	9963	359.4
46	151847.9	F.A.	42.9	-1.1	H	H	.802	7.5142E-04	-31.2	247.2	0.000	100000	9966	359.6
47	151848.8	F.A.	43.0	-1.0	H	H	.802	7.4572E-04	-31.3	247.8	0.000	100000	9964	359.5
48	151857.8	F.A.	13.3	-2.2	H	H	.595	5.6747E+00	7.5	247.6	0.000	100000	9960	359.7
49	151858.5	F.A.	13.1	-2.3	H	H	.595	5.5253E+00	7.4	248.3	0.000	100000	9960	359.7
50	151859.3	F.A.	13.1	-2.1	H	H	.595	7.4056E+00	8.7	249.1	0.000	100000	9962	359.8
51	151900.7	F.A.	13.2	-1.5	H	H	.595	6.7056E+00	8.3	248.9	0.000	100000	9959	359.8
52	151901.5	F.A.	13.3	-1.1	H	H	.595	5.6748E+00	7.5	249.7	0.000	100000	9961	359.9
53	151902.2	F.A.	13.3	-1.0	H	H	.595	6.4946E+00	8.1	248.9	0.000	100000	9961	359.9
54	151903.7	F.A.	13.3	-1.4	H	H	.595	5.5778E+00	7.5	248.2	0.000	100000	9960	359.8
55	151904.4	F.A.	13.2	-1.4	H	H	.595	6.0592E+00	7.8	249.5	0.000	100000	9961	359.8
56	151905.2	F.A.	13.3	-1.5	H	H	.595	6.0606E+00	7.8	249.3	0.000	100000	9961	359.9
57	151906.6	F.A.	13.2	-1.5	H	H	.595	5.4558E+00	7.4	247.8	0.000	100000	9959	360.0
58	151907.4	F.A.	13.3	-1.4	H	H	.595	5.8421E+00	7.7	248.4	0.000	100000	9960	360.0
59	151908.1	F.A.	13.2	-1.3	H	H	.595	5.4304E+00	7.3	248.4	0.000	100000	9960	213.1
60	151909.6	F.A.	13.3	-1.1	H	H	.595	6.9278E+00	8.4	248.5	0.000	100000	9960	.1
61	151910.3	F.A.	13.2	-1.2	H	H	.595	5.7202E+00	7.6	249.3	0.000	100000	9959	.1
62	151911.8	F.A.	13.2	-1.2	H	H	.595	6.7520E+00	8.3	247.6	0.000	100000	9957	.1
63	151912.5	F.A.	13.2	-1.3	V	V	.595	5.9210E+00	7.7	244.2	0.000	100000	9958	.2
64	151913.3	F.A.	13.2	-1.3	V	V	.595	4.7140E+00	6.7	244.4	0.000	100000	9956	.3
65	151914.0	F.A.	13.3	-1.2	V	V	.595	4.8794E+00	6.9	244.6	0.000	100000	9954	.3
66	151915.5	F.A.	13.3	-1.1	V	V	.595	4.9261E+00	6.9	243.4	0.000	100000	9954	.5
67	151916.2	F.A.	13.2	-1.2	V	V	.595	5.9873E+00	7.8	244.4	0.000	100000	9954	.5
68	151917.7	F.A.	13.3	-1.3	V	V	.595	4.4515E+00	6.5	245.0	0.000	100000	9951	.4
69	151918.4	F.A.	13.2	-1.3	V	V	.595	5.3231E+00	7.3	243.4	0.000	100000	9950	.4
70	151919.2	F.A.	13.2	-1.3	V	V	.595	5.7957E+00	7.6	243.6	0.000	100000	9951	.5
71	151920.6	F.A.	13.3	-1.0	V	V	.595	5.5595E+00	7.5	244.2	0.000	100000	9950	.6
72	151921.4	F.A.	13.3	-.6	V	V	.595	5.2076E+00	7.2	244.0	0.000	100000	9951	.8
73	151922.1	F.A.	13.2	-.4	V	V	.595	5.0653E+00	7.0	245.0	0.000	100000	9952	.9
74	151923.6	F.A.	13.2	-.4	V	V	.595	4.7133E+00	6.7	244.0	0.000	100000	9955	.9
75	151924.3	F.A.	13.3	-.7	V	V	.595	4.5975E+00	7.0	243.6	0.000	100000	9954	.9
76	151925.1	F.A.	13.2	-1.1	V	V	.595	6.0345E+00	7.8	244.2	0.000	100000	9954	.9
77	151925.8	F.A.	13.2	-1.4	V	V	.595	5.5154E+00	7.7	243.6	0.000	100000	9953	.9
78	151926.5	F.A.	13.2	-1.4	V	V	.595	5.1604E+00	7.1	244.2	0.000	100000	9954	1.1
79	151927.3	F.A.	13.1	-1.5	V	V	.595	5.3982E+00	7.3	243.3	0.000	100000	9958	1.1
80	151928.0	F.A.	13.1	-1.4	V	V	.595	4.6699E+00	6.7	244.2	0.000	100000	9961	1.2

KEY TO CODES-

0 NO FLAG	1000 POLAR REVERSAL
1 POSSIBLY OUTSIDE RANGE GATE	10000 EXCESSIVE DEPOL
10 OUTSIDE DYNAMIC RANGE	100000 REC TEMP ABNORMAL
100 EXCESSIVE DOPPLER	1000000 WARM LOAD TEMP ESTIMATED

COMBINATIONS OF FLAGS CAN OCCUR.

FIGURE 3. SAMPLE LISTING OF OUTPUT RECORDS

between the "negative" flight direction and the azimuthal look direction. The positive cross-track angle is defined to the right of the aircraft when looking aft. It is induced by aircraft roll and drift angle. The incident and cross-track angles are precisely computed for any aircraft attitude. The angles enable the investigator to locate the illumination area. The scatterometer transmit polarization and the scatterometer and radiometer receive polarization are presented in the next two columns, respectively. The scatterometer integration time is indicated in the following column. The radiometer integration time is not listed since it is constant (128 milliseconds) regardless of mode or angle. The normalized scattering coefficient (m^2/m^2) is shown in decimal as well as dB units. The radiometer antenna temperature is shown in column 11.

A depolarization factor appears in column 12. The depolarization factor when expressed as a percentage indicates the percent power transmitted at the opposite surface polarization. Whenever DEPOL exceeds 50 per cent a polarization reversal flag is generated under the S/R validation code (column 13) and the complementary depolarization factor (1-DEPOL) is posted in column 12. If a reversal is indicated and the (complementary) depolarization factor is small, the polarization designators in columns 6 and 7 may indeed be regarded in the opposite state. Polarization reversals will frequently occur when observations are conducted from an aircraft roll condition. When DEPOL exceeds 2 per cent a flag in the S/R code is raised.

Other flag conditions can occur under the S/R code. The flags are used as a quick indicator of an abnormal condition. The interpretations of flags are given in a key at the bottom of every double page. The range gate flag is specifically set whenever the aircraft is not within $\pm$ 300 feet of the range gate setting. On some occasions this condition may be purposely generated to check the scatterometer zeros. A dynamic range flag is set whenever the scatterometer return is above or below the dynamic capability of the scatterometer receiver. If any of the receiver temperatures are not within the proper operating range a flag is set. Whenever the receiver temperature data is missing for long periods of time (data drop out), the receiver temperatures are estimated and a flag is generated. The other keys are self-explanatory. For additional assistance in diagnosing the flagged condition the conversion report may be consulted.

The latter two columns denote aircraft radar altitude and flight direction. Other aircraft parameters are available from the listings of the aircraft mission tape.

Not listed but present on the tape is the ambient air temperature at altitude. This latter parameter is available should the investigator wish to use it to estimate the apparent temperature distribution*.

E. Program ICHAR

Program ICHAR maintains a historical tape file of RADSCAT instrument characteristics. The historical file will (eventually) consist of many sets of instrument parameters which have been entered chronologically and labeled numerically. The historical file is maintained to chart the changes in the instrument parameters as may occur through updating, instrument modifications or simply aging. The Conversion Program withdraws an appropriate set of parameters from the historical file and applies the withdrawn parameters to reduce the measurements.

ICHAR performs several useful functions. It will initially establish the file. Once the file has been established it will permit the user to append new sets of characteristics. To assist in the maintenance of the file, ICHAR may be used to print and punch old sets of characteristics. The punched sets may be modified, for example, and submitted to ICHAR as a new set to be appended to file.

F. Program TDUPE

Program TDUPE provides a master duplicate tape of the output tape formed by the Conversion Program for use on other computing machines. The bit conversion problem between machines is avoided by scaling and integerizing all the numerical data before transferring the output data to the duplicate tape. This technique has been successfully applied to tapes prepared by a CDC-6600 and read on a Honeywell 635. The CDC 6600 is a 60 bit machine which performs "ones complement" arithmetic whereas the Honeywell is a 36 bit machine which performs "twos complement" arithmetic. The scale factors may be withdrawn from the listing of TDUPE shown in Figure D-2. Each output file consists of a header label (a flight run), the instrument characteristics applied to the data, and the output data records.

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*See for example, Claassen, J. P. and A. K. Fung, "An Efficient Technique for Estimating the Apparent Temperature Distribution," University of Kansas Center for Research, Inc., Technical Report 186-8, January 1973.

Additional integerized tapes may be prepared from the master duplicate tape by using system utility programs.

G. Special Programs

In addition to the above production type programs two engineering routines WIDTH and GAIN are included in the reduction package. Program WIDTH computes the equivalent beamwidth when it is presented with the mainbeam antenna pattern. The equivalent beamwidth parameter is essential to the inversion of the scatterometer data. The program GAIN computes the beam solid angle and directivity. The initial factor is important to the inversion of the radiometer measurements whereas the second is required in the inversion of the scatterometer measurements.

Functional representations of the antenna pattern are required by both programs.

IV. OPERATING INSTRUCTIONS

A. Introduction

General operating requirements, preparation of data input files, construction of the job deck, descriptions of the data products, flags and aborts, etc., are treated in this section. It is primarily written for the user having little or no knowledge of the theory and design of the programs. The reader will find that Section II and Section III will be helpful in understanding the contents of this section. Supplementary as well as detailed information on these programs may be found in the Appendices. Sufficient information is intended to permit the user to operate the primary programs CONVERT, OUTPUT, ICHAR and TDUPE. The remaining programs WIDTH and GAIN are engineering routines and should be handled by an engineer (or equivalent) familiar with the RADSCAT antenna. However, it is also strongly advised that a competent engineer, thoroughly familiar with the RADSCAT instrument, be involved in the preparation of the data and in the operation of the primary programs.

System control cards are not specified. It is presumed that this section together with sufficient knowledge of the operating system will dictate the necessary system control cards.

B. Conversion Program (CONVERT)

1. General

This program reduces 50 word input records to 20 word output records. Various computational algorithms described in detail in the Appendices are applied to the input records to yield data products of interest to the investigator. The input records are members of a file having an indefinite number of records. The files are elements of a multi-file tape. Each file is labeled with the entries shown in Table 1. The files are footed with an "end of file" mark. It is anticipated that files (flight runs) from several missions can be stored on a single tape. Tapes of this type are designated Raw Data Tapes.

To initiate processing of any of the files or all of them, processing directives are employed. The directives permit seeking files of certain types and must appear as data cards in the job deck. Each processing directive must be accompanied with a file referral argument to select a set of instrument parameters from the Instrument

Characteristics Tape* on which sets of instrument parameters are indexed numerically (and presumably stored chronologically). A set of these parameters is employed by CONVERT to reduce the raw data records. Alternatively, the instrument parameters can be entered from the card reader should the file index be set at zero. Files processed under a particular directive are transferred to the Output Tape. Various processing directives may be applied successively. In each instance the file search is effectively initiated from the beginning of the tape. Processing continues until all directives have been exhausted.

Other types of directives perform service functions. The directive POST permits newly processed files to be appended to an old Output Tape. This directive, when used, must precede all processing directives. The PRINT and PUNCH commands will list and punch, respectively, a set or several consecutive sets of instruments parameters from the Instrument Characteristics Tape. When the PUNCH command is employed, a listing of the set is also generated.

The composition of a CONVERT job deck is illustrated in Figure 4.

2. Preparation of the Raw Data Tape

As mentioned above each file is identified by a header label. The first seven items in the label (Table 1) are integer variables. The integer variables must be right justified. Note that the date requires three words. The sixth and seventh items are appended to the label to assist in selecting the proper subset of instrument characteristics from the set index designated on the processing directive card. See Section IV D for a description of the instrument characteristic files. The frequency is specified in GHz. The feed type is declared in the seventh word and is an alphanumeric word.

Presently two feed types are employed by the RADSCAT instrument. One feed uses a mechanical waveguide switch and the other a ferrite circulator. The abbreviations WG SW and CIRC are recommended as designators. To establish a convention, they should be left justified. The label must be created with an unformatted WRITE statement.

Beneath the header label are a sequence of raw data records each a mixture of real and integer words. The records are blocked by groups of 10 records. The blocks

*This tape is physically separate from the Raw Data Tape.

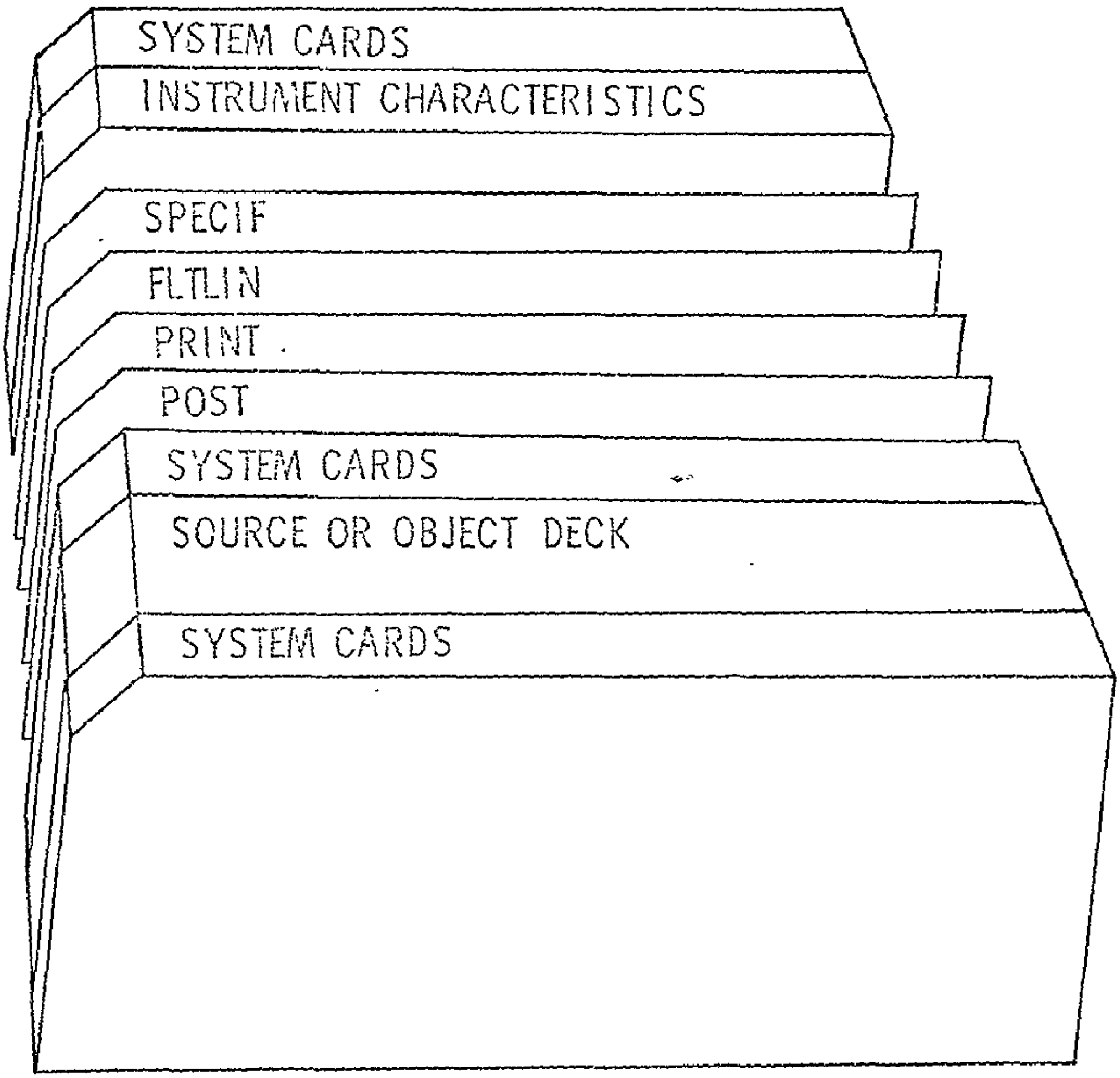

FIGURE 4. JOB DECK FOR PROGRAM CONVERT

Table 1 . File Label Entries Illustrated

Position	Name	Entry
1	Mission	207
2	Flight	11
3	Month	7
4	Day	21
5	Year	1972
6	Line	4
7	Run	9
8	Frequency	13.9
9	Feed	WG SW

must be created by unformatted WRITE statements. When insufficient records exist to fill the last block on a file, the remaining records must be filled with 99999.0 (floating point). These entries are used to flag the end of the records (file). In addition an EOF is appended to the foot of the file. As many files as practical may be created on the tape. The end of the files must be flagged with the label END OF REEL which fills the beginning of a nine word array and in effect is another file label.

The files are composed of three record types:

1. Normal Calibration
2. Baseline Calibration
3. Measurements

Calibration records may appear anywhere in the file and as frequently as desired. In a properly constructed file both types of calibrations should appear in the first records. However, should one (or both) type(s) of calibration be missing from the top of the file, the program will search for calibration records deeper in the file. Records bypassed in the search are transferred to a scratch unit for subsequent processing. Once found, the calibration information is extracted and applied to the bypassed records. Records following the calibration records are also treated with the same parameters until new calibration records are encountered. When the calibration information is totally missing or incomplete, the file is bypassed and an appropriate error message is printed.

The entries in the records are shown in Table II. Type and units of the variables are indicated. Parenthetical designators behind some of the entry names describe the computed results stored in those positions during processing. The integer

TABLE II RAW DATA VECTOR

NAME : DATA

POSITION	ENTRY	TYPE	UNITS
1	TIME	R	HR MIN SEC
2	FREQUENCY INDICATOR	I	—
3	MODE INDICATOR	I	—
4	DATA TYPE INDICATOR	I	—
5	ANGLE DESIGNATOR	I	—
6	TRANS POL INDICATOR	I	—
7	REC POL INDICATOR	I	—
8	SCAT 1 (OR CONVERTED SCAT)	R	VOLTS
9	SCAT 2	"	"
10	SCAT 3	"	"
11	SCAT 4	"	"
12	RAD POL INDICATOR	I	—
13	RAD (OR CONVERTED RAD)	R	VOLTS
14	SCAT ANGLE (OR INCID ANGLE)	R	"
15	RAD ANGLE (OR X-TRACK ANGLE)	R	"
16	RANGE GATE INDICATOR	I	—
17	T_1, 9.3 DICKE SWITCH	R	VOLTS
18	T_2, TRIPLEXER	R	"
19	T_3, T/R CIRCULATOR	R	"
20	T_4, 13.9 DICKE SWITCH	R	"
21	T_5, 9.3 TDA	R	"
22	T_6, 9.3 WARM LOAD	R	"
23	T_7, 9.3 LIMITER	R	"
24	T_8, BRACKET	R	"
25	T_9, COMMON T/R GUIDE	R	"
26	T_{10}, 11.7 DICKE SWITCH	R	"
27	T_{11}, 13.9 WARM LOAD	R	"
28	T_{12}, POLAR SWITCH OR CIRC.	R	"
29	T_{13}, SCAT CALIB SWITCH	R	"
30	T_{14}, 9.3 IMAGE REJECTION FILTER	R	"

TABLE II RAW DATA VECTOR (continued)

NAME : DATA

POSITION	ENTRY	TYPE	UNITS
31	T_{15}, BASEPLATE	R	VOLTS
32	T_{16}, OMT	R	"
33	T_{17}, HOT LOAD	R	VOLTS
34	V_{agc}	R	VOLTS
35	V_{supply}	R	"
36	FLAG (T_{11} MISSING)	I	—
37	EMPTY		
38	"		
39	"		
40	"		
41	RADAR ALTITUDE	R	FEET
42	GRD SPEED	R	FT/SEC
43	PITCH	R	DEGREES
44	DRIFT	R	DEGREES
45	ROLL	R	DEGREES
46	AMBIENT AIR TEMP	R	°C
47	FLIGHT DIRECTION	R	DEGREES
48	EMPTY		
49			
50			

indicator variables are defined in Table III. These indicators are employed to cue certain program actions or to index variables and must be right justified. Items 2 through 13 and 16 are extracted from the RADSCAT microwave data channel. Items 17 through 32 are retrieved from the RADSCAT ATM channel. Item 33 is presently entered by hand but may eventually appear on the ATM channel. Items 34 and 35 are presently ignored but may also eventually appear on the ATM channel. Item 36 is presently entered by hand and is used to flag missing temperature data (DATA(17) - DATA(32)). Items 41 to 45 and 47 are provided by the Litton Navigator LTN-51 aboard the C-130. Item 46 is provided by an external sensor aboard the aircraft.

The measurement records must be completed as shown in Table II. However, the calibration records may be abbreviated to include only the data type indicator (DATA(4)) and the calibration entries in the appropriate SCAT and/or in the RAD position. The normal calibration records must be ordered by SCAT channels (one through four) with the normal RAD calibration occurring in the fourth record (containing the SCAT channel 4 calibration). The routine which extracts calibration data will orient itself on the calibration record for SCAT channel 1 in an attempt to meet contingencies where calibration record drop-outs occur. Any number of normal calibration sequences (calibrations on channels one through four in each sequence) may occur successively. All will be averaged. Typically the instrument produces three sequences of normal calibrations. The baseline calibration record simply requires the appropriate RAD baseline calibration in the DATA(13) position (as well as the type indicator in DATA(4)) and may occur anywhere in the file except within a sequence of normal calibrations. It is essential that the baseline and normal calibrations be grouped by three or more consecutive records to assure that a statistically significant average will be established. The program will average consecutive baseline records, even if they are interspersed with sets of normal calibrations. The normal calibrations will also be averaged in this circumstance.

A routine prepared by Langley Research Center actually merges data from several sources to meet the above specifications.

3. Preparation and Use of the Control Cards

There are four types of processing directives and three service directives. The directives consist of a control word and some arguments. All control words are left justified; the arguments are right justified. Sample directives and their formats are defined in Table IV.

TABLE III. DEFINITION OF INTEGER INDICATOR VARIABLES

	0	1	2	3	4	5	6
Frequency Indicator		9.3 GHz	11.4*GHz	13.9 GHz			
Data Type	Measurement	Normal Calibration	Base Calibration				
Angle Designator		X	X	X	X	X	X
Polarization Indicator	Horizontal	Vertical					
Range Gate	2000 ft.	5000 ft.	10,000 ft.	20,000 ft.			
Mode Indicator**	R.O.	S.S.	F.A.	A.A.			

*NOT OPERATIONAL

**R.O. = RADIOMETER ONLY
S.S. = SHORT SCAT
F.A. = FIXED ANGLE
A.A. = ALTERNATING ANGLE

TABLE IV. CONTROL CARD OPTIONS ILLUSTRATED

	ARGUMENTS						
CONTROL WORD	MISSION	FLIGHT	LINE	RUN	LINE PRINT MODULUS	ICHAR SET NO.	FILES TO BE PROCESSED
A6, 4X	I5	I5	I5	I5	I5	I5	I5
SPECIF	207	12	2	3	1	2	1
	208						
FLTLIN	208	1	4	--	5	3	81
MISFLT	209	4	--	--	10	3	10
ALL	---	---	--	--	10	2	999
POST	---	---	--	--	--	--	---
PRINT	---	---	--	--	--	2	2
PUNCH	---	---	--	--	--	1	1

The control word for the processing directives designates the classification of the file search to be conducted. The search is conducted by comparing the arguments, mission, flight, line and run on the directive with the file labels on the Raw Data Tape. The depth of comparison in the label will depend on the type of processing directive. ALL will process all files on the tape, MISFLT will process all lines and runs under the designated mission and flight, FLTLIN will process all runs from the specified mission, flight, and line. SPECIF will process only a particular file labeled by the specified mission, flight, line and run. When consecutive processing directives are employed, the file search is effectively conducted from the beginning of the tape.

Arguments other than the mission, flight, line and run must also be provided. The sixth word LNPMOD controls the density of records on which reports will be made in the activity report. The use of this parameter will limit the amount of print out acquired during the reduction of records. It will not affect the density of output records.

The set of instrument characteristics (ICU) to be applied to the specified files is designated in the seventh word. The entry specifies the file position on a master tape of characteristics. If a zero is entered, the program will expect instrument parameters to be read from cards appended behind the program control card. When characteristics are read from the card reader, processing is limited to one physical file regardless of the directive. This control option is primarily reserved to test a set of instrument characteristics. See Section IV D for a description of the format required for the instrument characteristics. If 999 is specified, the last set of characteristics on the master (historical) tape will be used.

The last (eighth) entry NFP on the control card specifies the number of files to be processed under the directive. To process all files under the directive simply make NFP sufficiently large.

The special service command POST may be used to position a previously produced output tape to a point behind the last file on the tape. The use of this command will, therefore, permit new files to be appended to an old output tape. This command, when used, must appear before any processing directives. There are no arguments with this directive.

The two service directives PRINT and PUNCH are provided to list and list and punch a designated set of instrument characteristics, respectively. The desired set number is entered in columns 36 through 40 of the directive card. If n-1 sets behind the designated set are to be listed or punched also, NFP should be set to n; otherwise it is set equal to one. NFP appears in column 41 through 45 of the directive card.

4. Peripheral and Memory Requirement

The input and output unit requirements are illustrated in Figure 5. Under a processing directive units 01, 02, 04, 06, 08 are required; under the service directives PRINT or PUNCH units 04, 06, and 43 are required. Unit 08 is a scratch unit, either disc or tape, perferably disc. It is used to temporarily store bypassed records when it is necessary to search for calibration data.

Approximately 17000 decimal words of memory were required to load this program on a CDC-6600 to include buffer space and system routines.

5. Flags and Aborts

The activity report produced by the program conveys various messages to indicate the status of the processing. It is normal for the program to echo check the directives, to list the progress on the processing, and to indicate a normal termination. The Conversion Report will also make regular statements reflecting the progress of the processing and the quality of the measurements. A sample listing of the Conversion Report is shown in Figure 2 of Section III. In some instances however, improper use of the program or construction of the data will result in an error message or an abort.

When an abort condition is encountered, an error message is generated, an abort code is given, an end of file mark is appended to the output tape on unit 02, an END OF REEL statement is appended, and control is yielded to the system. Table V defines the various abort conditions. When invalid data records are encountered, an error message will identify the improper element and the entire record will be dumped in octal. The message will appear within the Conversion Report. When more than 10 bad records are encountered in a file, the remaining records in the file are bypassed and processing is directed to the next internal activity. When more than three bad files are encountered the processing is aborted.

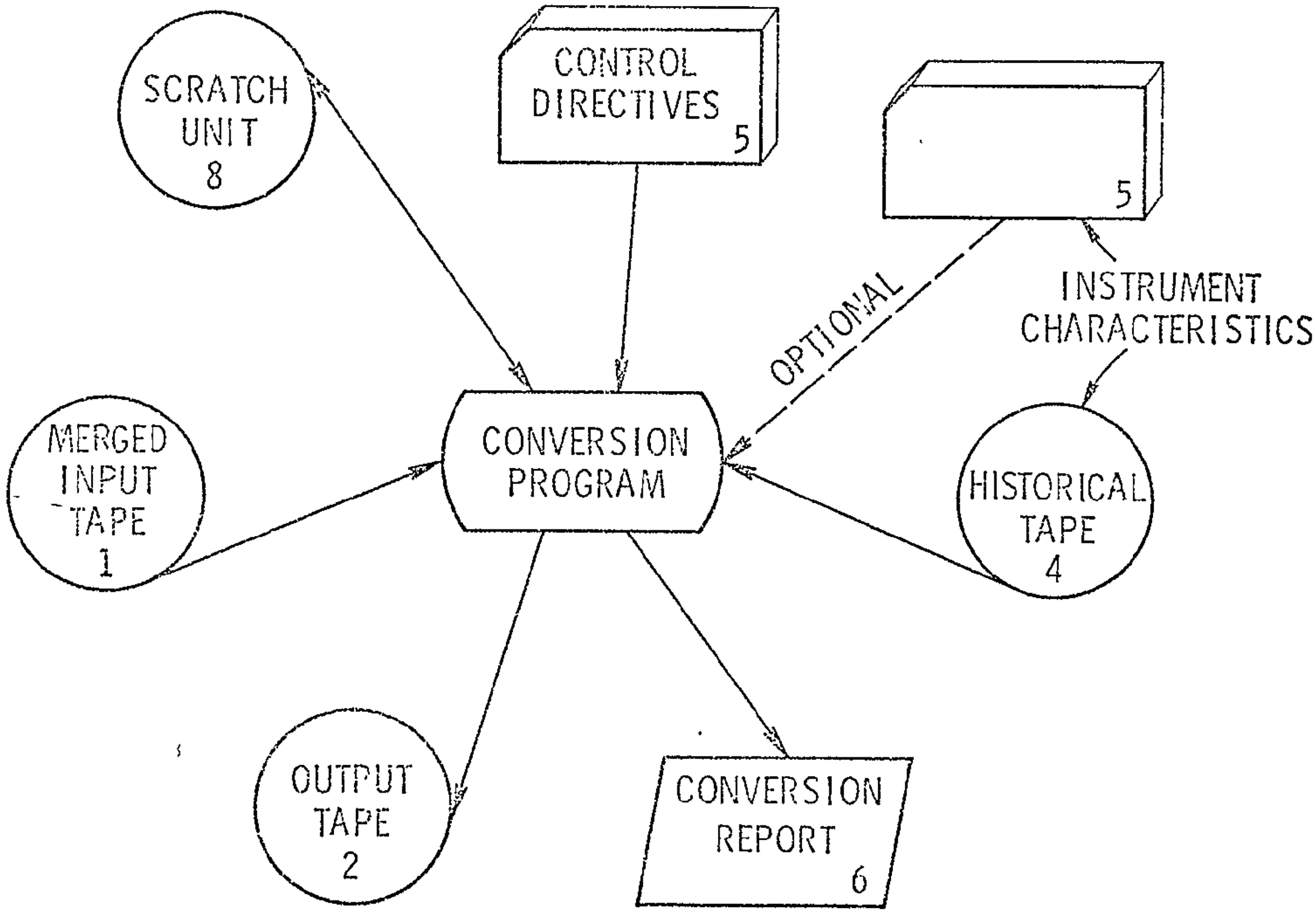

FIGURE 5. PERIPHERAL REQUIREMENTS FOR THE PROGRAM CONVERT

Table V. Definition of Abort Codes

UD	= Unrecognized Directive
IC	= Instrument Characteristic Missing
MF	= Missing Raw Data File
FF	= Unable to Find Instrument Characteristics with the Feed and Frequency Designated
ER	= Too Many File Errors
NFP	= NFP less than 1

6. Description of the Data Products

Normally two data products are generated by CONVERT, an activity report and an output tape. When the PUNCH option is employed a set or sets of punched instrument parameters can also occur. The character of the punched output is identical to that described in Section III D. The activity report reflects the program progress and largely contains items in the Conversion Report. See Figure 2 of Section III for an illustration of the Conversion Report. The Output Tape, however, will be described.

The output file structure is similar to that of the input raw data files. The file consists of the file label and blocks of output records. However, occurring between the label and output record blocks is the set of instrument parameters that had been used to process the input records. The entries in the file label are the same as that for the input files shown in Table I. The label and instrument parameters are created with separate unformatted WRITE statements. The entries in the instrument characteristics are described in Section III D. The output records occurring beneath the instrument parameters are blocked in 20 records groups. Each block is created with a binary WRITE statement. The elements in the output records consist of mixed integer and floating point entries. The entries are defined in Table VI. When insufficient records exist to fill the the last block in the file, the remaining entries are filled with integer zeros. An "end of file" mark is created after the last block in the file.

When all directives have been exhausted or the program aborted an "end of reel" statement is appended behind the last output file.

TABLE VI OUTPUT DATA VECTOR

POSITION	ENTRY	TYPE	UNITS
1.	TIME	R	HR, MIN, SEC
2.	MODE	I	—
3.	INCIDENCE ANGLE	R	DEGREES
4.	CROSS TRACK ANGLE	R	DEGREES
5.	TRANSMIT POLARIZATION	I	—
6.	RECEIVE POLARIZATION	I	—
7.	SCAT INTEGRATION TIME	R	SECONDS
8.	NORMALIZE SCATTERING COEF.	R	M^2/M^2
9.	NORMALIZE SCATTERING COEF.	R	dB
10.	ANTENNA TEMPERATURE	R	DEGREES KELVIN
11.	DEPOLARIZATION FACTOR	R	—
12.	DATA VALIDATION CODE	I	—
13.	ALTITUDE		FEET
14.	FLIGHT DIRECTION		DEGREES wrt TRUE NORTH
15.	AMBIENT AIR TEMP		DEGREES KELVIN
16-20.	EMPTY		

C. Output Program

1. General

The Output Program simply lists the output records prepared by program CONVERT. The output listings are organized by files which are selected by external directives similar to those described for the Conversion Program. A sample of a listing is illustrated in Figure 3 of Section III. The file heading together with instrument characteristic identifiers compose the page heading. Beneath the heading are listed 80 record images; each image consists of the first fourteen entries in an output record as defined in Table VI. The fifteenth entry is not printed but is available on tape should the investigator choose to use it to further reduce the radiometer data. Each line of print-out is appended with the record number. The record number corresponds to those used in the Conversion Report. The 80 records are intended to fill two consecutive pages of print-out where the page size is 8-1/2" by 15". Appended to the foot of each double page is a key defining the S/R validation code in column 13.

The instrument characteristics although present on the output tape are not listed. The set which has produced the data is identified in the heading on the right by the set number and date. No option is provided to print the characteristics.

The job deck for the program OUTPUT is organized identically to the conversion program (however, no instrument characteristics must appear in the data deck). File types are selected from the output by proper use of the directives:

1. ALL
2. MISFLT
3. FLTLIN
4. SPECIF

The meaning and use of these directives have been presented in Sections III B.1 and III B.2. The format of these control cards is identical to those described above. In the argument field of the control card the appropriate file identifiers must be present. No provision is made to limit the number of files to be processed, nor can the record density be controlled through a line print modulus. It is, of course, meaningless to specify the instrument characteristics ICU.

2. Program Messages

In addition to listing the output file, OUTPUT will keep the user posted on its internal activity as it searches for the specified files. The directive is initially echo checked, bypassed files are identified and the user is notified when the reel is encountered. Unrecognized directives will terminate the processing.

3. Peripheral and Memory Requirement

Peripheral requirements are illustrated in Figure 6. The program required approximately 7000 decimal words of memory on a CDC 6600 to include buffer space and system routines.

D. Program ICHAR

1. General

The primary purpose of program ICHAR is to maintain a file of instrument characteristics. The file is maintained not only to serve as a source of parameters to reduce raw data records but also to serve as a history of the changes undergone by the RADSCAT instrument. The file can consist of many sets of instrument parameters which are appended to the file numerically. The user may also identify the set by a date which is entered with the parameters.

Each set of instrument characteristics can consist of four subsets. The four subsets permit characterizing the instrument for a combination of two feeds and two frequencies. Each subset is composed of a set of radiometer parameters and a set of scatterometer parameters. The subsets are identified by feed and frequency. These identifiers are used by the Conversion Program to select the appropriate subset of characteristics.

This file maintenance program is operated by means of external control cards. Four directive (processing) options are offered:

1. INITIALIZE
2. APPEND
3. PRINT
4. PUNCH

They must be left justified and occupy columns 1 through 10 of the control card. INITIALIZE will create the historical file by storing the first set of characteristics on the tape. The set must appear behind the control card. APPEND will permit other sets to be added to the existing historical file. The characteristics set to be appended must appear behind the APPEND command card. When several sets are added at one operation, each set must be led by an APPEND card and intervening PRINT or PUNCH commands are not permitted. When sets are appended to the file, the old sets are transferred from the old tape to a new tape and the new sets are then

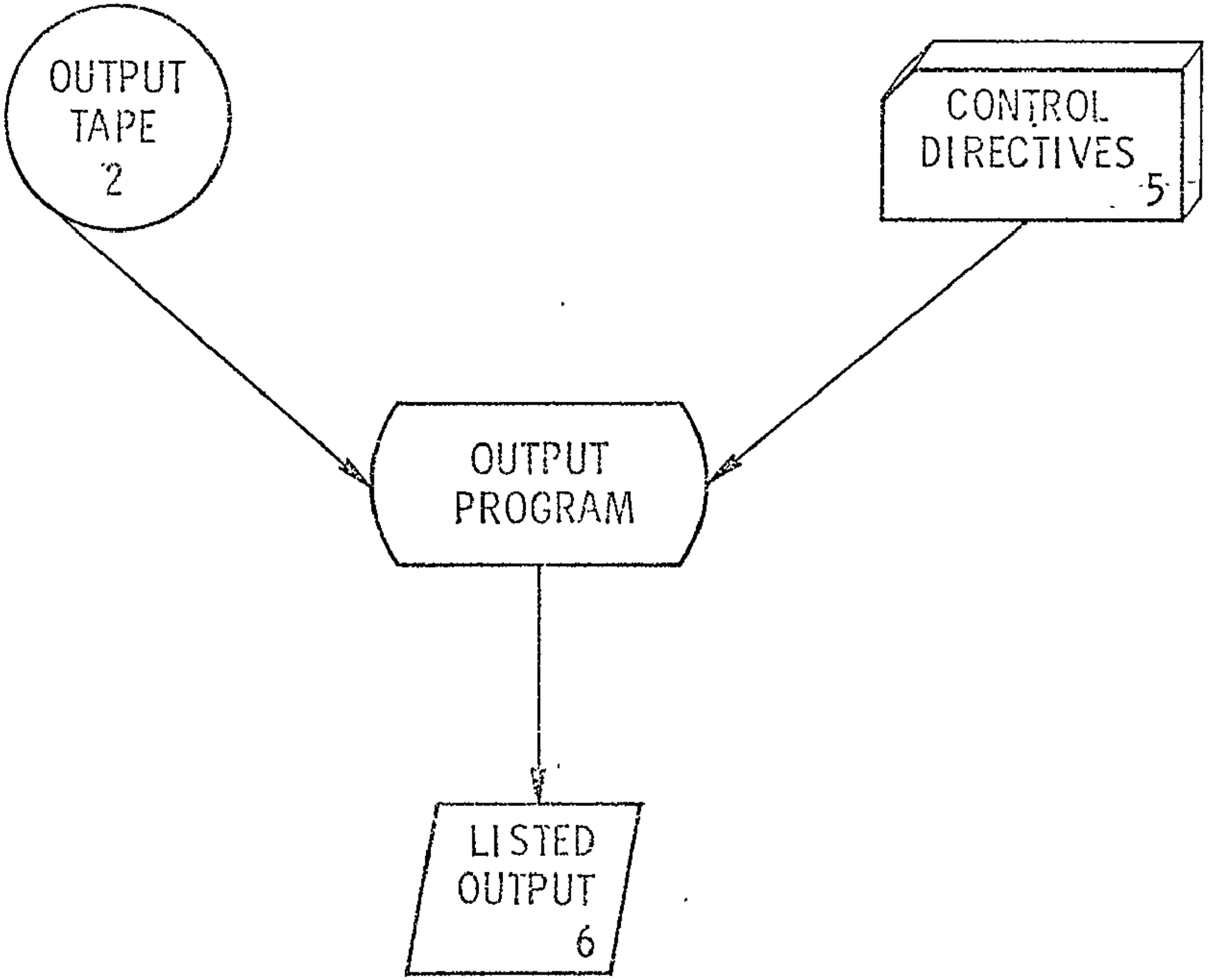

FIGURE 6. PERIPHERAL REQUIREMENTS FOR THE PROGRAM OUTPUT

added to the new tape. Before appending a new set of characteristics, it is advisable to have tested them in the Conversion Program by entering them from the card reader.

The PRINT and PUNCH commands perform the same service as they do in the Conversion Program. However, one command must be used for each set to be printed or punched. The set to be printed or punched must be specified on the control card in columns 11 through 15. The set number must be right justified. A listing accompanies the punched output. The PRINT or PUNCH may preceed or follow a set of APPEND commands but must not intermingle with them. These commands are provided so that new sets may be formed easily from old sets of characteristics.

A sample deck is illustrated in Figure 7.

2. Preparation of the Instrument Characteristics

The instrument parameters cards must be prepared in groups of four subsets. When insufficient data exists to complete one of the subsets, a complete subset may be repeated an appropriate number of times to fill the requirement. A sample subset is shown in Figure 8. The lines actually represent card images (except for the word SET). The entries in the upper half are radiometer parameters whereas the entries in the lower half are scatterometer parameters. This subset would be used for measurements taken at 13.9 GHz with a waveguide switch (WG SW) as the polarization switch. The radiometer and scatterometer parameters are identified with the set number of which it is a member and with a date of entry (origin). The first line of radiometer or scatterometer parameters must be punched with the format 4I5, 10X, E10.3, A10, E10.3 whereas the remaining lines must be punched according to the format 7E10.3. Excluding the set number and date, the radiometer parameters array consist of 75 words and the scatterometer parameter array consists of 85 words. Not all words are necessarily filled.

The entries in the radiometer and scatterometer arrays are defined in Tables VII and VIII, respectively. Many of the entries can be clarified by referring to a description of the reduction algorithms in the Appendices. These algorithms have been developed from the transfer and calibration characteristics of the RADSCAT instrument. As a consequence the entries may change (and perhaps the program algorithms) when the instrument is modified. Many of the entries must be based on special calibrations and measurements. Explanations are required for some of the

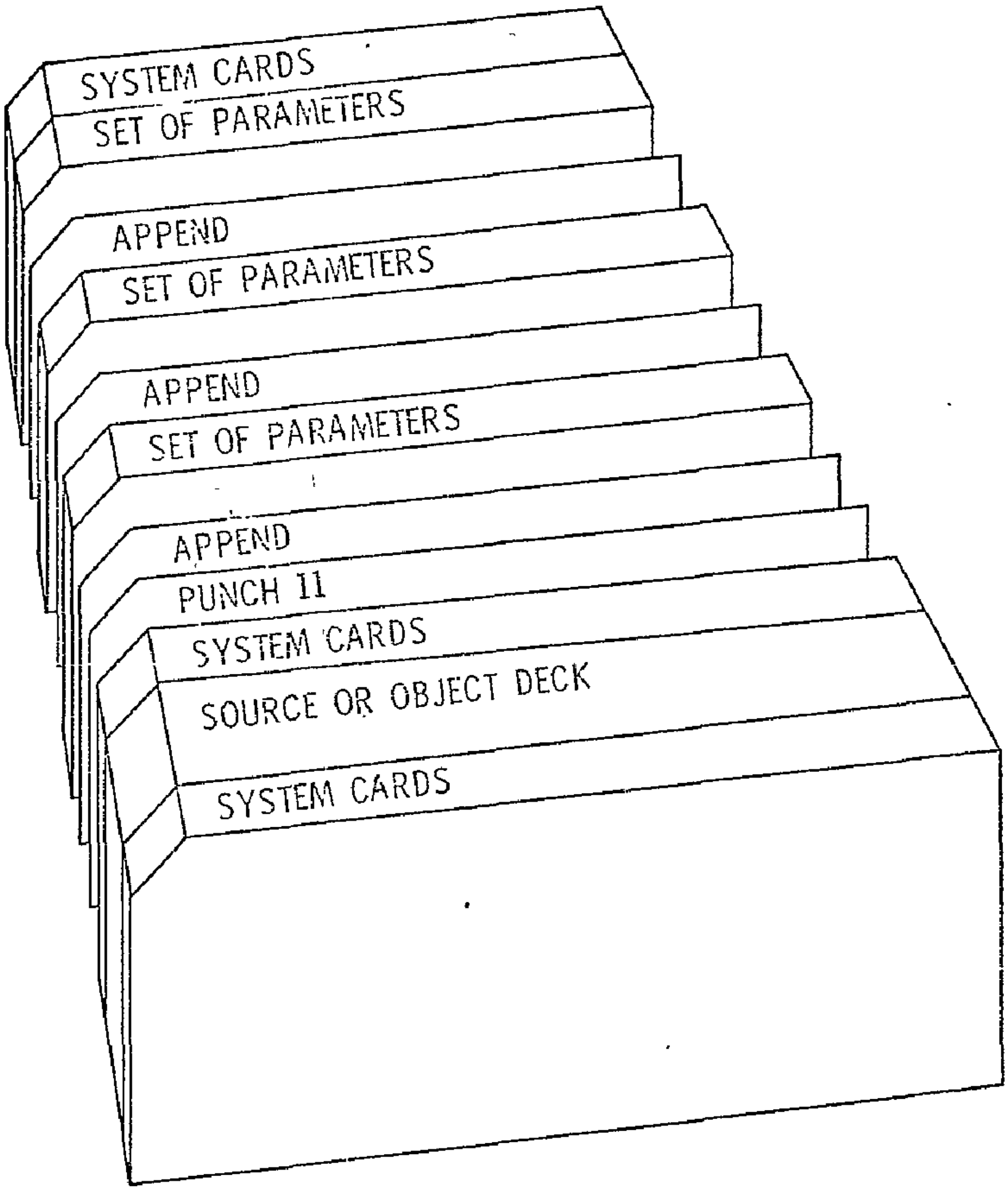

FIGURE 7. JOB DECK FOR PROGRAM ICHAR

SET 1 DATE	10 23 72	1.3900E+10	WG SW	0.		
0.	3.9900E+02	1.0540E+00	1.9950E+02	4.0000E-01	8.0000E-02	8.0000E-02
1.0200E-02	1.0150E-02	6.0000E-02	6.0000E-02	0.	0.	-0.
-0.	1.2800E-01	1.0000E-01	3.2500E+02	3.0500E+02	-8.7800E+00	7.9924E+01
-8.7800E+00	7.9871E+01	-8.7800E+00	7.9169E+01	-8.7800E+00	7.8879E+01	-8.7800E+00
7.9476E+01	-8.7800E+00	7.8730E+01	-8.7800E+00	7.9415E+01	-8.7800E+00	7.9704E+01
-8.7800E+00	7.9388E+01	-8.7800E+00	7.9889E+01	-8.7800E+00	8.0178E+01	-8.7800E+00
7.8826E+01	-8.7800E+00	7.9757E+01	-8.7800E+00	7.9309E+01	-8.7800E+00	7.9573E+01
-8.7800E+00	7.9379E+01	1.0000E+00	-2.7318E+02	-0.	-0.	-0.
-0.	-0.	-0.	-0.	-0.	-0.	-0.
-0.	-0.	-0.	-0.	-0.	-0.	-0.
-0.	-0.					

SET 1 DATE	10 23 72	1.3900E+10	WG SW	1.0000E-01		
5.8000E-01	5.9500E-01	6.3700E-01	7.0700E-01	8.0200E-01	9.2400E-01	3.0000E-01
3.7568E-01	3.7916E-01	0.	0.	4.9753E-01	5.0213E-01	2.0893E-07
1.0000E+00	1.0000E-02	3.1623E-04	3.1623E-06	-8.0000E+03	3.5000E+03	2.5000E+02
1.4125E+04	1.4125E+04	1.4000E+00	1.0500E+01	1.4000E-01	-6.3400E+00	5.0000E+01
2.2514E-01	2.2514E-02	0.	0.	4.6000E-02	7.1000E-02	9.6000E-02
1.3000E-01	1.6500E-01	2.1300E-01	2.6200E-01	2.8600E-01	3.0000E-01	6.4200E-01
5.1500E-01	6.0000E-01	7.6900E-01	8.8500E-01	1.0000E+00	1.1730E+00	1.3460E+00
1.3460E+00	1.3460E+00	1.2500E+00	1.1540E+00	1.0960E+00	1.0380E+00	1.0190E+00
1.0000E+00	1.0560E+00	1.1120E+00	1.2170E+00	1.3230E+00	1.3730E+00	1.4230E+00
1.4850E+00	1.5380E+00	1.4420E+00	1.3460E+00	1.1570E+00	9.6900E-01	7.6000E-01
5.5000E-01	4.2100E-01	2.9700E-01	2.3300E-01	1.7300E-01	1.4400E-01	1.1500E-01
1.0000E-01	8.5000E-02	-0.	-0.	-0.		

FIGURE 8. SAMPLE OF INSTRUMENT CHARACTERISTICS

TABLE VII RADIOMETER PARAMETERS

VARIABLE NAME : RPAR

POSITION	ENTRY		TYPE	UNITS
1	FREQUENCY		R	GHZ
2	FEED (WG SW OR CIRC)		A	UNITLESS
3	CROSS FEED CONSTANT	ξ_{HV}	R	"
4	" "	ξ_{VH}	R	"
5	HOT LOAD REFERENCE CONST	σ_1	R	°K
6	WARM LOAD REFERENCE CONST	σ_2	R	"
7	HOT LOAD BIAS FACTOR	σ_3	R	"
8	WARM LOAD BIAS FACTOR	σ_4	R	UNITLESS
9	SWITCH COMPENSATION FACTOR	ρ_{1H}	R	UNITLESS
10	" " "	ρ_{1V}	R	"
11	OMT " "	ρ_{2H}	R	"
12	" " "	ρ_{2V}	R	"
13	CUTLER FEED " "	ρ_{3H}	R	"
14	" " "	ρ_{3V}	R	"
15	INPUT GUIDE " "	ρ_{4H}	R	"
16		ρ_{4V}	R	"
17	RESIDUAL "	ρ_{5H}	R	
18	"	ρ_{5V}	R	
19	MEASUREMENT PERIOD	τ	R	SEC
20	CALIBRATION PERIOD	τ_C	R	SEC
21	UPPER TEMP LIMIT	UP	R	°K
22	LOWER TEMP LIMIT	LOW	R	°K
23	THERMISTOR CONVERSION FACTOR	α_1	R	°C/VOLT
24	" " "	β_1	R	°C
25	" " "	α_2	R	°C/VOLT
26	" " "	β_2	R	°C
27	" " "	α_3	R	°C/VOLT
28	" " "	β_3	R	°C
29	" " "	α_4	R	°C/VOLT
30	" " "	β_4	R	°C

TABLE VII RADIOMETER PARAMETERS (continued)

POSITION	ENTRY				TYPE	UNITS
31	THERMISTOR	CONVERSION	FACTOR	α_5	F6.2	°C/VOLT
32	"	"	"	β_5	"	°C
33	"	"	"	α_6	"	°C/VOLT
34	"	"	"	β_6	"	°C
35	"	"	"	α_7	"	°C/VOLT
36	"	"	"	β_7	"	°C
37	"	"	"	α_8	"	°C/VOLT
38	"	"	"	β_8	"	°C
39	"	"	"	α_9	"	°C/VOLT
40	"	"	"	β_9	"	°C
41	"	"	"	α_{10}	"	°C/VOLT
42	"	"	"	β_{10}	"	°C
43	"	"	"	α_{11}	"	°C/VOLT
44	"	"	"	β_{11}	"	°C
45	"	"	"	α_{12}	"	°C/VOLT
46	"	"	"	β_{12}	"	°C
47	"	"	"	α_{13}	"	°C/VOLT
48	"	"	"	β_{13}	"	°C
49	"	"	"	α_{14}	"	°C/VOLT
50	"	"	"	β_{14}	"	°C
51	"	"	"	α_{15}	"	°C/VOLT
52	"	"	"	β_{15}	"	°C
53	"	"	"	α_{16}	"	°C/VOLT
54	"	"	"	β_{16}	"	°C
55	"	"	"	α_{17}	"	°C/VOLT
56	"	"	"	β_{17}	"	°C
57	EMPTY					
.	.					
.	.					
.	.					
75	EMPTY					

TABLE VIII SCATTEROMETER PARAMETERS

POSITION	ENTRY		TYPE	UNITS
1	FREQ		R	HZ
2	FEED (WG SW OR CIRC)		A	—
3	CALIBRATION PERIOD	C	R	SEC
4	INT. TIME #1	1	R	"
5	INT. TIME #2	2	R	"
6	INT. TIME #3	3	R	"
7	INT. TIME #4	4	R	"
8	INT. TIME #5	5	R	"
9	INT. TIME #6	6	R	"
10	SHORT SCAT INT TIME	7	R	"
11	TRANSFER FUNCTION	G_{HT}	R	—
12	" "	G_{VT}	R	—
13	" "	G_{VHT}	R	—
14	" "	G_{HVT}	R	—
15	" "	G_{HR}	R	—
16	" "	G_{VR}	R	—
17	" "	G_C	R	—
18	CAL ATTN CHAN 1	A_1	R	—
19	" " " 2	A_2	R	—
20	" " " 3	A_3	R	—
21	" " " 4	A_4	R	—
22	FILTER LOWER LIMIT (NEG)		R	HZ
23	FILTER UPPER LIMIT (POS)		R	HZ
24	FILTER RESOLUTION		R	HZ
25	ANT GAIN H	Γ_H	R	—
26	ANT GAIN V	Γ_V	R	—
27	CHAN #1 SATURATION LEVEL		R	VOLTS
28	EMPTY			—
29	MINIMUM SQUARE LAW LEVEL FOR ALL CHANNELS		R	VOLTS
30	ANGLE CONVERSION FACTOR		R	DEG/VOLT

TABLE VIII SCATTEROMETER PARAMETERS (continued)

POSITION	ENTRY		TYPE	UNITS
31	ANGLE CORRECTION FACTOR*		R	DEG.
32	EQUIVALENT BEAMWIDTH H	θeq	R	RADIANS
33	EQUIVALENT BEAMWIDTH V	θeq	R	"
34	EMPTY			—
35	"			—
36	"			—
37	"			—
38	RELATIVE FILTER GAIN,	f= 3000	R	—
39	"	f= 2750	R	—
40	"	f= 2500	R	—
41	"	f= 2250	R	—
42	"	f= 2000	R	—
43	"	f= 1750	R	—
44	"	f= 1500	R	—
45	"	f= 1250	R	—
46	"	f= 1000	R	—
47	"	f= 750	R	—
48	"	f= 500	R	—
49	"	f= 250	R	—
50	"	f= 0	R	—
51	"	f= -250	R	—
52	"	f= -500	R	—
53	"	f= -750	R	—
54	"	f=-1000	R	—
55	"	f=-1250	R	—
56	"	f=-1500	R	—
57	"	f=-1750	R	—
58	"	f=-2000	R	—
59	"	f=-2250	R	—
60	"	f=-2500	R	—

*Includes relative pitch between aircraft frame and antenna gimbal.

TABLE VIII SCATTEROMETER PARAMETERS (continued)

POSITION	ENTRY		TYPE	UNITS
61	RELATIVE FILTER GAIN,	f=-2750	R	—
62	"	f=-3000	R	—
63	"	f=-3250	R	—
64	"	f=-3500	R	—
65	"	f=-3750	R	—
66	"	f=-4000	R	—
67	"	f=-4250	R	—
68	"	f=-4500	R	—
69	"	f=-4750	R	—
70	"	f=-5000	R	—
71	"	f=-5250	R	—
72	"	f=-5500	R	—
73	"	f=-5750	R	—
74	"	f=-6000	R	—
75	"	f=-6250	R	—
76	"	f=-6500	R	—
77	"	f=-6750	R	—
78	"	f=-7000	R	—
79	"	f=-7250	R	—
80	"	f=-7500	R	—
81	"	f=-7750	R	—
82	"	f=-8000	R	—
83	EMPTY			
84	"			
85	"			

entries. The thermistor conversion factors in RPAR(23) through RPAR(56) convert the thermistor voltages in DATA(17) through DATA(33) to temperature in centigrade (see Table II). A sampled representation of the scatterometer doppler filter frequency characteristic appears in SPAR(34) through SPAR(85). The sample frequency interval is designated in SPAR(24) and the frequency domain of the doppler filter is specified in SPAR(22) and SPAR(23).

3. Peripheral and Memory Requirements

The peripheral requirements are illustrated in Figure 9. To load the program required approximately 10,000 decimal words of memory on a CDC-6600 to include buffer space and system routines.

E. Program TDUPE

Program TDUPE scales and integerizes output files prepared by program CONVERT and transfers the result to another tape. The resulting tape serves as a master tape which may be duplicated and sent to the investigator for use on another type of computing machine.

The scaling and transferring of an output tape is implemented by an external control card appended to the source or object deck. The card simply states the files by mission and flight which are to be transferred. The control card requires a 2I10 format. The input files must be located on tape unit 01. The specified file types are transferred to a tape on unit 02. An activity report, stating the status on the transfers, is generated. The program requires approximately 8000 decimal words on a CDC-6600. The peripheral requirements are illustrated in Figure 10.

F. Special Programs

Several engineering application programs are provided to compute and/or verify certain antenna parameters employed in the instrument parameters. Program WIDTH computes the equivalent pencil beamwidth, an important parameter to the inversion of the scatterometer data (SPAR(32) and SPAR(33)). The program GAIN computes the antenna gains SPAR(25) and SPAR(26) and the beam solid angle.

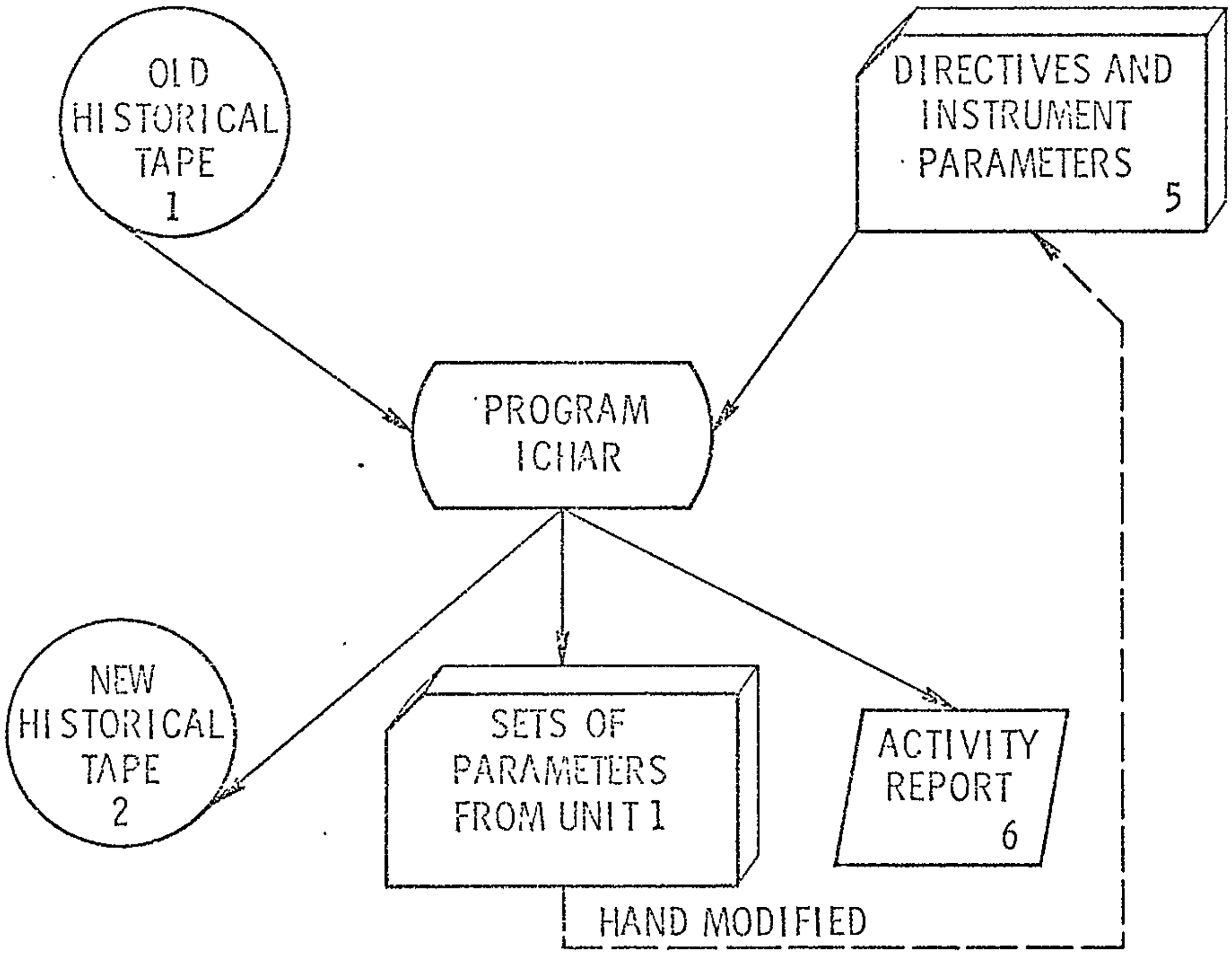

FIGURE 9. PERIPHERAL REQUIREMENTS FOR PROGRAM ICHAR

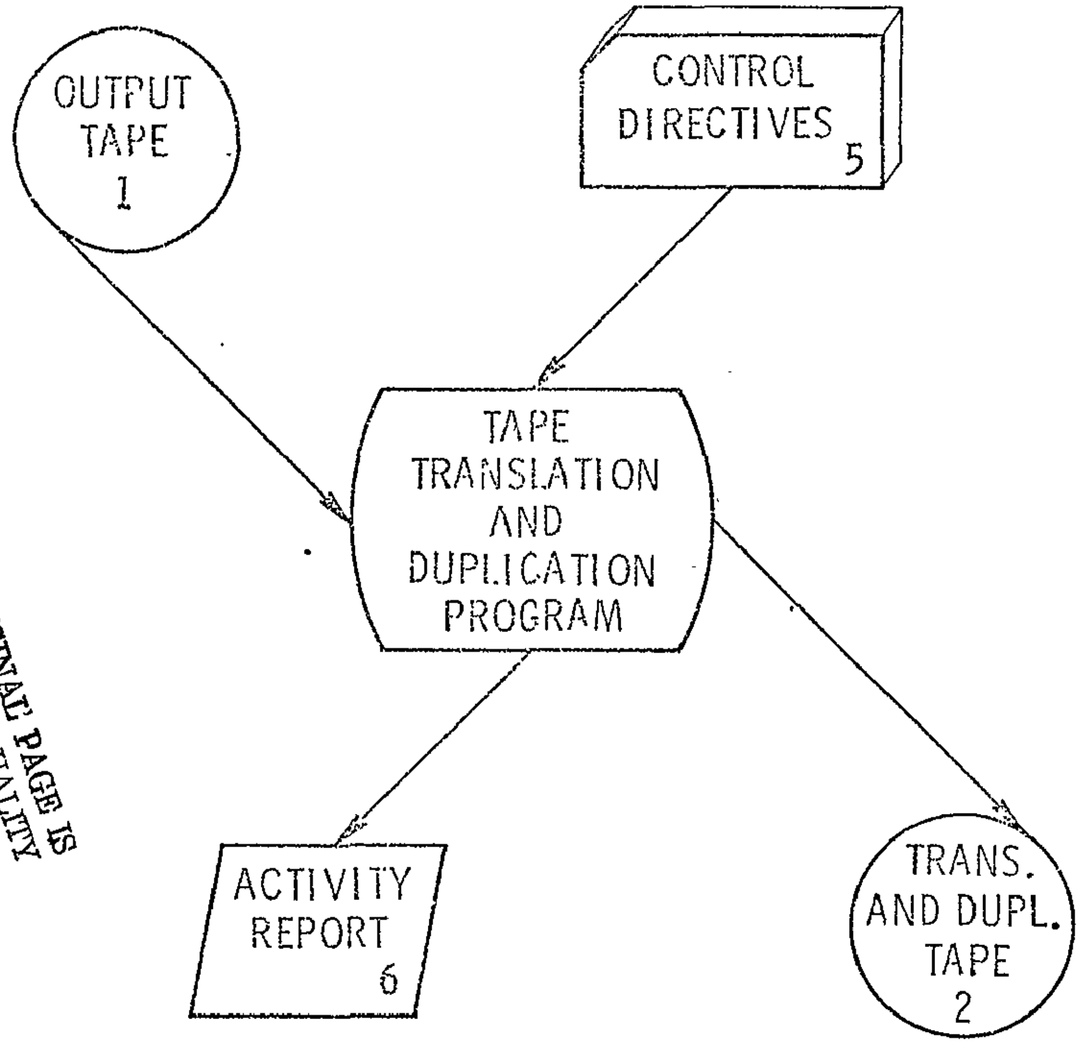

FIGURE 10. PERIPHERAL REQUIREMENTS FOR PROGRAM TDUPE

Program WIDTH is self sufficient when antenna pattern information is provided in the FUNCTION subroutine FUN. Presently functional representations of the main beam out to 6 degrees from boresight are provided. This routine may be replaced by a sampled version of the main beam. However, interpolation between sampled values must be provided since a double integration routine requires values dictated by the Gaussian Legendre quadrature technique.

Program GAIN requires both polarized and cross polarized power patterns. Functional representations of the polarized pattern is now given in FUN1 and the cross polarized pattern in FUN2. These may be replaced with sampled valued representation, if desired. Again, interpolation will be required.

For more specific information see Appendix E.

APPENDICES

APPENDIX A

CONVERSION PROGRAM

I. INTRODUCTION

The conversion program (CONVERT) applies many reduction algorithms to the raw RADSCAT data to provide the investigator with a set of comprehensive data products with which to interpret the scattering and emission characteristics of the scene represented by the data. CONVERT consists of the Control Section and the following subroutines:

1. IREAD	7. CALIB
2. READ1	8. RCONV
3. WRITE2	9. ANGLE
4. ABORT	10. DOPCHK
5. SEARCH	11. SCONV
6. CRUNCH	12. THERMO

The theory and design of these routines are treated in this appendix.

II. GENERAL OVERVIEW

The Control Section reads and interprets external directives. On the basis of the directive, the appropriate files are retrieved and presented to the processing subroutines. Subroutine SEARCH executes entry into the data records of the file in search of the appropriate calibration records. When found, the calibration information is extracted and averaged in subroutine CALIB. When sufficient calibration data cannot be found, the file is bypassed. The actual processing is performed by subroutine CRUNCH which applies various algorithms and calibration information to reduce the data. Many of the algorithms are embodied in subroutines, bearing descriptive names, which are called from CRUNCH.

Subroutine ANGLE computes the incident and cross-track angles using aircraft attitude and look angle information. Subroutine THERMO checks internal receiver temperatures. The antenna temperature is computed in RCONV using the transfer function of the RADSCAT radiometer, the temperatures developed in THERMO and RAD calibration parameters. When scatterometer data is present, the maximum on-scale measurement is selected from the four SCAT channels with an in-line routine in CRUNCH. Using aircraft ground speed, DOPCHK computes the doppler shift in the scatterometer signal. The doppler filter gain is chosen accordingly. The scatterometer transfer function is applied in subroutine SCONV to compute the scatterometer normalized input power. An in-line routine in CRUNCH applies antenna inversion parameters to the input power to compute the normalized scattering coefficient.

When additional calibration records are encountered, the old calibration information is replaced by the new calibration information by subroutine CALIB.

Subroutine IREAD and READ1 perform the file read functions, whereas subroutine WRITE2 performs the write functions.

Subroutine ABORT is employed by the CONTROL Section to abort the job when an abnormal condition is encountered.

III. CONTROL SECTION

A. Theory and Design

The control section was developed to give the user a large amount of flexibility in the choice of the instruments characteristics and the files to be processed. As many or as few files of a particular type can be processed. Some files can be treated with one set of instrument characteristics and others with another. These features permit the user to (1) test a set instrument parameters, (2) group the files by type, (3) process different types of files with different instrument parameters, (4) etc. The flexibility in the choice of parameters was incorporated with the full realization that the instrument would undergo modifications.

Control of the program is executed by the choice of appropriate directives entered as data cards. The types of controls have already been discussed in Section II and III of the text and will not be treated here again. The method by which control cards are read and files are retrieved is shown in the logic diagram of Figure A-1.

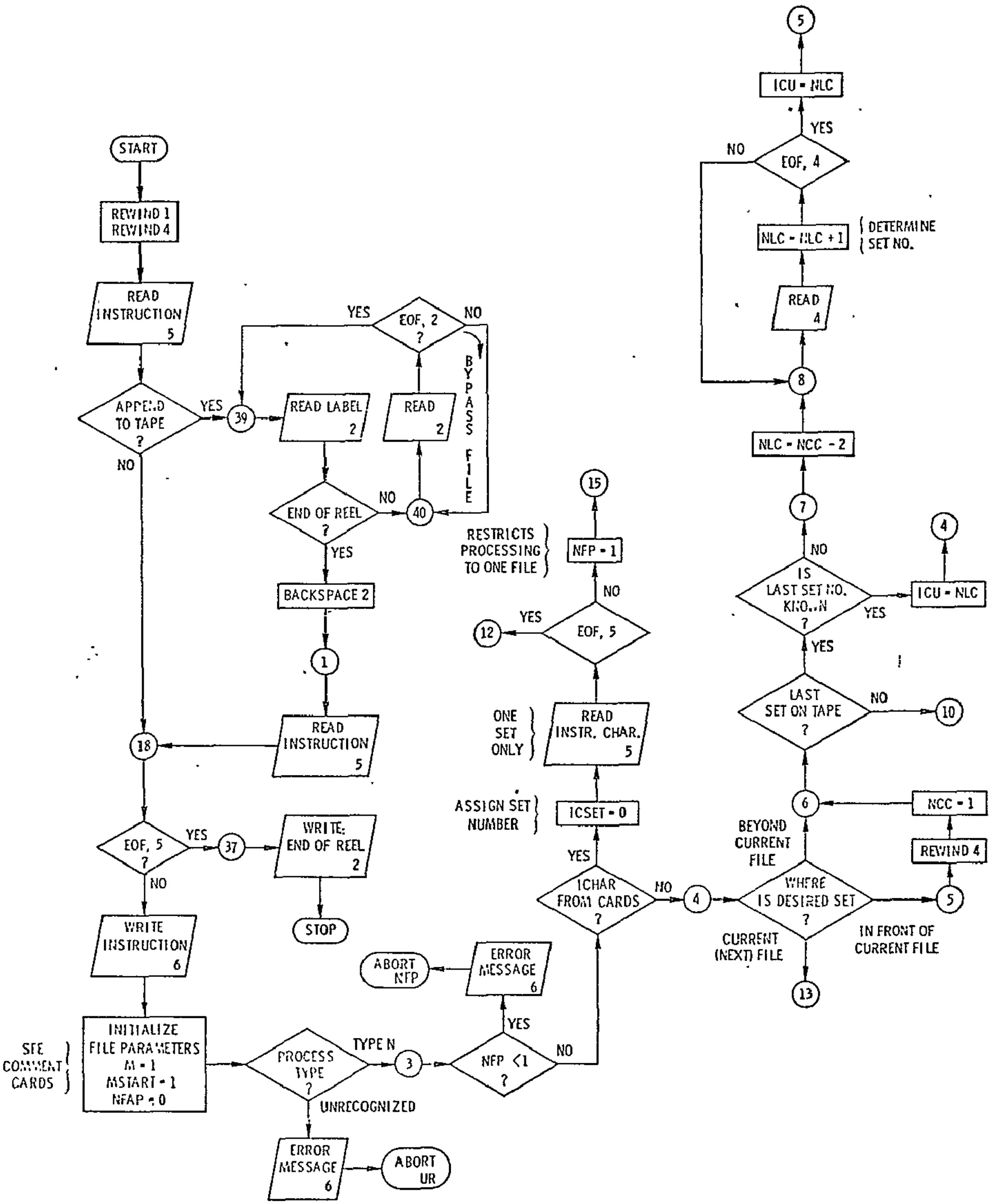

FIGURE A-1(a). DESCRIPTIVE LOGIC DIAGRAM FOR THE CONTROL SECTION

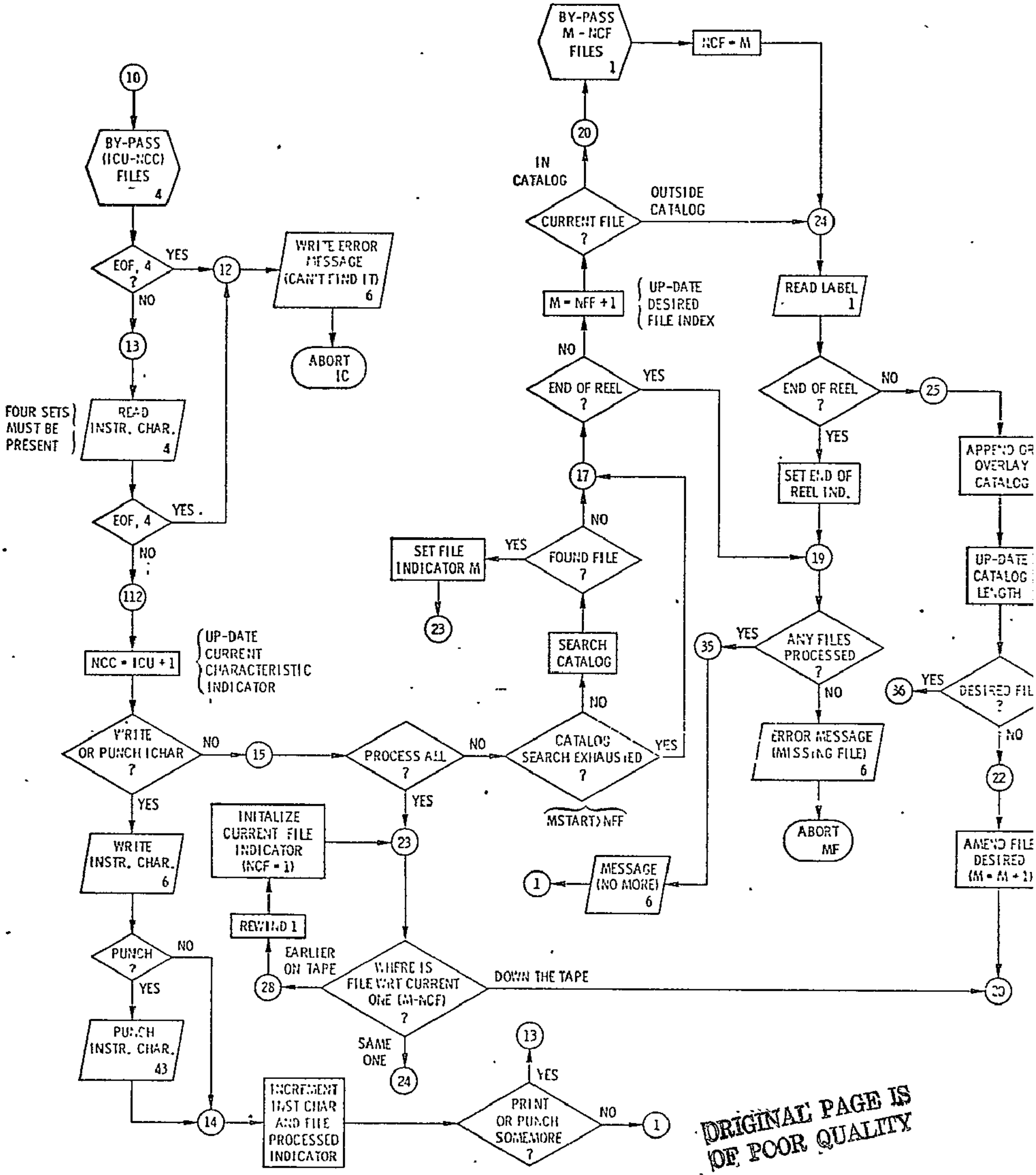

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FIGURE A-1. (b) DESCRIPTIVE LOGIC DIAGRAM FOR FOR THE CONTROL SECTION

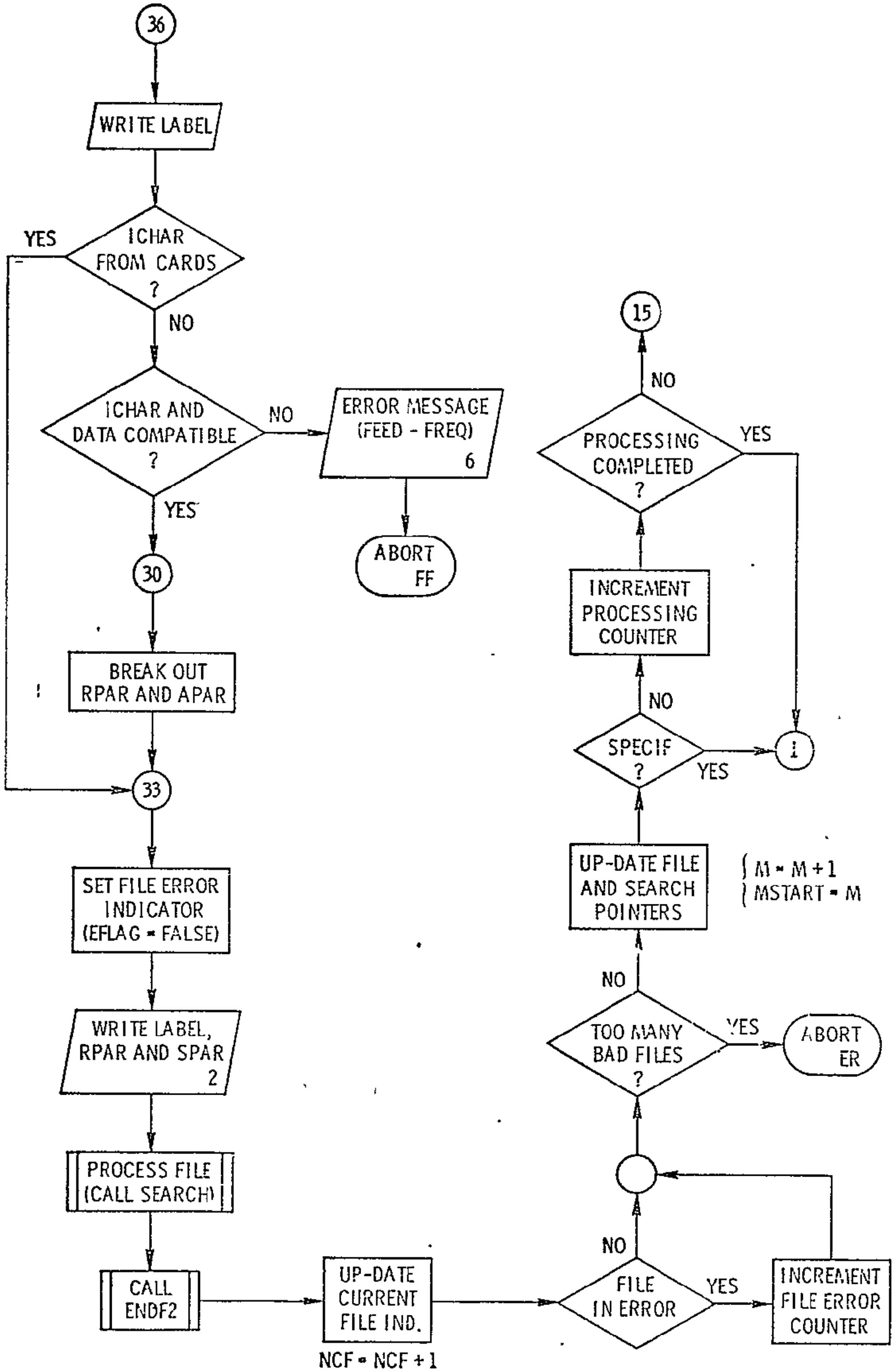

FIGURE A-1. (c) DESCRIPTIVE LOGIC DIAGRAM FOR THE CONTROL SECTION

The numbers on the connecting points coincide with the statement numbers of the text shown in Figure A-2.

An instruction is read from the card reader. If it is POST, the files on an old output tape are bypassed in statements between 39 and 1 of the diagram. Another instruction is then read. The instruction is echo checked, file parameters are initialized and in the subsequent blocks of Figure A-1, the processing type is identified. Thereafter the specified instrument characteristic is read from unit 04 or 05. If the last set of characteristics on a file code 04 is desired and its file number is not known (ICU=999), the last file number is determined in statements between 6 and 5. If, on the other hand, they are to be read from cards (ICU=0), the appropriate action is taken and control is advanced to statement 15. If a specific file is designated, an appropriate number of files is bypassed until tape unit 04 is positioned on the correct file (see steps between statements 10 and 13).

If the set is to be punched or printed, the appropriate action is taken in steps preceeding statement 14. If NFP>1, NFP-1 subsequent sets are also punched or printed. (See steps between 112 and 13). When completed, the next control card is read.

When the control card is a processing directive, the instrument characteristic tape will have been positioned to the correct file (set of parameters) or the set will have been entered from cards. Steps following 15 search for the appropriate data file. The search is governed by the type of directive. Bypassed files are cataloged in steps between 25 and 22. If the desired file is in the catalog and the current file is strictly in the catalog, the appropriate number of files are bypassed in steps between 22 and 24. If the file is beyond the catalog, the catalog is updated as the program advances the tape in search of the file.

Once found, the file label is listed and the appropriate subset of instrument parameters is withdrawn from tape if they weren't entered from the reader. SEARCH is then called to find the calibration data. SEARCH in turn calls CRUNCH to process the measurement records. Once completed control returns to the Control Section where additional files are sought or another directive is read.

B. Program Listing

The Control Section Listing is shown in Figures A-2(a) through A-2(e). The variables are defined in the listing.

```
      PROGRAM CONVERT(INPUT,OUTPUT,PUNCH,TAPE1,TAPE2,TAPE4,TAPE8,
     *   TAPE5=INPUT,TAPE6=OUTPUT,TAPE43=PUNCH)
CCCCS          CONVERSION CONTROL SECTION
C
C              THIS PROGRAM WAS PREPARED BY
C
C                   JOHN P. CLAASSEN
C                   GLEN E. ELLIOTT
C
C              UNIVERSITY OF KANSAS CENTER FOR RESEARCH
C
C
C                             PROGRAM DESCRIPTION.
C              FILE CODES USED.
C
C              01 -- INPUT RAW DATA.
C              02 -- OUTPUT PROCESSED DATA.
C              04 -- INPUT INSTRUMENT CHARACTERISTICS FILE.
C              05 -- SYSTEM INPUT - DIRECTIVE CARDS.
C              06 -- SYSTEM OUTPUT - PRINT LINES.
C              08 -- SCRATCH FILE - USED BY COMPUTATION SECTION.
C              43 -- SYSTEM OUTPUT - PUNCHED CARDS.
C
C              VARIABLE NAMES USED.
C
C     LBLTBL   *LABEL TABLE*.  TABLE CONTAINING
C              LABEL INFORMATION (MISSION, FLIGHT, LINE, RUN) FOR ALL
C              DATA FILES BYPASSED SO FAR.
C
C     NWPST    *NEW POSITION.* ARRAY CONTAINING LABEL INFO (M,F,L,R)
C              OF NEXT FILE TO BE PROCESSED.
C
C     NCF      *NUMBER OF CURRENT FILE.*  POSITION POINTER FOR
C              FILE CODE 01.
C
C     NFF      *NUMBER OF FINAL FILE.*  INDEX OF LAST ENTRY IN
C              *LBLTBL* TABLE.
C
C     NSTART   STARTING POINT FOR SEARCH IN *LBLTBL* TABLE.
C
C     NI       INPUT FILE TO USE.  RELATIVE POSITION ON FILE CODE 01.
C
C     EORI     *END OF REEL INDICATOR.*  LOGICAL VARIABLE, SET TRUE
C              WHEN END OF REEL ON FILE CODE 01 IS DETECTED, INDICATING
C              *LBLTBL* TABLE IS COMPLETE.
C
C     IEOR     INTEGER ARRAY CONTAINING WORDS *END OF REEL*.
C
C     IPTYPE   INTEGER *PROCESSING TYPE* ARRAY, CONTAINING RECOGNIZED
C              PROCESSING TYPES.
C
C     JPTYPE   INPUT DESIRED PROCESSING TYPE.
C
C     N        INDEX OF POSITION OF *JPTYPE* IN *IPTYPE*.
C
C     ICU      *INSTRUMENT CHARACTERISTICS TO USE*.  NUMBER OF THE I.C.
C              SET TO BE USED.  REFLECTS THE POSITION OF THE SET ON
C              FILE CODE 04.
C              0 INDICATES I.C. TO BE READ FROM CARDS (FC=05),
C              999 MEANS USE THE LAST SET ON FILE 04.
C
C     NCC      *NUMBER OF CURRENT CHARACTERISTICS*.  REFLECTS POSITION
C              FILE CODE 04.
C
C     NLC      *NUMBER OF LAST CHARACTERISTIC*.  USED WHEN ICU=999.
C              NLC=0 INDICATES THIS VALUE IS YET UNKNOWN.
C
C     RPAR     *RADIOMETER PARAMETERS*.
C     SPAR     *SCATTEROMETER PARAMETERS*.
C
C     PAR      *PARAMETERS*  ARRAY CONTAINING UP TO 4 SETS OF RADSCAT
C              INSTR PARAMETERS READ FROM FILE CODE 04 OR 05. RAD
C              PARAMETERS COMPOSE THE FIRST 75 ENTRIES OF PAR AND SCAT
C              PARAMETERS OCCUPY THE NEXT 85 ENTRIES IN EACH SUBSET.
C              THE APPROPRIATE SUBSET OF PARAMETERS IS SELECTED ON THE
C              BASIS OF FREQUENCY AND FEED.
C
C     NFP      *NUMBER OF FILES TO PROCESS* USING THE PROCESSING TYPE
C              GIVEN BY *JPTYPE* AND DESCRIPTION IN *NWPST*.
C              NFP IS IGNORED IF JTYPE = SPECIF.  IF ICU = 0,
C              NFP IS SET TO 1.
C
C     NFAP     *NUMBER OF FILES ALREADY PROCESSED.*  COMPARED TO *NFP*
C              TO CHECK FOR TERMINATE CONDITION.
C
```


FIGURE A-2. (a) LISTING OF CONTROL SECTION

```
      C       LNPMOD   *LINE PRINTING MODULUS*. USED TO REDUCE OUTPUT              C0000102
      C                FROM COMPUTATION SECTION.  0 IS TAKEN AS 1.                 C0000103
      C                                                                            C0000104
      C       NERR     *NUMBER OF ERRORS*. NUMBER OF TIMES COMPUTATION SECTION     C0000105
      C                RETURNED ERROR CONDITION.  NERR = 4 CAUSES ABORT.           C0000106
      C
      C       ERRFLG   EAC FILE ERROR FLAG.
      C                                                                            C0000107
      C                                                                            C0000108
      C                            DIRECTIVE CARD USAGE                            C0000109
      C                                                                            C0000110
      C       PROCESSING                 MEANING                                   C0000111
      C        TYPE                                                                C0000112
      C       ALL      START FROM FIRST OF INPUT FILE AND PROCESS WITHOUT          C0000113
      C                 REGARD TO LABEL INFORMATION.                               C0000114
      C                                                                            C0000115
      C       MISFLT   CHECK LABEL ONLY FOR CORRECT MISSION AND FLIGHT.            C0000116
      C                                                                            C0000117
      C       FLTLIN   CHECK FOR CORRECT MISSION, FLIGHT, AND FLIGHT LINE.         C0000118
      C                                                                            C0000119
      C       SPECIF   CHECK FOR MISSION, FLIGHT, FLT. LINE, AND RUN.              C0000120
      C                                                                            C0000121
      C       PRINT    PRINT OUT VALUES OF INSTRUMENT CHARACTERISTICS.             C0000122
      C                                                                            C0000123
      C       PUNCH    PRINT AND PUNCH I.C.*S.                                     C0000124
      C                                                                            C0000125
      C       POST     MAY BE USED AS THE FIRST PROCESSING TYPE.  IF SO,           C0000138
      C                THE PROGRAM WILL SPACE DOWN THE OUTPUT TAPE SEARCHING       C0000139
      C                FOR THE END OF REEL.  POST IS ILLEGAL EXCEPT ON THE         C0000140
      C                FIRST DIRECTIVE CARD.                                       C0000141
      C
      C                DIRECTIVE CARD FORMAT.                                      C0000126
      C                                                                            C0000127
      C       JPTYPE      MISS  FLT LINE  RUN LNPM  ICU  NFP                       C0000128
      C        A6    4X    I5    I5   I5   I5   I5   I5   I5                     C0000129
      C                                                                            C0000130
      C       ALL           *     *    *    *    1    3    6                       C0000131
      C       MISFLT       207   12    *    *    5    3    2                       C0000132
      C       FLTLIN       207   12    1    *   10    3    5                       C0000133
      C       SPECIF       207   12    1    2    1    3    1                       C0000134
      C       PUNCH         *     *    *    *    *    4    6
      C       PRINT         *     *    *    *    *    5    7
      C       POST          *     *    *    *    *    *    *

      C                                                                            C0000135
      C                * INDICATES FIELD IS IGNORED BY PROGRAM.                    C0000136
      C                                                                            C0000137
      C                                                                            C0000142
C00003        DIMENSION NWPST(4), LBLTBL(4,300), IEOR(2), RPAR(75), SPAR(85),      C0000018
            *  PAR(160,4), IPTYPE(6), IDAT(3)                                      C0000019
C00003        DIMENSION LBL(9)                                                     C0000020
C00003        EQUIVALENCE (LBL(8),FREQ),(LBL(9),FEEC)                              C0000021
C00003        EQUIVALENCE (IDAT(1),ID1),(IDAT(2),ID2),(IDAT(3),ID3)                C0000022
C00003        LOGICAL  EORI, ERRFLG                                                C0000023
C00003        DATA IEOR   /10HEND OF REE,1HL/                                      C0000024
C00003        DATA IPTYPE/6HFLTLIN,6HMISFLT,6HSPECIF,3HALL,5HPRINT,5HPUNCH/        C0000025
C00003        DATA IPOST/4HPOST/                                                   C0000026
C00003        DATA EORI/.FALSE./, NLC,NCC/0,1/, NCF,NFF/1,0/, NERR/0/              C0000027
C00003        REWIND 1                                                             C0000143
C00005        REWIND 4                                                             C0000144
C00007        READ(5,500)  JPTYPE, NWPST, LNPMOD, ICU, NFP                         C0000145
C00025        IF(JPTYPE.NE.IPOST) GO TO 18                                         C0000146
C00027   39   READ(2) LB1,LB2                                                      C0000147
C00036        IF(LB1.NE.IEOR(1)) GO TO 40                                          C0000148
C00040        IF(LB2.NE.IEOR(2)) GO TO 40                                          C0000149
C00042        BACKSPACE 2                                                          C0000150
C00044        GO TO 1                                                              C0000151
C00045   40   READ(2)                                                              C0000152
C00050        IF(EOF,2) 39, 40                                                     C0000153
      C                                                                            C0000154
      C                 READ DIRECTIVES                                            C0000155
      C                                                                            C0000156
C00053    1   READ(5,500)  JPTYPE, NWPST, LNPMOD, ICU, NFP                         C0000157
C00071  500   FORMAT(A6,4X,7I5)                                                    C0000158
C00071   18   IF(EOF,5)  37,41                                                     C0000159
C00074   41   WRITE(6,600) JPTYPE, NWPST, LNPMOD, ICU, NFP                         C0000160
C00112  600   FORMAT(1H1,//10X,17H CONTROL CARD IS ,                               C0000161
            *          A6,4X,7I5)                                                  C0000162
      C                                                                            C0000163
      C                 WHAT MANNER TO PROCESS                                     C0000164
      C                                                                            C0000165
C00112        M=1                                                                  C0000166
C00113        MSTART=1                                                             C0000167
C00114        NFAP=0                                                               C0000168
C00115        DO 2 N=1,6                                                           C0000169
C00117    2   IF(JPTYPE.EQ.IPTYPE(N)) GO TO 3                                      C0000170
C00123        WRITE(6,601)                                                         C0000171
```

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FIGURE A-2. (b) LISTING OF CONTROL SECTION

```
000126    601   FORMAT(10X,30HUNRECOGNIZED PROCESSING FORMAT)
000126          CALL ABORT(2HCF)
000130    3     IF(NFP.GE.1) GO TO 59
000133          WRITE(6,610) NFP
000140    610   FORMAT(//10X,*NFP LT 1*,5X,*NFP = *,I5//)
000140          CALL ABORT(3HNFP)
          C
          C            FIND INSTRUMENT CHAR.
          C
000142    59    IF(ICU.NE.0) GO TO 4
          C                                 READ FROM CARDS
000143          ICSET=0
000144          READ(5,4303) NUMBER,ID1,ID2,ID3,RPAR(1),RPAR(2),RPAR(3)
000166          IF(EOF,5) 12, 60
000171    60    WRITE(6,603) ICSET,ID1,ID2,ID3,RPAR(1),RPAR(2),RPAR(3)
000213          DO 61 J=4,75,7
000215          L=J+6
000217          IF(L.GT.75) L=75
000222          READ(5,4304)(RPAR(K),K=J,L)
000235          IF(EOF,5) 12, 61
000240    61    WRITE(6,604)(RPAR(K),K=J,L)
000255          READ(5,4303) NUMBER,ID1,ID2,ID3,SPAR(1),SPAR(2),SPAR(3)
000277          IF(EOF,5) 12, 62
000302    62    WRITE(6,603) ICSET,ID1,ID2,ID3,SPAR(1),SPAR(2),SPAR(3)
000324          DO 63 J=4,85,7
000326          L=J+6
000330          IF(L.GT.85) L=85
000333          READ(5,4304)(SPAR(K),K=J,L)
000346          IF(EOF,5) 12, 63
000351    63    WRITE(6,604)(SPAR(K),K=J,L)
000366          NFP=1
000367          GO TO 15
000370    4     IF(ICU-NCC) 5,13,6
000373    5     REWIND 4
000375          NCC=1
000376    6     IF(ICU.NE.999) GO TO 10
          C                                 FIND LAST SET ON FILE.
000400          IF(NLC.EQ.0) GO TO 7
000401    42    ICU=NLC
000403          GO TO 4
000403    7     NLC=NCC-2
000405    8     READ(4)
000410          NLC=NLC+1

000412          IF(EOF,4) 45, 8
000415    45    ICU=NLC
000417          GO TO 5
          C                                 POSITION TO THE SET
000417    10    NC1=NCC+1
000421          DO 11 I=NC1,ICU
000422          READ(4)
000425          IF(EOF,4) 12,11
000430    11    CONTINUE
000433          GO TO 13
000433    12    WRITE(6,602)
000437    602   FORMAT(10X,34HNO SUCH INSTRUMENT CHARACTERISTICS)
000437          CALL ABORT(2HIC)
          C                                 READ THEM
000441    13    READ(4) ICSET,ID1,ID2,ID3,PAR
000456          IF(EOF,4)  12,112
000461    112   NCC=ICU+1
000463          IF(N.LT.5) GO TO 15
          C
          C            WRITE (AND PUNCH) INST. CHAR.
          C
000466          DO 55 I=1,4
000467          WRITE(6,603)    ICU,ID1,ID2,ID3,PAR(1,I),PAR(2,I),PAR(3,I)
000515    603   FORMAT(//* SET*,I5,*  DATE*,3I5,E15.4,5X,A10,E15.4)
000515          DO 54 J=4,75,7
000517          L=J+6
000521          IF(L.GT.75) L=75
000524    54    WRITE(6,604)(PAR(K,I),K=J,L)
000543    604   FORMAT(7E15.4)
000543          WRITE(6,603)    ICU,ID1,ID2,ID3,PAR(76,I),PAR(77,I),PAR(78,I)
000572          DO 55 J=79,160,7
000574          L=J+6
000576          IF(L.GT.160) L=160
000601    55    WRITE(6,604)(PAR(K,I),K=J,L)
000622          IF(N.NE.6) GO TO 14
000624          DO 57 I=1,4
000626          LL=1
000627          WRITE(43,4303)    ICU,ID1,ID2,ID3,PAR(1,I),PAR(2,I),PAR(3,I),
               *          ICU,I,LL
000664    4303  FORMAT(4I5,10X,E10.3,A10,E10.3,12X,I2,I1,I5)
000664          DO 56 J=4,75,7
000666          LL=LL+1
000670          L=J+6
```

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FIGURE A-2. (c) LISTING OF CONTROL SECTION

```
000672   56    WRITE(43,4304)(PAR(K,I),K=J,L),ICU,I,LL
000715   4304  FORMAT(7E10.3,2X,I2,I1,I5)
000715         LL=LL+1
000717         WRITE(43,4303)    ICU,IDAT,PAR(76,I),PAR(77,I),PAR(78,I),
             *          ICU,I,LL
000747         DO 57 J=79,100,7
000751         LL=LL+1
000753         L=J+6
000755   57    WRITE(43,4304)(PAR(K,I),K=J,L),ICU,I,LL
001002   14    ICU=ICU+1
001004         NFAP=NFAP+1
001005         IF(NFAP.LT.NFP) GO TO 13
001007         GO TO 1
          C
          C             FIND THE DATA RECORD.
          C
001010   15    IF(N.EQ.4) GO TO 23
001012         IF(MSTART.GT.NFF) GO TO 17
          C
          C             SEE IF WE'VE BEEN BY IT ALREADY.
          C
001016         DO 16 M=MSTART,NFF
001017         IF(NWPST(1).NE.LBLTBL(1,M)) GO TO 16
001022         IF(NWPST(2).NE.LBLTBL(2,M)) GO TO 16
001025         IF(N.EQ.2) GO TO 23
001027         IF(NWPST(3).NE.LBLTBL(3,M)) GO TO 16
001032         IF(N.EQ.1) GO TO 23
001033         IF(NWPST(4).NE.LBLTBL(4,M)) GO TO 16
001036         GO TO 23
001036   16    CONTINUE
001041   17    IF(EORI) GO TO 19
          C
          C             GUESS IT'S FURTHER DOWN THE TAPE.
          C
001043         M=NFF+1
001045         IF(NCF.GT.NFF) GO TO 24
001050   20    M1=M-1
001052         DO 27 I=NCF,M1
001054   26    READ(1)
001057         IF(EOF,1) 27, 26
001062   27    CONTINUE
001065         NCF=M
001066   24    READ(1) LBL

001073         IF(LBL(1).NE.IEOR(1)) GO TO 25
001075         IF(LBL(2).NE.IEOR(2)) GO TO 25
001077         EORI=.TRUE.
001100   19    IF(NFAP.NE.0) GO TO 35
001101         WRITE(6,606)
001105   606   FORMAT (10X,19HNO SUCH DATA RECORD)
001105         CALL ABORT(2HPF)
001107   35    WRITE(6,607) NFAP
001115   607   FORMAT(10X,I3,32H FILES FOUND.  CAN FIND NO MORE.)
001115         GO TO 1
001116   25    LBLTBL(1,NCF)=LBL(1)
001121         LBLTBL(2,NCF)=LBL(2)
001124         LBLTBL(3,NCF)=LBL(6)
001126         LBLTBL(4,NCF)=LBL(7)
001130         NFF=MAX0(NFF,NCF)
001133         IF(N.EQ.4) GO TO 36
001135         IF(NWPST(1).NE.LBLTBL(1,M)) GO TO 22
001140         IF(NWPST(2).NE.LBLTBL(2,M)) GO TO 22
001143         IF(N.EQ.2) GO TO 36
001144         IF(NWPST(3).NE.LBLTBL(3,M)) GO TO 22
001147         IF(N.EQ.1) GO TO 36
001150         IF(NWPST(4).NE.LBLTBL(4,M)) GO TO 22
001153         GO TO 36
001153   22    M=M+1
001155         GO TO 20
001155   23    IF(M-NCF) 28, 24, 20
001160   28    REWIND 1
001162         NCF=1
001163         GO TO 23
          C                                   FOUND IT. IT'S THIS ONE.
001164   36    WRITE(6,608) LBL, ICSET, ID1, ID2, ID3
001202   608   FORMAT(1H1,51X,17HCONVERSION REPORT,
             * //10X,8HMISSION-,I3,9H  FLIGHT-,I3,
             *          7H  DATE-,2I3,I5,2X,11H  FLT LINE-,1X, I5,6H  RUN-,I3,
             *          13H   FREQUENCY-,F5.1,7H  FEED-,2X,A6,
             *          6H IPAR=,I2,3I3////)
001202         IF(ICU.EQ.0) GO TO 33
          C                                   GET CORRECT INST. CHAR.
001203         DO 29 K=1,4
001205         IF(ABS(FREQ-PAR(1,K)/1.0 E9).GT.1.0) GO TO 29
001215         IF(FEED.EQ.PAR(2,K)) GO TO 30
001221   29    CONTINUE
001223         WRITE(6,605) FREQ, FEED
```

FIGURE A-2. (d) LISTING OF CONTROL SECTION

```
001233   605  FORMAT (10X,17HNO SUCH FREQ-FEED,F10.5,1X,A10)
001233        CALL ABORT(2HFF)
001235    30  DO 31 I=1,75
001237    31  RPAR(I)=PAR(I,K)
001246        DO 32 I=1,65
001247    32  SPAR(I)=PAR(I+75,K)
            C                                 CALL COMPUTATION SECTION.
001256    33  ERRFLG=.FALSE.
            C                                 LABEL OUTPUT TAPE
001257        WRITE(2) LBL
001264        WRITE(2) ICSET, ID1, ID2, ID3, RPAR, SPAR
001303        CALL SEARCH(SPAR,RPAR,LKPMOD,ERRFLG)
001306        CALL ENDF2
001307        NCF=NCF+1
001311        IF(ERRFLG) NERR=NERR+1
001313        IF(NERR.GT.3) CALL ABORT(2HER)
001317        M=M+1
001321        MSTART=M
            C                                 MORE FILES TO PROCESS
001322        IF(N.EQ.3) GO TO 1
001324        NFAP=NFAP+1
001325        IF(NFAP.GE.NFF) GO TO 1
001327        GO TO 15
            C
            C               TERMINATIONS.
001330    37  WRITE(2) IECR, (I,I=3,9)
001342        WRITE(6,700)
001346   700  FORMAT(1H1,///11X,10(1H*),18HNORMAL TERMINATION,10(1H*))
001346        STOP
001350        END
```

FIGURE A-2. (e) LISTING OF CONTROL SECTION

C. Peripheral Requirements

UNIT 01	RADSCAT Raw Data Tape
UNIT 02	Output Tape
UNIT 04	Characteristics Tape
UNIT 05	Card Reader
UNIT 06	Printer
UNIT 08	Scratch Unit (Perferably Disc)
UNIT 43	Punch

IV. SUBROUTINES

A. Subroutine Search

1. Theory and Design

This routine serves as an entry and exit point for the selected file. One of its primary purposes is to find calibration data of both kinds. It anticipates that both NORMAL and BASELINE calibrations are in the opening records of the file. If this is the case the processing of the remainder of the file is given to CRUNCH. Otherwise, a search for the missing calibrations is conducted deeper into the file. The bypassed files are stored on a scratch unit (08) for subsequent processing. When both types of calibrations are found, the bypassed records on file code 08 are processed by CRUNCH and the remainder of the records on file code 01 are also.

If the return from CRUNCH is without an error flag, control is simply returned to the Control Section. If not, an error message is given and the remainder of the file bypassed before returning.

See Figure A-3 for a descriptive logic diagram of SEARCH.

2. Program Listing and Variables

The listing for SEARCH is shown in Figure A-4(a) and A-4(b). The definitions of the variables are given in Table A-1. The entries in DATA were defined in Section III B.

Table A-1 Definition of Variable Used in SEARCH

DATA	=	Vector Containing Raw RADSCAT DATA
IDATA	=	Integer Equivalent of DATA
SCAL	=	SCAT Calibration Vector (Channels 1-4)

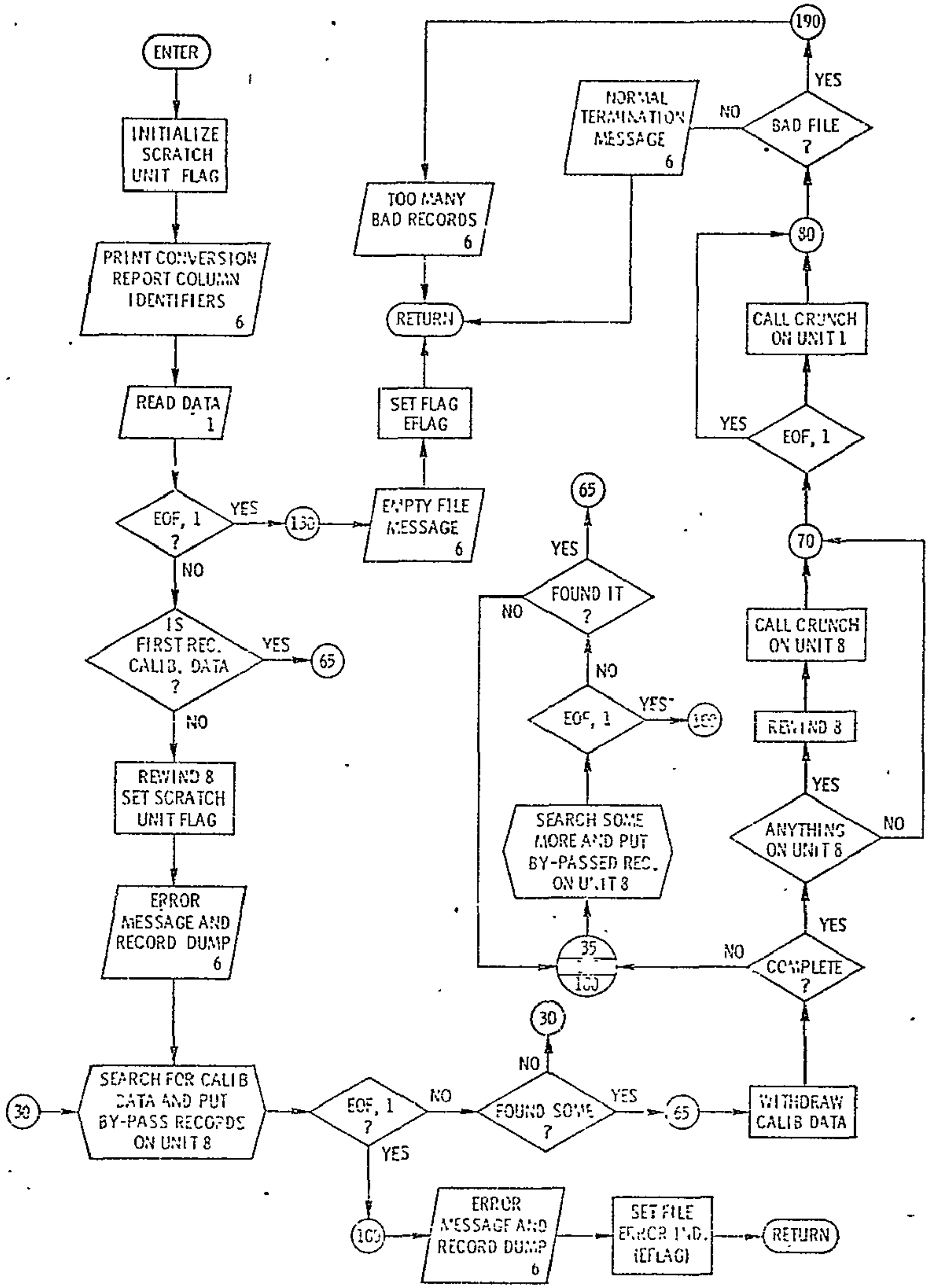

FIGURE A-3. DESCRIPTIVE LOGIC DIAGRAM FOR SEARCH

```
            SUBROUTINE SEARCH(SPAR,RPAR,LNPMOD,EFLAG)
      CSEARCH                     CALIB SEARCH ROUTINE
      C               SUBROUTINE SEARCH(SPAR,RPAR,LNPMOD,EFLAG)
      C
      C               THIS PROGRAM WAS PREPARED BY
      C
      C                  JOHN P. CLAASSEN
      C                  GLEN E. ELLIOTT
      C
      C               UNIVERSITY OF KANSAS CENTER FOR RESEARCH
      C
      C
      C               THIS SUBROUTINE EXECUTES ENTRY INTO THE CONTENTS OF THE
      C               FILE AND SEEKS CALIBRATION INFORMATION, BOTH NORMAL AND
      C               BASELINE. THE PROGRAM ANTICIPATES THAT BOTH TYPES OF
      C               CALIBRATIONS ARE PRESENT IN THE INITIAL RECORDS.  HOWEVER
      C               WHEN THIS NOT THE CASE, THE FILE IS SEARCHED UNTIL BOTH
      C               TYPES ARE FOUND.  BY-PASSED RECORDS ARE STORED ON UNIT 8
      C               SUBSEQUENT PROCESSING.
      C
C00007          DIMENSION DATA(50), IDATA(50),
             *            SPAR(65), RPAR(75), SCAL(4), RCAL(2)
C00007          COMMON /INPUT/ EOF1, DATA
C00007          EQUIVALENCE (DATA(1),IDATA(1))
C00007          LOGICAL  EFLAG, EOF1, EOF8
C00007          LOGICAL NORMAL, BASE
      C
      C          READ DATA RECORD FROM TAPE UNIT 1
      C
C00007          IPASS=0
000010          WRITE(6,60)
C00013    60    FORMAT(12H RECORD NO.*,13X,7HMESSAGE,19X,1H*,20X,
             *          10HPARAMETERS///)
000013          CALL READ1
C00014          IF(EOF1) GO TO 130
      C
      C             CHECK IF RECORD IS CALIB DATA
      C
C00020    10    IF (IDATA(4) .EQ. 0 .OR. IDATA(4).EQ.2) GO TO 50
      C
      C               PREPARE DISC FOR BY-PASSED RECORDS
      C

C00027          REWIND 8
C00031          IPASS=1
      C
      C             ERROR MESSAGE
      C
C00032          WRITE(6,20) IDATA(4)
000040     20   FORMAT(5X,1H*,5X,27HFILE STRUCTURE INCOMPATIBLE,7X,1H*,5X,
             *                 33HFIRST RECORD NOT CALIBRATION DATA,5X, 6HMODE= ,I3/)
000040          WRITE(6,120) DATA
      C
      C             SEARCH FOR CALIBRATION RECORD
      C
C00046    30    WRITE(8) DATA
C00053    35    CALL READ1
C00054          IF(EOF1) GO TO 100
      C
      C             CHECK IF CALIB DATA
      C
000060    40    IF (IDATA(4) .NE. 0 .AND. IDATA(4).NE.2) GO TO 30
000067    50    ICOUNT=0
C00070          IL=0
      C
      C             WITHDRAW CALIBRATION INFORMATION
      C
C00071          NORMAL = .FALSE.
C00072          BASE = .FALSE.
C00073    65    CALL CALIB(SCAL,RCAL,RPAR,NORMAL,BASE)
C00077          IF (.NOT. NORMAL .AND. .NOT. BASE) GO TO 35
C00104          IF (.NOT. NORMAL) GO TO 160
000106          IF (.NOT. BASE) GO TO 180
C00107          IF(IPASS.EQ.0) GO TO 70
000110          ENDFILE 8
C00112          REWIND 8
000114          CALL CRUNCH(8,DATA,IDATA,IL,ICOUNT,SCAL,RCAL,
             *                 SPAR,RPAR,LNPMOD,EFLAG,EOF8)
000131    70    IF(EOF1) GO TO 80
C00135          CALL CRUNCH(1,DATA,IDATA,IL,ICOUNT,SCAL,RCAL,
             *                 SPAR,RPAR,LNPMOD,EFLAG,EOF1)
000152          IF(EFLAG) GO TO 190
      C
      C             NORMAL TERMINATION MESSAGE
      C
C00156    80    WRITE (6,90) IL, ICOUNT
```


FIGURE A-4. (a) SOURCE LISTING FOR SUBROUTINE SEARCH

```
000166     90    FORMAT (I6,5X,1H*,2X,36HCOMPLETED COMPUTATIONS FOR THIS FILE,
               *         1X,1H*,5X,10HTHERE WERE,I5,
               *         24H WARNING FLAGS GENERATED)
000166           RETURN
          C
          C          ERROR MESSAGE
          C
000167    100    WRITE (6,110)
000173    110    FORMAT (11X,1H*,5X,27HFILE STRUCTURE INCOMPATIBLE,7X,1H*,5X,
               *         25HUNABLE TO FIND CALIB DATA)
000173           WRITE(6,120) DATA
000201    120    FORMAT(/10(5O22/)/)
          C
          C          ABORT FILE AND SEEK NEXT INSTRUCTION
          C
000201           EFLAG=.TRUE.
000204           RETURN
000205    130    WRITE(6,140)
000211    140    FORMAT(11H EMPTY FILE)
000211           LFLAG=.TRUE.
000214           RETURN
          C
          C              SEARCH FOR MISSING CALIB DATA
          C
000215    150    WRITE(8) DATA
000222    160    CALL READ1
000223           IF(EOF1) GO TO 100
000227    165    IF (IDATA(4) .NE. 0) GO TO 150
000230           GO TO 65
000231    170    WRITE (8) DATA
000236    180    CALL READ1
000237           IF(EOF1) GO TO 100
000243    185    IF (IDATA(4) .NE. 2) GO TO 170
000245           GO TO 65
000246    190    WRITE(6,195)
000252    195    FORMAT(///11X,1H*,5X,28HEXCESSIVE NO. OF BAD RECORDS,6X,1H*)
000252           IF(EOF1) RETURN
000257    200    READ(1)
000262           IF(EOF,1) 250,200
000270    250    RETURN
000271           END
```

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OF POOR QUALITY

FIGURE A-4. (b) SOURCE LISTING FOR SUBROUTINE SEARCH

(Continued)
Table A-1 Definition of Variable Used in SEARCH entries in DATA

RCAL	=	RAD Calibrations (NORMAL, BASE)
EOF1	=	End of File for Unit 1
EOF8	=	End of File for Unit 8
EFLAG	=	File Error Flag
IPASS	=	Flag for Data on Unit 8
NORMAL	=	Flag for Normal RAD Cals
BASE	=	Flag for Baseline RAD Cals
ICOUNT	=	RADSCAT Performance Error Counter
IL	=	Record Counter

B. Subroutine CRUNCH

1. Theory and Design

The reduction algorithms are applied in or from subroutine CRUNCH. The routine was designed to process RADSCAT data whether it consisted of radiometer measurements (RAD only mode) or both scatterometer and radiometer measurements (alternating angles, fixed angle, or short SCAT modes). In processing the records on an independent basis, there is a tacit assumption that coupling between polarization is negligible. It was also necessary to equip the routine with the ability to read records from file code 01 (raw data tape) or file code 08 (scratch unit). A description of the internal operation of CRUNCH is shown in the logic diagram of Figure A-5.

In the opening steps of CRUNCH the data record is extracted from the file and verified by an in-line routine. The first sixteen entires in the data record are checked for type and magnitude. If an invalid entry is present, an error message identifying the bad entry is given and a bad record counter is incremented (NGR). If more than 10 bad records are encountered, an error flag (EFLAG) is set and control is returned to SEARCH. If not, the next record in read (statement 100) and the process repeated. If the record is valid, it is further examined to determine if it is a calibration record. If it is, CALIB is called (statement 220) to extract and average the calibrations. The next record is then read and the process

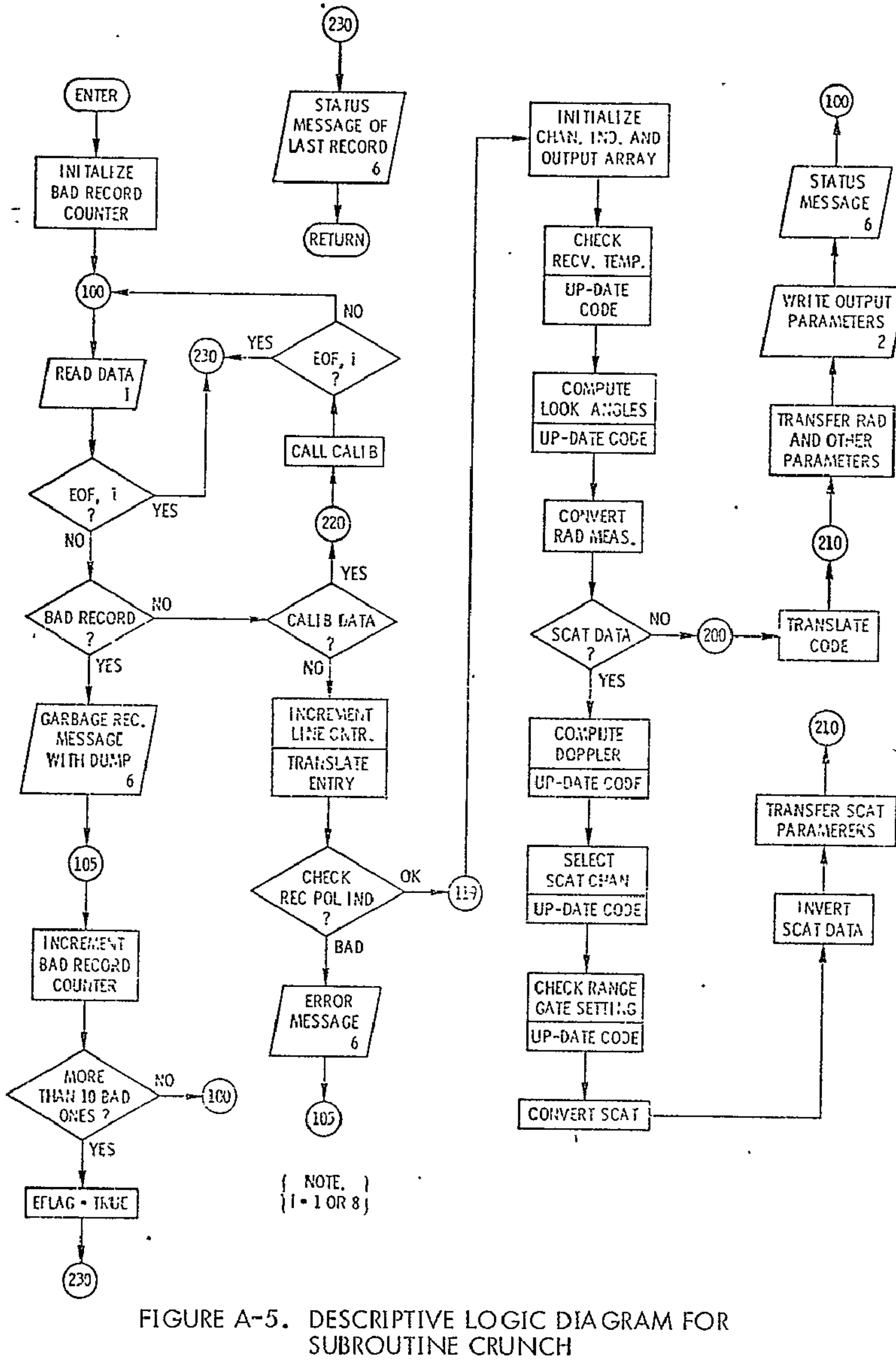

FIGURE A-5. DESCRIPTIVE LOGIC DIAGRAM FOR SUBROUTINE CRUNCH repeated. If it is not calibration data, the mode entry is translated and the SCAT and RAD receiver polarization are checked for agreement when the instrument is not in the "RAD only" mode. If they disagree the record is declared invalid and treated as a bad record.* If the measurement occurred in the "RAD only" mode or the polarization agree, the record is then processed in the steps following and including statement number 119.

Initially the record counter is incremented, the SCAT channel indicator initialized and the output array cleared. CRUNCH then calls THERMO to compute and check receiver temperatures. An interpretation code is updated after which subroutine ANGLE is called. ANGLE computes the incident and cross-track angles and again the interpretational code is updated. Subroutine RCONV (radiometer convert) is called to compute the antenna temperature. If no scatterometer data is present, control advances to statement 200 where the computed results are transferred to the output array. Otherwise when SCAT data is present, DOPCHK is called to compute the doppler shift and set the doppler filter band index. The interpretational code is then updated.

In the following statements (up to number 170), the maximum on-scale SCAT measurement is selected from the four output channels (DATA(8) through DATA(11)). To select the appropriate channel output, the channels are tested for an output in excess of a value that would cause the output to saturate on the next higher sensitivity channel. Note that channel 1 (DATA(8)) is least sensitive whereas channel 4 (DATA (11)) is most sensitive. The selected measurement is stored in DATA(8) after scaling it with some channel dependent parameters. If the SCAT return fell below or above the channels, an interpretational flag is set in statements between 170 and 175.

Following the channel selection, the range gate setting is compared with the aircraft altitude. If the altitude is not within 300 feet of the range gate setting, an interpretation flag is set.

Subroutine SCONV (SCAT convert) is then called to compute the normalized input power. Once computed, the scatterometer measurement is inverted for antenna pattern effects with an in-line statement (number 190). The antenna inversion is based on the notion of an equivalent pencil beam replacing the actual main beam

---

*The implication is that the instrument didn't operate correctly.

antenna pattern. Computer simulations have shown that the method is extremely accurate (errors $\leq$ 0.1 dB) for narrow beam antennas. Briefly the equivalent beamwidth notion is based on the fact that the normalized input power

$$I(\theta_o) = \iint \frac{P^2(\theta,\phi)\ \sigma^\circ(\theta')\ dA}{R^4}$$

where

= normalized scattering coefficient

= radar range to elemental area dA

= normalized antenna pattern

= elemental area

can be approximated by an algebraic expression through the following considerations. For narrow beam antenna

$$I(\theta_o) = \iint \frac{P^2(\theta,\phi)\ \sigma^\circ(\theta')\ \sin\theta\ R^2 \quad d\theta\ d\phi}{R^4\ (\cos\theta')}$$

where $\cos\theta'$ is a projection factor, may be approximated by

$$I(\theta_o) \cong \frac{\sigma^\circ(\theta_o)}{R^2(\cos\theta_o)} \iint P^2(\theta,\phi)\ \sin\theta\ d\theta\ d\phi$$

The integral may be computed numerically from a description of the antenna pattern and equated to the effect produced by a pencil beam of width θeq , i.e.,

$$\iint P^2(\theta,\phi)\sin\theta\ d\theta\, d\phi = \int_0^{2\pi}\int_0^{\theta_{eq}/2} \sin\theta\ d\theta\ d\phi$$

$$\cong \frac{\pi\ \theta_{eq}^2}{4}$$

Therefore the normalized scattering coefficient is given by

$$\sigma^{\circ}(\theta_o) = \frac{4\, I(\theta_o)\, R^2 \cos\theta_o}{\pi\, \theta_{eq}^2}.$$

But note that $R = h/\cos\theta_o$ so that

$$\sigma^{\circ}(\theta_o) = \frac{4\, I(\theta_o)\, h^2}{\pi\, \theta_{eq}^2 \cos\theta_o}$$

where h is the aircraft altitude. The entry θ_{eq} is computed by the engineering routine WIDTH described in Appendix E as well as Section IV F of the text.

The scatterometer and radiometer products are then stored in the output array and the output array is transferred to the output tape (unit 02).

The next data record is then read (statement 100) and the sequence of events repeated. If an end of file is encountered on the input tape, control is returned to SEARCH.

2. Program Listing and Variables

The source listing for CRUNCH is shown in Figures A-6(a) through A-6(d). The variablesemployed in CRUNCH are defined in Table A-2. Entires in SPAR

Table A-2 Definition of Variables Used in CRUNCH

DATA	=	Input Raw Data Vector
IDATA	=	Integer Equivalent of DATA
SPAR	=	SCAT Parameters
RPAR	=	RAD Parameter
SCAL	=	SCAT Calibration Vector (Channel 1 to 4)
RCAL	=	RAD Calibration Vector (Normal and Base)
VERI	=	Data Validation Parameters
IVERI	=	Integer Equivalent of VERI
EOFIFC	=	End of File Indicator for FC 01
EFLAG	=	File Verification Indicator
IL	=	Record Count

```
          SUBROUTINE CRUNCH(IFC,DATA,IDATA,IL,ICOUNT,SCAL,RCAL,
         *      SPAR,RPAR,LNFMOD,EFLAG,EOFIFC)
CCRUNCH                          CRUNCH
C
C              THIS PROGRAM WAS PREPARED BY
C
C                    JOHN P. CLAASSEN
C                    GLEN E. ELLIOTT
C
C              UNIVERSITY OF KANSAS CENTER FOR RESEARCH
C
C
C         THE PRIMARY FUNCTION OF THIS ROUTINE IS TO CONVERT SCATTER-
C         OMETER AND RADIOMETER OUTPUT VOLTAGES INTO THEIR RESPECTIVE
C         NORMALIZED INPUT POWERS. THE CONVERTED SCAT DATA IS
C         SUBSEQUENTLY INVERTED FOR THE SCATTERING COEFFICIENT.
C         PRIMARY COMPUTATIONS ARE PERFORMED IN SUBROUTINE CRUNCH
C         WHICH CALLS A NUMBER OF IMPORTANT ROUTINES.  FROM CRUNCH
C         INTERNAL CALIBRATION INFORMATION IS WITHDRAWN FROM THE DATA
C         RECORDS AND APPLIED TO SUBSEQUENT MEASUREMENTS. THE VIEW
C         ANGLE IS CORRECTED FOR AIRCRAFT ORIENTATION. A WARNING FLAG
C         IS GIVEN WHEN THE ROLL ANGLE CAUSES EXCESSIVE DEPOLARIZATION.
C         A FLAG IS ALSO GENERATED WHEN THE DOPPLER SHIFT EXCEEDS
C         THE DOPPLER FILTER BANDWIDTH. THERMISTER DATA IS
C         CHECKED FOR REASONABLE TEMPERATURES AND TEMPERATURES OF
C         CRITICAL COMPONENTS ARE WITHDRAWN FOR SUBSEQUENT USE IN
C         CONVERTING RADIOMETER MEASUREMENTS.
C
000017          DIMENSION DATA(50), IDATA(50), SPAR(85), RPAR(75), SCAL(4),
               *      RCAL(2), ARRAY(20), IARRAY(20), ALT(4)
000017          DIMENSION ICHG(3)
000017          DIMENSION VERI(15,2), IVERI(15,2)
000017          DIMENSION VMAX(15), VMIN(15), IVMAX(15), IVMIN(15)
000017          EQUIVALENCE (VMAX(1),IVMAX(1)),(VMIN(1),IVMIN(1))
000017          EQUIVALENCE (VERI(1,1),VMIN(1)),(VERI(1,2),VMAX(1))
000017          EQUIVALENCE (VERI(1,1),IVERI(1,1))
000017          EQUIVALENCE (ARRAY(1),IARRAY(1))
000017          LOGICAL EOFIFC
000017          DATA (IVMIN(I),I=1,6)/1,0,0,1,0,0/
000017          DATA (IVMAX(I),I=1,6)/3,4,2,6,1,1/
000017          DATA (VMIN(I),I=7,10),(VMAX(I),I=7,10)/4*0.0, 4*10.5/
000017          DATA IVERI(11,1),IVERI(11,2)/0,1/

000017          DATA (VMIN(I),I=12,14),(VMAX(I),I=12,14)/3*0.0, 10.5, 10.5, 10.5/
000017          DATA IVERI(15,1), IVERI(15,2)/0,3/
000017          DATA ICHG/1,0,2/
000017          DATA ALT/2000.0, 5000.0, 10000.0, 20000.0/
       C
       C         READ IN NEXT RECORD
       C
000017          NGR=0
000020    100   IF(IREAD(IFC).NE.0) GO TO 230
000026    101   I=12
       C
       C                VERIFY CONTENTS OF RECORD
       C
000027          IF(IDATA(I).LT.IVERI(I-1,1).OR.
               *              IDATA(I).GT.IVERI(I-1,2)) GO TO 115
000041          I=16
000042          IF(IDATA(I).LT.IVERI(I-1,1).OR.
               *              IDATA(I).GT.IVERI(I-1,2)) GO TO 115
000054          DO 111 I=2,7
000055    111   IF(IDATA(I).LT.IVERI(I-1,1).OR.
               *              IDATA(I).GT.IVERI(I-1,2)) GO TO 115
000071          DO 112 I=8,11
000072    112   IF(DATA(I).LT.VERI(I-1,1).OR.
               *              DATA(I).GT.VERI(I-1,2)) GO TO 115
000106          DO 113 I=13,15
000107    113   IF(DATA(I).LT.VERI(I-1,1).OR.
               *              DATA(I).GT.VERI(I-1,2)) GO TO 115
000123          GO TO 118
000123    115   WRITE(6,116) I
000131    116   FORMAT(//11X,1H*,11H BAD RECORD,28X,1H*,5X,9HCOMPONENT,I3,
               * 12H IS GARBAGE.//)
000131          WRITE(6,117) DATA
000143    117   FORMAT(/10(5O22/)/)
000143    105   NGR = NGR + 1
000145          IF(NGR.LE.10) GO TO 100
000152          EFLAG = .TRUE.
000153          GO TO 230
       C
       C         BRANCH IF CALIB DATA
       C
000154    118   IF (IDATA(4) .EQ. 0 .OR. IDATA(4).EQ.2) GO TO 220
       C
       C              TRANSLATE CERTAIN ENTRIES IN FILE
```

FIGURE A-6. (a) SOURCE LISTING FOR CRUNCH

```
          C
000163              IDATA(3)=IDATA(3)-1
          *         IJK=IDATA(4)
          *         IDATA(4)=ICHC(IJK+1)
          *         IDATA(6)=1-IDATA(6)
          C
          C               CHECK FOR AGREEMENT IN RECEIVE POL
          C
000165              IF(IDATA(7).EQ.IDATA(12).OR.IDATA(3).EQ.0) GO TO 119
000175              WRITE(6,1000) IDATA(7), IDATA(12)
000212       1000   FORMAT(//11X,1H*,31H RECEIVE POLARIZATIONS DISAGREE,8X,1H*,5X,
                  * 9HSCAT REC=,I3,5X,8HRAD REC=,I3//)
000212              GO TO 105
          C
          C               INITIALIZE CHANNEL INDICATOR FLAG AND CLEAR OUTPUT ARRAY.
          C
000216        119   ICHAN=0
000217              DO 120 I=1,20
000221        120   IARRAY(I)=0
000224              IL = IL + 1
          C
          C           CHECK TEMPERATURES OF CRITICAL ELEMENTS
          C
000226              CALL THERMC (DATA,IDATA,RPAR,IL,LNPMOD,IFLAG,IWARM)
          C
          C           FORM ERROR CODE MESSAGE FOR SCAT AND RAD
          C
000234              IARRAY(12) = IWARM
000236              ICOUNT = ICOUNT + IWARM
000242              IARRAY(12) = IARRAY(12)*10 + IFLAG
000245              ICOUNT=ICOUNT + IFLAG
          C
          C               COMPUTE LOOK ANGLES.
          C
000246              CALL ANGLE (DATA,SPAR,IL,LNPMOD,IFLAG)
          C
          C           AMEND ERROR CODE
          C
000252              ICOUNT=ICOUNT+IFLAG/10
000262              IARRAY(12) = IARRAY(12)*100+IFLAG
          C
          C           CONVERT RADIOMETER DATA
          C

000264              CALL RCONV (DATA,IDATA,RPAR,RCAL,IL)
          C
          C           BRANCH IF RAD ONLY DATA
          C
000270              IF (IDATA(3) .EQ. 0) GO TO 200
          C
          C           CHECK DOPPLER
          C
000275              CALL DOPCHK (DATA,SPAR,IL,IBAND,LNPMOD,IFLAG)
          C
          C           AMEND INDICATOR
          C
000301              IARRAY(12) = IARRAY(12) *10+IFLAG
000304              ICOUNT=ICOUNT+IFLAG
          C
          C                 SELECT SCAT CHANNEL OUTPUT
          C
          C
          C           THIS SECTION SELECTS THE MAXIMUM ON-SCALE SCAT CHANNEL OUTPUT
          C           AND TRANSFORMS IT TO A NORMALIZED RECEIVER INPUT POWER.
          C           WHERE READING FALLS OUTSIDE OF DYNAMIC RANGE OF THE FOUR
          C           CHANNELS, THE DATA IS YET SELECTED, HOWEVER, A FLAG
          C           ACCOMPANIES THE VALUE. THE TRANSFORMED VALUE IS FOUND
          C           IN DATA(8).
          C
          C               INITIALIZE FLAG
          C
000310              IFLAG =0
          C
          C               DETERMINE WHAT CHANNEL MEASUREMENT FELL IN
          C
000311              IF (DATA (8) .GE. SPAR(29)) GO TO 140
000314              IF (DATA (9) .GE. SPAR(29)) GO TO 150
000317              IF (DATA (10).GE. SPAR(29)) GO TO 160
000322              IF (DATA (11).GE. SPAR(29)) GO TO 130
          C
          C           DATA FELL BENEATH RANGE
          C
000326              DATA(11)=DATA(11)+1.0 E-10
000330              IFLAG =1
          C
          C           APPLY SCALE FACTORS
          C
```

FIGURE A-6. (b) SOURCE LISTING FOR CRUNCH

```
000331   130   DATA (8)= DATA (11)*SPAR(21)/SCAL(4)
000336         ICHAN=4
000337         GO TO 170
         C
         C         DATA FELL ABOVE RANGE
         C
000337   140   IF (DATA(8) .GE. SPAR(27)) IFLAG=1
         C
         C         APPLY SCALE FACTORS
         C
000344         DATA (8)= DATA (6)*SPAR(18)/SCAL(1)
000350         ICHAN=1
000351         GO TO 170
000351   150   DATA (8)= DATA(9)*SPAR(19)/SCAL(2)
000356         ICHAN=2
000357         GO TO 170
000357   160   DATA (8)= DATA(10)*SPAR(20)/SCAL(3)
000364         ICHAN=3
         C
         C              END SELECTION OF SCAT CHANNEL.
         C
         C         AMEND ERROR INDICATOR
         C
000365   170   IARRAY(12)=IARRAY(12)*10+IFLAG
000370         ICOUNT=ICOUNT+IFLAG
000371         IF(IFLAG.NE.1) GO TO 175
000373         IF(MOD(IL,LNFMCD).EQ.0) WRITE(6,1700) IL
000410   1700  FORMAT(I6,5X,2H* 22HEXCEEDED DYNAMIC RANGE,16X,1H*)
         C
         C              CHECK RANGE GATE SETTING
         C
000410   175   IFLAG = 0
000411         IALT = IDATA(16)+1
000414         CHECK=ALT(IALT)
000416         IF(DATA(41) .LT. CHECK+300. .AND. DATA(41) .GT. CHECK-300.)
              *        GO TO 177
000431         IFLAG = 1
000432         WRITE(6,1760) CHECK,DATA(41)
000445   1760  FORMAT(I6,5X,2H* ,32HNOT WITHIN 300 FT. OF RANGE GATE,6X,1H*,
              * 5X,11HRANGE GATE=,F7.0,5X,9HALTITUDE=,F7.0)
000445   177   IARRAY(12) = IARRAY(12)*10 + IFLAG
000450         ICOUNT=ICOUNT+IFLAG
         C

         C              COMPLETE CONVERSION OF SCAT DATA
         C
000454   180   CALL SCONV (DATA,IDATA,SPAR,IBAND)
         C
         C              SCAT INVERSION.
         C
         C
         C              COMPARE SCAT POLARIZATIONS.
         C
000457         IXMT=IDATA(6)
000464         IREC=IDATA(7)
000466         IF(IXMT.EQ.IREC) GO TO 190
         C
         C              ERROR MESSAGE
         C
000467         IF(MOD(IL,LNFMCD).EQ.0) WRITE(6,1800) IL, IXMT, IREC
000511   1800  FORMAT(I6,5X,2H* ,37HUNABLE TO HANDLE CROSS POLARIZED DATA,
              *        1X,2H* ,4X,26HWILL ASSUME POLARIZED DATA, 5X,
              *        10HXMIT POL.=,I2,5X,10HREC. POL.=,I2)
         C
         C              INVERT SCAT DATA
         C
000511   190   DATA(8) = 4.0*DATA(8)*DATA(41)*DATA(41)/(COS(0.017453293*
              *          DATA(14))*3.14159265*SPAR(IXMT+32)*SPAR(IREC+32)*
              *          9.290304)
         C
         C              TRANSFER SCAT INT PERIOD
         C
000533         IND=IDATA(5)
000535         ARRAY(7)=SPAR(IND+3)
000537         IF(IDATA(3).EC.1) ARRAY(7)=SPAR(10)
         C
         C         TRANSFER SCAT DATA TO OUTPUT ARRAY
         C
000544         IARRAY(5) =IDATA (6)
000546         IARRAY(6) =IDATA (7)
000547         ARRAY(8) = DATA (8)
000551         ARRAY(9) = 10.0*ALOG10(DATA(8))
000562         GO TO 210
         C
         C         TRANSFER RAD DATA TO OUTPUT ARRAY
         C
000562   200   IARRAY(12)=IARRAY(12)*1000
```


FIGURE A-6. (c) SOURCE LISTING FOR CRUNCH

```
000565   210   ARRAY (10)= DATA (13)
         C
         C       TRANSFER OTHER SELECTED DATA
         C
000567         ARRAY(1)=LATA(1)
000570         IARRAY(2)=IDATA(3)
000572         ARRAY(3)=LATA(14)
000573         ARRAY(4)= DATA(15)
000575         ARRAY(11)=DATA(40)
000576         ARRAY (13)= DATA(41)
000600         ARRAY (14)= LATA (47)
000601         ARRAY (15)= DATA (46)
         C
         C              WRITE TO OUTPUT TAPE
         C
000603         CALL WRITE2(ARRAY)
         C
         C              INTERMEDIATE PRINT-OUT
         C
000604         IF(MOD(IL,LNPRCD).EQ.0) WRITE(6,2000) IL, ARRAY(10), ARRAY(8),
        *               ICHAN,IBAND
000643   2000  FORMAT(I6,5X,2H**,4X,29HCOMPLETED RECORD COMPUTATIONS,4X,2H**,
        *               4X,14H ANTENNA TEMP=,F6.1,2X,16HSCATTERING COEF=,E12.6,
        *               2X,8HCHANNEL=,I2,2X,9HDOP BAND=,I3)
000643         GO TO 100
000644   220   CALL CALIB(SCAL,RCAL,RPAR,NORMAL,BASE)
000650         IF(.NOT.ECFIFC) GO TO 100
000656   230   WRITE(6,2000) IL, ARRAY(10), ARRAY(8), ICHAN, IBAND
000702         RETURN
000703         END
```

FIGURE A-6. (d) SOURCE LISTING FOR CRUNCH

Table A-2 Definition of Variables Used in CRUNCH (Continued)

ICOUNT	=	Number of Interpretational Flags
LNPMOD	=	Line Print Modulus
IFC	=	Unit Code Number (1 or 8)
NGR	=	Number of Bad Records
ALT	=	Range Gate Settings
CHECK	=	One of Gate Settings
IXMT	=	Transmit Polarization Indicator
IREC	=	Receive Polarization Indicator
IND	=	SCAT Integration Selector
ARRAY	=	Output Array
IARRAY	=	Integer Equivalent

and RRAR are defined in Section III D; whereas, the entries in ARRAY are defined in Section III C.

C. Subroutine CALIB

1. Theory and Design

Subroutine CALIB extracts, averages and displays calibration parameters from calibration records. CALIB was designed to anticipate calibration records in a format generated by the RADSCAT instrument. Although additional flexibility is provided so that baseline records, which are entered by hand, may be inserted in almost any fashion. The baseline records may occur anywhere in the file except within a group of four normal calibration records. In regards to sequences of normal calibrations, the subroutine will orient itself on a set of four by interrogating whether the first normal calibration record causes SCAT outputs to saturate in channels 2, 3 and 4. This feature was embedded in the routine when it became apparent that the RADSCAT instrument would occasionally drop calibrations on the first few SCAT channels. A descriptive logic diagram for subroutine CALIB is shown in Figure A-7.

The baseline (BCAL) and normal calibration counters are initialized upon entry into the routine. Also the SCAT channel (CAL1(I), I = 1,4) and RAD accumulators (CAL1(5), RCL) are cleared. If the type of calibration record (normal or baseline, see Section III B) is normal (IDATA(4) = 0), processing is directed to statements including and following 4. Otherwise, if it is a baseline record, it is accumulated in RCL, the baseline counter is incremented, and the next record is

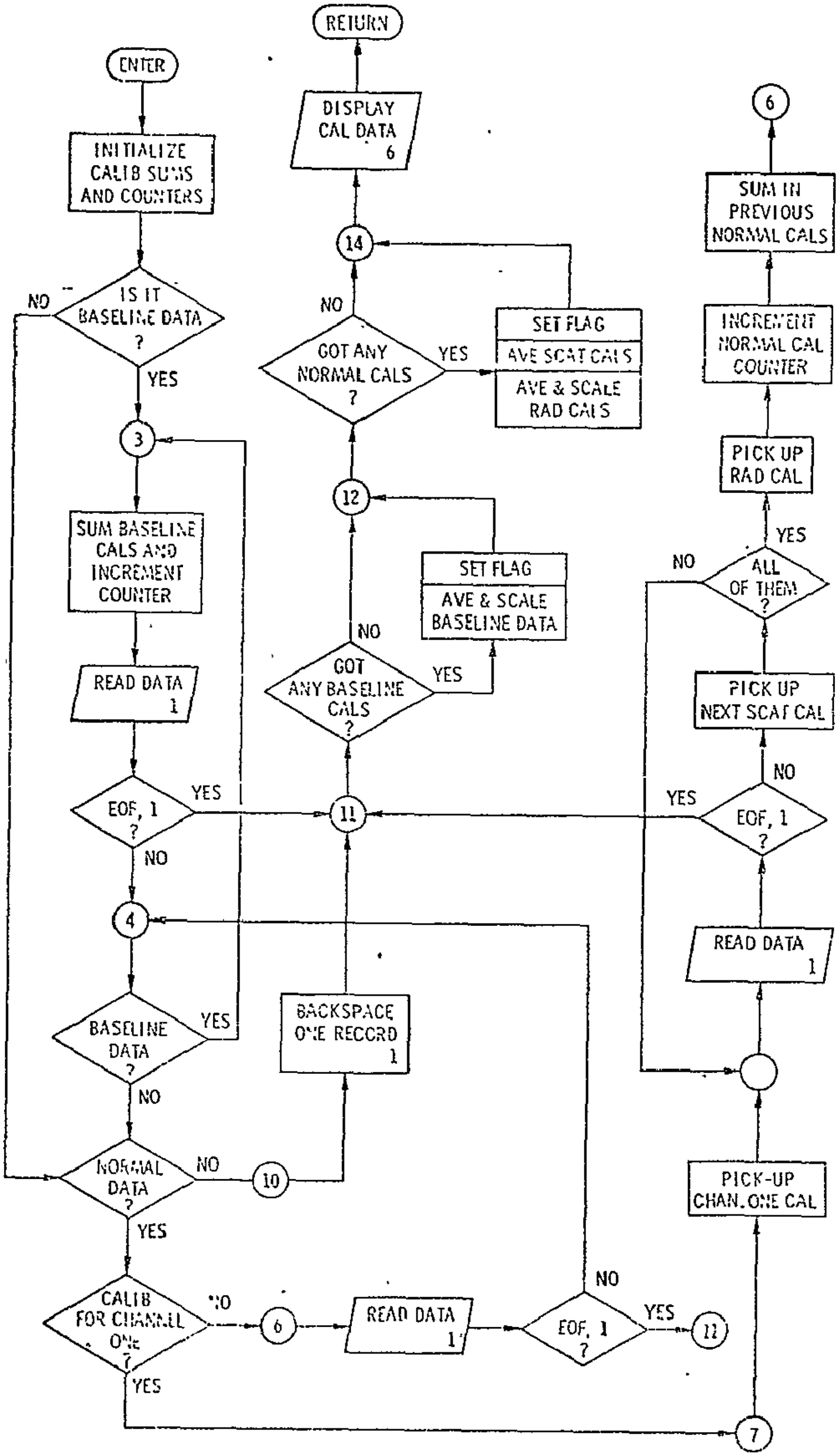

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FIGURE A-7. DESCRIPTIVE LOGIC DIAGRAM FOR SUBROUTINE CALIB read. In statement 4 and the one following, the type of record is again determined. If additional baselines records are present (IDATA(4) = 2), the above processing is repeated; if it is normal calibration data, the record is examined to determine whether the calibration indeed occurred on channel 1 (see DO loop terminating in statement 5). If not, the next record is read and the type is again determined. Once the program is aligned on the calibration for channel one, it extracts it in statement 7 and pulls the SCAT calibrations from the subsequent records for channels 2, 3 and 4 and the normal RAD calibration from the last SCAT calibration record (Channel 4). The normal cal counter is incremented and the calibration accumulator update.

The next record is read and the type determined again. If it is a calibration record the above steps are repeated. If not (measurement record), the unblocking routine READ1 is called to backspace a record (statement 10). The steps 11 through 60 determine what kinds of calibrations were present and how many. The accumulated calibrations are averaged and scaled accordingly. The types of calibrations present are reflected by setting the logical variables NORMAL and BASE to TRUE. The calibration parameters are then printed and control is returned to the calling routine, either SEARCH or CRUNCH.

2. Program Listing and Variables

The source listing for CALIB is shown in Figure A-8. The definitions of the variables are listed in Table A-3.

Table A-3 Variables Used in CALIB

DATA	=	Input Raw Data Vector
IDATA	=	Integer Equivalent of DATA
SCAL	=	SCAT Calibration Vector
RCAL	=	RAD Calibration Vector
RPAR	=	RAD Parameters
NORMAL	=	Normal Cal Indicator
BASE	=	Baseline Cal Indicator
BCAL	=	Baseline Cal Record Counter
CAL	=	Normal Cal Record Counter
RCAL	=	Baseline Cal Accumulator
CAL1	=	Normal Cal Accumulator

```
                  SUBROUTINE CALIB(SCAL,RCAL,RPAR,NORMAL,BASE)
         CCALIB                        CALIBRATION SUBROUTINE
         C
         C              THIS PROGRAM WAS PREPARED BY
         C
         C                  JOHN P. CLAASSEN
         C                  GLEN E. ELLIOTT
         C
         C              UNIVERSITY OF KANSAS CENTER FOR RESEARCH
         C
         C          THIS SUBROUTINE EXTRACTS CALIBRATION INFORMATION FROM
         C          THE RADSCAT DATA FILE AND DISPLAYS IT.
         C
000010            COMMON /INPUT/ EOF1, DATA
000010            LOGICAL NORMAL, BASE, EOF1
000010            DIMENSION DATA(50), IDATA(1), SCAL(1), RCAL(1), RPAR(1)
000010            DIMENSION CAL1(5), CAL2(5)
000010            EQUIVALENCE (DATA(1),IDATA(1))
         C
         C              INITIALIZE CAL COUNTERS
         C
000010            BCAL=0.0
000011            RCL=0.0
000012            CAL=0.0
         C
         C              CLEAR CAL ACCUMULATORS
         C
000013            DO 1 I=1,5
000014     1      CAL1(I)=0.0
         C
         C              BRANCH WHEN NOT BASELINE
         C
000017     2      IF(IDATA(4).NE.2) GO TO 4
         C
         C              EXTRACT BASELINE
         C
000021     3      RCL=RCL+DATA(13)
         C
         C              UPDATE BCAL COUNT
         C
000023            BCAL=BCAL+1.0
         C

         C              READ NEXT RECORD
         C
000025            CALL READ1
000026            IF(EOF1) GO TO 11
000033     4      IF(IDATA(4).EQ.2) GO TO 3
         C
         C              EXIT WHEN NO MORE CAL DATA
         C
000035            IF(IDATA(4).NE.0) GO TO 10
         C
         C              CHECK IF RECORD CONTAINS CAL ON
         C              FIRST SCAT CHANNEL
         C
000036            DO 5 I=2,4
000037     5      IF(DATA(I+7).LT.9.0) GO TO 6
000044            GO TO 7
         C
         C              FIND FIRST SCAT CAL
         C
000044     6      CALL READ1
000045            IF(EOF1) 11,4
         C
         C              EXTRACT SCAT 1
         C
000053     7      CAL2(1)=DATA(8)
         C
         C              EXTRACT REMAINDER OF CALS
         C
000055            DO 8 I=2,4
000056            CALL READ1
000057            IF(EOF1) GO TO 11
000064    15      IF(IDATA(4).NE.0) GO TO 4
000065     8      CAL2(I)=DATA(I+7)
000071            CAL2(5)=DATA(13)
000073            CAL=CAL+1.0
         C
         C              ACCUMULATE REPETITIVE CALS
         C
000075            DO 9 I=1,5
000076     9      CAL1(I)=CAL1(I)+CAL2(I)
000102            GO TO 6
         C
         C              REPOSITION DATA RECORD
```

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FIGURE A-8. (a) FORTRAN LISTING FOR CALIB

```
        C
000102  10     CALL BCKSP1
        C
        C              CHECK FOR PRESENCE OF BASELINE CAL
        C
000103  11     IF(BCAL.LT.1.0) GO TO 12
000111         BASE = .TRUE.
        C
        C              AVERAGE AND TRANSLATE BASELINE
        C
000111         RCAL(1)=(RCL/BCAL)*RPAR(19)/RPAR(20)
        C
        C              CHECK FOR PRESENCE OF NORMAL CAL
        C
000115  12     IF(CAL.LT.1.0) GO TO 14
000120         NORMAL = .TRUE.
000120         DO 13 I=1,4
        C
        C              AVERAGE SCAT CALS
        C
000122  13     SCAL(I)=CAL1(I)/CAL
        C
        C              AVERAGE AND TRANSLATE RAD CAL
        C
000126         RCAL(2)=(CAL1(5)/CAL)*RPAR(19)/RPAR(20)
        C
        C              DISPLAY CAL DATA
        C
000132  14     WRITE (6,100) (I,SCAL(I),I=1,4),RCAL(2), RCAL(1), CAL, BCAL
000167  100    FORMAT (11X,1H*10X,16HCALIBRATION DATA,13X,1H*,3X,
             *         4(2X,4HCHAN,I2,1H=,F7.3),
             *         /51X,1H*,5X,5HRCAL=F7.3,2X,6HRBASE=,F7.3,
             *         7H  NCAL=,F6.0,9H    NBCAL=,F6.0)
000167  60     RETURN
000170         END
```


FIGURE A-8. (b) (continued)

D. Subroutine ANGLE

1. Introduction

This routine computes the incident angle and cross track angle both of which are required to define the beam position on the surface with respect to the aircraft flight vector. When roll or pitch becomes excessive, as the case may be, so as to make the polarization difficult to interpret a flag is generated. Irrespective of the flagged condition the data is reduced in the standard way. The theory by which these angles are computed and the method by which the angles are applied to determine the polarization break-up at the surface are described below.

2. Theory and Design

a. Incident and Cross-Track Angles - Suppose the aircraft is vectored along the positive x axis of an unprimed coordinate system where the z axis corresponds to the local vertical. The orientation of the aircraft is represented in a primed coordinate system where x' axis is located along the fore-aft axis of the aircraft. They are related to the unprimed system by a drift angle ϕ_d about the z axis, a pitch angle θ_p with respect to the x, y plane and a roll angle ϕ_r about the x' axis (Figure A-9).*

The antenna points at an angle θ_a with respect to the $-z'$ axis. θ_a is assumed to be corrected for the relative angle between aircraft and antenna platforms. The true incident angle θ on the ground is desired. The incident angle may be derived from relation

$$\cos\theta = -\bar{\tau}_r \cdot \bar{\iota}_z \qquad (1)$$

where τ_r is a unit vector in the boresight direction. Also of interest is the cross track angle ϕ_c measured in the x,y plane with respect to the -x axis as shown in Figure A-10. Clearly we have

$$\tan\phi_c = \frac{\bar{\iota}_r \cdot \bar{\iota}_y}{-\bar{\iota}_r \cdot \bar{\iota}_x} \qquad (2)$$

---

*It should be noted that these definitions of roll, pitch and drift coincide with those provided by the Litton Navigator LTN-51.

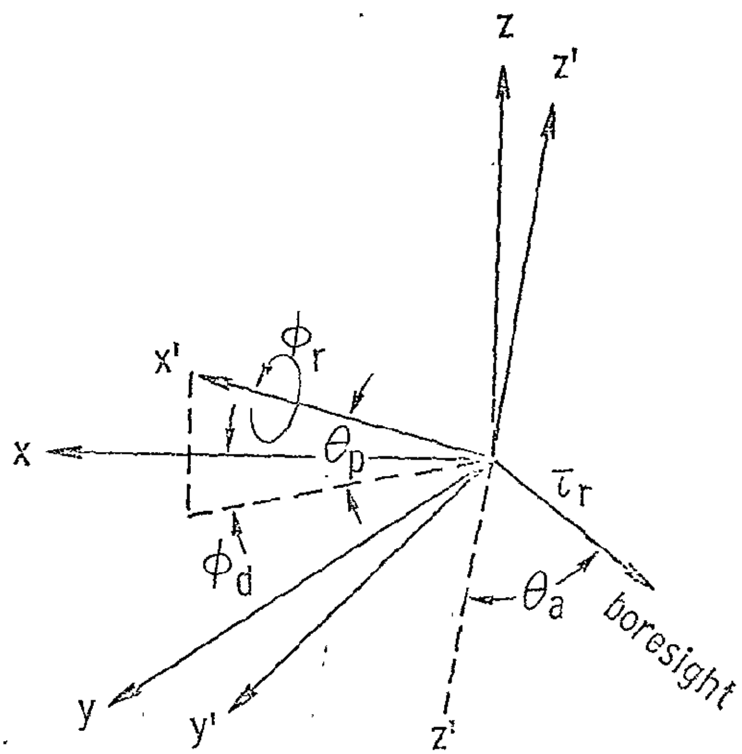

Figure A-9. Aircraft Flight Geometry

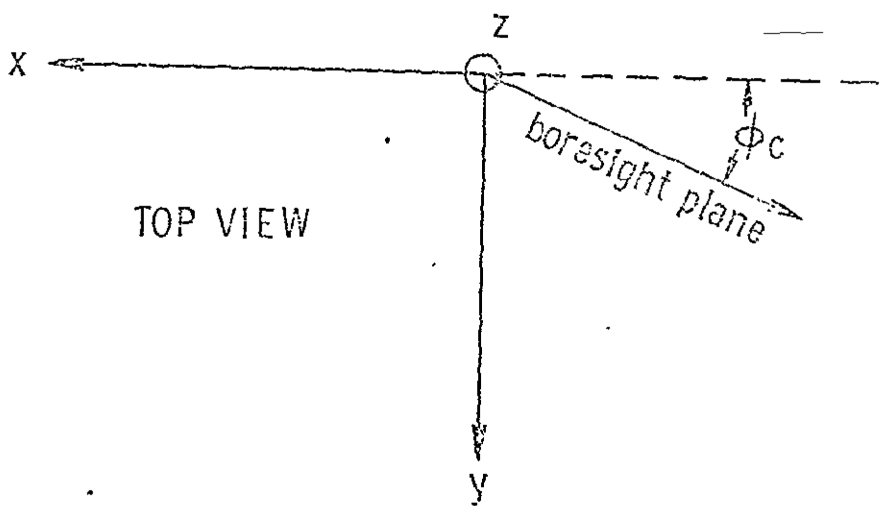

Figure A-10. Geometry Defining the Cross-Track Angle.

Now in the primed coordinate system the boresight axis is described by

$$\overline{\iota}_r = -\sin\theta_a\,\overline{\iota}_{x'} - \cos\theta_a\,\overline{\iota}_{z'} \qquad (3)$$

The primed and unprimed coordinate systems are related by the following successive transformation

$$\begin{pmatrix} \bar{i}_{x'} \\ \bar{i}_{y'} \\ \bar{i}_{z'} \end{pmatrix} = ABC \begin{pmatrix} \bar{i}_{x} \\ \bar{i}_{y} \\ \bar{i}_{z} \end{pmatrix} \tag{4}$$

where

$$A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\phi_r & \sin\phi_r \\ 0 & -\sin\phi_r & \cos\phi_r \end{pmatrix}$$

$$B = \begin{pmatrix} \cos\theta_p & 0 & \sin\theta_p \\ 0 & 1 & 0 \\ -\sin\theta_p & 0 & \cos\theta_p \end{pmatrix}$$

$$C = \begin{pmatrix} \cos\phi_d & \sin\phi_d & 0 \\ -\sin\phi_d & \cos\phi_d & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Substitution of (3) and (4) into (1) yields

$$\cos\theta = \sin\theta_p \sin\theta_a + \cos\theta_p \cos\theta_a \cdot \cos\phi_r \tag{5}$$

which reduces to the expected result when $\phi_r = 0$, namely, $\cos(\theta_p + \theta_a)$.

When the drift angle is considered zero, a similar approach will yield

$$\tan\phi_c\,(\phi_d = 0) = \frac{\sin\phi_r \cos\theta_a}{\sin\theta_a \cos\theta_p - \sin\theta_p \cos\theta_o \cos\phi_r} \tag{6}$$

When $\phi_d = 0$, it is clear from Figure A-11 that the correction for ϕ_d is simply given by

$$\phi_c(\phi_d = 0) = -\left[\phi_d - \phi_c(\phi_d = 0)\right] \tag{7}$$

or

$$\phi_c(\phi_d = 0) = -\phi_d + \tan^{-1}\left[\frac{\sin\phi_r \cos\theta_a}{\sin\theta_a \cos\theta_p - \sin\theta_p \cos\theta_a \cos\phi_r}\right] \tag{8}$$

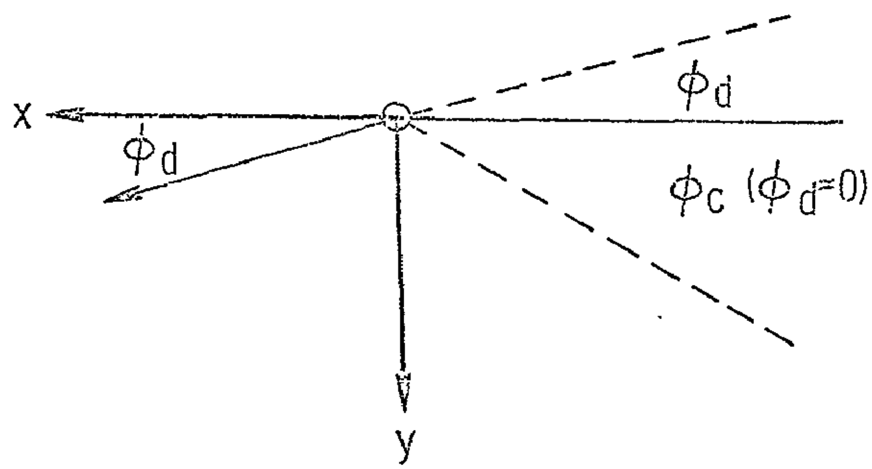

Figure A-11. Cross-Track Angle Correction for Drift.

Equations 5 and 8 thus define the beam position on the sea with respect to the aircraft trajectory.

b. Polarization Decomposition - When the aircraft pitches and rolls, the incident polarization can decompose into vertically and horizontally polarized components. When the unwanted component becomes excessive, the measurement becomes difficult to interpret; and, consequently, the reduced data should be flagged.* To determine the size of the undesired component, the degree of "de-polarization" is computed from considerations similar to those above.

*Correction for this situation is possible when polarized measurements are considered jointly.

Without loss of generality we may assume that the aircraft is vectored along the -x axis with zero drift. It is pitched at an angle of θ_p with respect to the -x axis and a positive roll of ϕ_r is induced about the -x' axis. The x,y plane forms the local horizontal and the z axis is pointed at nadir. See Figure A-12.

The antenna is boresighted in the x', z' plane with an angle θ_a from the z' axis. The vertical polarization emitted by the antenna is described by

$$\bar{i}_{\theta'} = \cos\theta_a\ \bar{i}_{x'} - \sin\theta_a\ \bar{i}_{z'} \tag{9}$$

along the boresight axis. The horizontal surface polarization at the boresight point is described as

$$\bar{i}_{\phi} = -\sin\phi_c\ \bar{i}_x + \cos\phi_c\ \bar{i}_y \tag{10}$$

where ϕ_c corresponds to the cross-track angle for the zero drift condition. Now the percent power de-polarization is approximately given by $100\ |\bar{i}_{\theta'} \cdot \bar{i}_{\phi}|^2$ for points illuminated by the main beam.

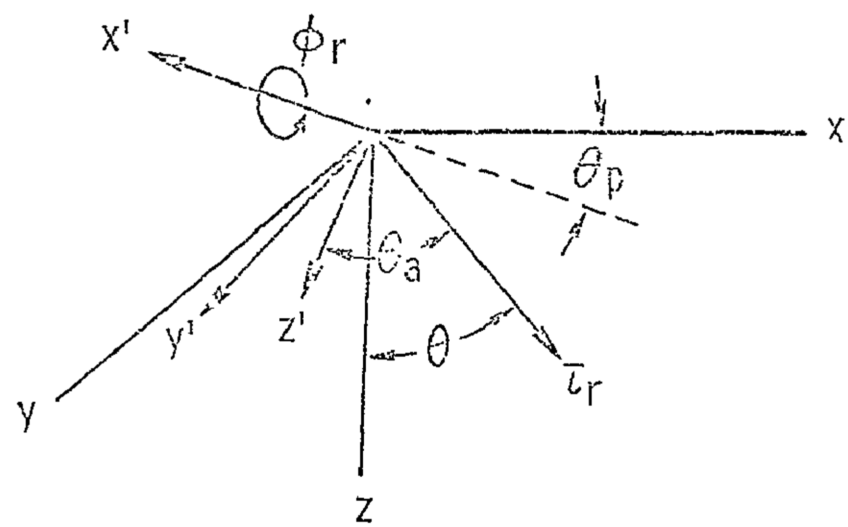

Figure A-12. "Depolarization" Geometry.

Now the transformation between the coordinates is given by

$$\begin{pmatrix} \bar{\imath}_{x'} \\ \bar{\imath}_{y'} \\ \bar{\imath}_{z'} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\phi_r & -\sin\phi_r \\ 0 & \sin\phi_r & \cos\phi_r \end{pmatrix} \cdot \begin{pmatrix} \cos\theta_p & 0 & \sin\theta_p \\ 0 & 1 & 0 \\ -\sin\theta_p & 0 & \cos\theta_p \end{pmatrix} \begin{pmatrix} \bar{\imath}_{x} \\ \bar{\imath}_{y} \\ \bar{\imath}_{z} \end{pmatrix} \tag{11}$$

or

$$\begin{pmatrix} \bar{\imath}_{x'} \\ \bar{\imath}_{y'} \\ \bar{\imath}_{z'} \end{pmatrix} = \begin{pmatrix} \cos\theta_p & 0 & \sin\theta_p \\ \sin\phi_r \sin\theta_p & \cos\phi_r & -\sin\phi_r \cos\theta_p \\ -\cos\phi_r \sin\theta_p & \sin\phi_r & \cos\phi_r \cos\theta_p \end{pmatrix} \begin{pmatrix} \bar{\imath}_{x} \\ \bar{\imath}_{y} \\ \bar{\imath}_{z} \end{pmatrix} \tag{12}$$

With the help of (12) we may thus write

$$\begin{aligned} |\bar{\imath}_{\theta'} \cdot \bar{\imath}_{\phi}| = |\sin\phi_c (\cos\theta_a \cos\theta_p + \sin\theta_a \cos\phi_r \sin\theta_p) \\ + \cos\phi_r \sin\theta_a \sin\phi_r | \end{aligned} \tag{13}$$

Now a suitable criterion for excessive polarization may be formed by requiring that

$$|\bar{\imath}_{\theta'} \cdot \bar{\imath}_{\phi}|^2 < \epsilon \tag{14}$$

where $0 < \epsilon << 1$. However, when the aircraft roll becomes excessive so that $|\bar{\imath}_{\theta}' \cdot \bar{\imath}_{\phi}|^2 > 0.5$ the interpretation of the incident polarization should be reversed from that defined by the instrument. Under this circumstance the polarization criterion should be written as

$$1 - |\bar{\imath}_{\theta'} \cdot \bar{\imath}_{\phi}|^2 < \epsilon \tag{15}$$

where $0 < \epsilon << 1$. This latter criterion should be useful when RADSCAT observations are conducted from an aircraft in a roll (blank) attitude.

From Section IV.B.1 we noted that for zero drift

$$\tan \phi_c = \frac{\sin \phi_r \cos \theta_a}{\sin \theta_a \cos \theta_p + \sin \theta_p \cos \theta_a \cos \phi_r} \qquad (16)$$

The drift angle does not influence the polarization decomposition as a little thought will substantiate. This is fortunate since drift angle is not well defined in a roll maneuver. As a consequence the criterion is now formed on the basis of measured and computed parameters.

Relationships (13), (14), (15) and (16) establish the depolarization parameters and the polarization reversal criterion.

3. Program Listing and Variables

The FORTRAN listing for ANGLE is shown in Figure A-13. The comment statements are sufficient to establish the logic of the program. The variables defined in Table A-4 should be helpful.

Table A-4 Definition of Variables in Subroutine ANGLE

DATA	=	Input Raw Data Vector
SPAR	=	SCAT Parameters
IL	=	Record Count
LNPMOD	=	Line Print Modulus
IFLAG	=	Excessive Depolarization and Reversal Flag
DEGRAD	=	Degress to Radians Conversion Factor
ANTA	=	Antenna Angle
PITCH	=	Aircraft Pitch
DRIFT	=	Aircraft Drift
ROLL	=	Aircraft Roll
THETA	=	Incident Angle
ARG1,ARG2	=	Intermediate Storage
PHI	=	Cross-track Angle
DEPOL	=	Depolarization Factor

```
              SUBROUTINE ANGLE (DATA,SPAR,IL,LAPPCL,IFLAG)
       CANGLE                      COMPUTE INCIDENCE ANGLE
       C           SUBROUTINE ANGLE (DATA,SPAR,IL,LAPPOU,IFLAG)
       C
       C           THIS PROGRAM WAS PREPARED BY
       C
       C                JOHN P. CLAASSEN
       C                GLEN E. ELLIOTT
       C
       C           UNIVERSITY OF KANSAS CENTER FOR RESEARCH
       C
       C      THIS ROUTINE COMPUTES THE INCIDENT ANGLE THETA FROM AIRCRAFT
       C      AND ANTENNA PARAMETERS. CORRECTION IS MADE FOR THE RELATIVE
       C      ANGLE BETWEEN THE AIRCRAFT AND ANTENNA PLATFORM.
       C      THE BORESIGHT CROSS-TRACK ANGLE PHI IS ALSO COMPUTED.
       C      WHEN THE ROLL OR PITCH ANGLE BECOMES EXCESSIVE, AS THE CASE
       C      MAY BE, SO AS TO MAKE THE RETURN OR EMISSION POLARIZATION
       C      DIFFICULT TO INTERPRET, A FLAG IS GENERATED.
       C
C00010        DIMENSION DATA(1), SPAR(1)
       C
       C      DEGREE-RADIAN CONVERSION FACTOR.
       C
C00010        DATA DEGRAD/0.0174532925/
       C
       C      INITIALIZE FLAG
       C
000010        IFLAG=0
       C
       C      AVERAGE SCAT AND RAD ANGLES
       C
C00010        DATA(14)=(DATA(14)+DATA(15))/2.0
       C
       C      CONVERT TO DEGREES
       C
C00013        DATA(14)=DATA(14)*SPAR(30)
       C
       C      COMPENSATE FOR  ANTENNA PITCH RELATIVE TO AIRCRAFT
       C
C00015        DATA(14)=DATA(14)+SPAR(31)
       C
       C      CONVERT TO RADIANS
       C
C00017        ANTA= DATA(14)*DEGRAD
C00021        PITCH=DATA(43)*DEGRAD
C00022        DRIFT=DATA(44)*DEGRAD
C00024        ROLL =DATA(45)*DEGRAD
       C
       C       COMPUTE INCIDENT ANGLE
       C
000025        THETA = SIN(ANTA)*SIN(PITCH)+COS(PITCH)*COS(ANTA)*COS(ROLL)
C00043        THETA = ACOS(THETA)
       C
       C       CONVERT TO DEGREES.
       C
C00046        DATA(14)=THETA/DEGRAD
       C
       C      COMPUTE CROSS TRACK ANGLE
       C
C00052        ARG1=SIN(ROLL)*COS(ANTA)
C00057        ARG2=SIN(ANTA)*COS(PITCH)-SIN(PITCH)*COS(ANTA)*COS(ROLL)
C00075        IF (ABS(ARG2).LT. 1.E-07) GO TO 30
C00104        IF(ABS(ARG1).LT.1.0E-07) GO TO 10
C00107        PHI=ATAN2(ARG1,ARG2)
000112        GO TO 40
000115   10   PHI=0.
000116        IF(ARG2.LT.0.0) PHI=3.14159265
C00121        GO TO 40
000122   30   PHI=SIGN(1.57079633,ARG1)
C00125   40   DATA(15)=PHI/DEGRAD-DATA(44)
       C
       C       COMPUTE THE DEPOLARIZATION
       C
C00130        DEPOL= SIN(PHI)*
             *     (COS(ANTA)*COS(PITCH)+SIN(ANTA)*COS(ROLL)*SIN(PITCH))+
             *      COS(PHI)*SIN(ANTA)*SIN(ROLL)
       C
       C          CHECK FOR POLARIZATION REVERSALS.
       C
000162        DEPOL = DEPOL*DEPOL
000163        IF(DEPOL.GT.0.500) GO TO 50
000172        GO TO 60
C00172   50   DEPOL = 1.0 - DEPOL
       C
       C          FLAG REVERSAL
```


FIGURE A-13. (a) FORTRAN LISTING FOR SUBROUTINE ANGLE

```
       C
000174          IF(MOD(IL,LNPMCD).EQ.0) WRITE(6,500) IL
000210    500   FORMAT(I6,5X,2H* 21HPOLARIZATION REVERSAL,17X,1H*)
000210          IFLAG=1
       C
       C                  FLAG EXCESSIVE DEPOL.
       C
000211    60    IF(DEPOL.GT.0.02) GO TO 70
000215          RETURN
000215    70    IFLAG=IFLAG+10
000216          IF(MOD(IL,LNPMCD).EQ.0) WRITE(6,700) IL, DEPOL
000235    700   FORMAT(I6,5X,2H* 24HEXCESSIVE DEPOLARIZATION,14X,1H*,
             *         5X,6HDEPOL=,F7.3)
000235          DATA(40)=DEPOL
000237          RETURN
000240          END
```


FIGURE A-13. (b) FORTRAN LISTING FOR SUBROUTINE ANGLE

E. Subroutine THERMO

Temperatures within the RADSCAT microwave assembly are monitored at various points. Certain of these temperatures are essential to the reduction of the radiometer data. All of the temperatures should be checked to determine whether the instrument is operating within its temperature limits.

The temperatures are monitored by means of thermistors. Above 283° the thermistor output voltages are linearly proportional to temperature. This routine converts the recorded thermistor voltages, DATA(17) through DATA(33), to degrees Kelvin by using linear conversion constants, RPAR(23) through RPAR(56). Once converted the computed temperatures are examined to see that they appear in the operating temperature range specified by RPAR(21) and RPAR (22). Those that fall outside this range are flagged with a message in the Conversion Report. A flag is also generated in the S/R validation code appearing in the output files. Routinely the temperatures critical to the conversion of radiometer data are reported by this routine.

The above steps are reflected in the FORTRAN listing for THERMO shown in Figure A-14. The variables employed in the routine are defined in Table A-5.

Table A-5 Definition of Variables Used in THERMO

DATA	=	Raw Data Vector
IDATA	=	Integer Equivalent of DATA
RPAR	=	Radiometer Parameters
IL	=	Record Number
LNPMOD	=	Line Print Modulus
IFLAG	=	Abnormal Receiver Temperature Flag
IWARM	=	Warm Load Temperature Estimate Flag

F. Subroutine RCONV

1. Introduction

This routine converts the radiometer output voltage into an antenna (input) temperature. Radiometer baseline calibration RCAL(1) and normal calibrations RCAL(2) are employed to properly scale the output voltage DATA(13) to a receiver input temperature. Thermal noise contributions from front-end elements are subtracted

```
                 SUBROUTINE THERMO (DATA,IDATA,RPAR, IL,LNPMOD,IFLAG,IWARM)
         C
         CTHERMO                            CHECKS TEMPERATURE
         C
         C                THIS PROGRAM WAS PREPARED BY
         C
         C                       JOHN P. CLAASSEN
         C                       GLEN E. ELLIOTT
         C
         C                UNIVERSITY OF KANSAS CENTER FOR RESEARCH
         C
         C           THIS ROUTINE EXAMINES ATM VOLTAGES AND CONVERTS THEM TO
         C           TEMPERATURES. THE TEMPERATURE VALUES ARE CHECKED TO SEE
         C           IF THEY OCCUR IN THE PERMISSIBLE OPERATING RANGE.  WHEN
         C           THEY FALL OUTSIDE THE RANGE A FLAG IS GENERATED AND AN ERROR
         C           MESSAGE DISCLOSING THE BAD VALUE AND MONITORING LOCATION
         C           IS PRINTED. THE VOLTAGE TO TEMPERATURE PARAMETERS ARE
         C           ENTERED FROM RPAR. THE STARRED STATEMENT IS TO BE
         C           USED WHEN THE HOT LOAD TEMP IS AVAILABLE.
         C
C00012           DIMENSION DATA(1), RPAR(1), IDATA(1)
         C
         C                INITIALIZE FLAGS
         C
C00012           IFLAG=0
C00012           IWARM = 0
         C
         C           CONVERT TO TEMPERATURES
         C
C00013           J = 22
C00014           DO 20 I= 1,17
C00016           K=I+J
C00020           DATA(I+16)=RPAR(K)*DATA(I+16)+RPAR(K+1)+273.18
C00025           T=DATA(I+16)
C00027           J = J+1
C00031           IF(I.EQ.17) GO TO 20
C00033           IF (T.LT.RPAR(21) .AND. T.GT. RPAR(22)) GO TO 20
         C
         C           FLAG AND PRINT MESSAGE WHEN NOT IN LIMITS.
         C
C00043    10     IFLAG=1
C00044           IF(MOD(IL,LNPMOD).EQ.0) WRITE (6,100) IL,I,T

C00066   100     FORMAT(I6,5X,41H* RECVR TEMP NOT WITHIN OPERATING RANGE *,
              *         5X,12HLOCATION NO. I3,5X,
              *         13HTEMPERATURE =,F5.1,7H KELVIN)
C00066    20     CONTINUE
         C
         C                CHANGE AIR TEMP TO KELVIN
         C
C00070           DATA(46) = DATA(46) + 273.18
         C
         C                CHECKS FOR ESTIMATED WARM LOAD TEMPERATURE
         C
C00072           IF (IDATA(36) .EQ. 0)  GO TO 30
C00074           IWARM = 1
C00074           IF (MOD(IL,LNPMOD) .EQ. 0)  WRITE(6,150)  IL
C00113    150   FORMAT (I6,5X,2H* ,31HWARM LOAD TEMPERATURE ESTIMATED,7X,,1H*)
         C
         C                LIST CRITICAL TEMPERATURES
         C
C00113     30   IF(MOD(IL,LNPMOD).EQ.0) WRITE (6,200) IL, DATA(27), DATA(33),
              *         DATA(32), DATA(28), DATA(46), DATA(25)
C00167   200    FORMAT (I6,5X,2H* 21HCRITICAL TEMPERATURES,17X,
              *         1H*,5X,5HWARM=,F6.1,2X,4HHOT=,F6.1,2X,4HOMT=,F6.1,
              *         2X,3HSW=,F6.1,2X,4HAIR=,F6.1,2X,4HGDE=,F6.1)
C00167           RETURN
C00170           END
```

FIGURE A-14. FORTRAN LISTING FOR SUBROUTINE THERMO out to refer the receiver input temperature to the antenna terminals with the help of conversion constants RPAR and temperatures of input elements, DATA (17) to DATA (33).

2. Theory and Design

The radiometer conversion model was developed in TM 186-3.* In view of the involvement in the derivation, only an outline of the derivation will be presented here.

During baseline calibration an output proportional to a zero receiver intpu temperature is generated

$$V_b = -\frac{\tau_c}{RC}\left[V_r + \frac{G}{4(T_{1r}-T_{2r})}(T_{1r}+T_{2r}-T_{1r}-T_{2r})\right] \quad (1)$$

where
- τ_c = calibration integration period
- RC = output integrator time constant
- G = receiver gain established by AGC circuit
- V_r = output reference bias
- T_{1r} = hot load temperature referred to receiver input
- T_{2r} = warm load temperature referred to receiver input

During a normal calibration sequence the output integration produces a voltage given by

$$V_n = -\frac{\tau_c}{RC}\left[V_r - \frac{G}{4(T_{1r}-T_{2r})}(2T_{1r}-2T_{2r})\right] \quad (2)$$

This result yields the unknown gain factor

$$G = \frac{2RC}{\tau_c}(V_n - V_b) \quad (3)$$

where (1) has been employed. A measurement cycle yields an output voltage given by

$$V_m = -\frac{\tau}{RC}\left[V_r + \frac{G(2T_{ar}-T_{1r}-T_{2r})}{4(T_{1r}-T_{2r})}\right] \quad (4)$$

---

*Claassen, J. P., "The RADSCAT Radiometer Transfer Function and Its Application to the Reduction of RADSCAT Data," University of Kansas Center for Research, Inc. Lawrence, Kansas, December 1971.

C, 2

where T_{ar} is the temperature at the antenna port of the Dicke switch. This result may be written as

$$T_{ar} = \frac{T_{1r} + T_{2r}}{2} - \rho_m (T_{1r} - T_{2r}) \tag{5}$$

where

$$\rho_m = \frac{V_m - V_b \, \tau/\tau_c}{(V_n - V_b) \, \tau/\tau_c} \tag{6}$$

and where (1) and (3) have been employed. From pages 8-11 of TM 186-3 it is noted that certain leakages at the Dicke switch require that certain terms in (5) be modified with reflection factors R_a and R_c so that the modeling equation actually becomes

$$T_{ar} (1 - R_L) = \frac{T_{1r} + T_{2r}}{2} (1 - R_a) - \rho_m \; (T_{1r} - T_{2r}) \tag{7}$$

Now the temperature at the antenna port of the Dicke switch can be described by

$$(1 - R_a) \, T_{ar} = \rho_1 T_a + \rho_2 T_g + \rho_3 T_s + \rho_4 T_F + \rho_5 T_o + \rho_6 T_c + \rho_7 + \rho_8 T_L \tag{8}$$

where
T_a = desired antenna temperature
T_L = leakage from opposite port
T_g = internal guide temperature
T_S = temperature of polarization switch
T_F = temperature of feed between switch and OMT
T_o = temperature of OMT
T_c = temperature of cutler feed
ρ_i = referral constants $i = 1, 2, \ldots, 8$

It should be noted that the factor ρ_7 simply accounts for small but unknown contributions originating from front-end elements not well defined physically. Now let

$$\frac{T_{1r} + T_{2r}}{2} (1 - R_a) = \nu_1 \, T_1 + \nu_2 \, T_2 \tag{9}$$

and

$$\rho_m (T_{1r} - T_{2r}) = \rho_m (v_3 T_1 - v_4 T_2) \tag{10}$$

Then (7) may be written as

$$\begin{aligned} \beta_1 T_a + \beta_8 T_L = v_1 T_1 + v_2 T_2 - \rho_m (v_3 T_1 - v_4 T_2) \\ - \beta_2 T_g - \beta_3 T_s - \beta_4 T_F - \beta_5 T_o \\ - \beta_6 T_c - \beta_7 \end{aligned} \tag{11}$$

or after division by β_1 as

$$\begin{aligned} T_a + \xi_c T_L = \sigma_1 T_1 + \sigma_2 T_2 - \rho_m (\sigma_3 T_1 - \sigma_4 T_2) \\ - \eta_1 T_g + \eta_2 T_s - \eta_3 T_F - \eta_4 T_o \\ - \eta_5 T_c - \eta_6 \end{aligned} \tag{12}$$

Now since T_F is not monitored it will be assumed that $T_F = a_o T_s + a_1 T_o$ where $a_o + a_s = 1$. In this case the conversion model simplifies to the form

$$\begin{aligned} T_a + \xi_c T_L = \sigma_1 T_1 + \sigma_2 T_2 - \rho_m (\sigma_3 T_1 - \sigma_4 T_2) - \sigma_5 T_g \\ - \sigma_6 T_s - \sigma_7 T_o - \sigma_8 T_c - \sigma_9 \end{aligned} \tag{13}$$

The leakage term T_L is actually the antenna temperature at the opposite polarization. This term can be estimated from measurements at that polarization. There is no guarantee that it is always available; however, over the sea it can be estimated from T_a with reasonable accuracy when the sky is clear. Hollinger* has shown that the polarized temperatures are related by

$$T_{av} = \frac{1 - c}{1 + c} T_{ah}$$

where

$C = 0.00012 \quad \theta^2$

θ = observation angle in degrees

*Hollinger, J. P., "Passive Microwave Measurements of the Sea Surface," Journal of Geophysical Research, vol. 75, no. 27, pp. 5209-5213, September 1970.

The latter estimating technique is employed by the subroutine since temperatures at the opposite polarization are not always available. Fortunately ξ_c is small (estimated at .004) so that under some circumstances the leakage term can be ignored (by setting ξ_c =0).

The above model is incorporated in RCONV. The listing for the subroutine is shown in Figure A-15. The variables are defined in Table A-6.

Table A-6 Definition of Variables in Subroutine RCONV

I	=		Receive Polarization Index
J	=		Frequency Indicator
RPAR(5)	=	σ_1	
RPAR(6)	=	σ_2	
RPAR(7)	=	σ_3	
RPAR(8)	=	σ_4	
RPAR(I+9)	=	σ_6	
RPAR(I+11)	=	σ_7	
RPAR(I+13)	=	σ_8	
RPAR(I+15)	=	σ_5	
RPAR(17)	=	σ_9	
EST	=	$\xi_c T_L$	
DATA(28)	=	T_s	
DATA(32)	=	T_o	
DATA(46)	=	T_c	
DATA(18)	=	T_g	

G. Subroutine DOPCHK

1. Introduction

This subroutine computes the doppler frequency shift induced by the relative motion between aircraft and sea. The doppler shift is compared with the doppler filter characteristic to determine whether the shift is within the bandpass. When it is, a frequency index IBAND, which is employed to locate the filter gain, is computed. When the doppler shift lies outside the defined doppler filter characteristic, the band index is set at the appropriate extreme and a flag is set.

```
          SUBROUTINE RCONV (DATA,IDATA,RPAR,RCAL,IL)
       CRCONV                        CONVERT RADIOMETER
       C             SUBROUTINE RCONV (DATA,IDATA,RPAR,RCAL,IL)
       C
       C             THIS PROGRAM WAS PREPARED BY
       C
       C                  JOHN P. CLAASSEN
       C                  GLEN E. ELLIOTT
       C
       C             UNIVERSITY OF KANSAS CENTER FOR RESEARCH
       C
       C
       C         THIS PROGRAM CONVERTS RADIOMETER OUTPUT VOLTAGES TO ANTENNA
       C         TEMPERATURE.
       C
C00010     DIMENSION DATA(1), IDATA(1), RPAR(1), RCAL(1)
       C
       C
       C             FORM POLARIZATION AND FREQUENCY INDEX.
       C
C00010     I=IDATA(12)
C00011     J=IDATA(2)
       C
       C             EXTRACT LOAD TEMPERATURES
       C
C00012     T1 = DATA(33)
C00014     T2=DATA(22)
C00015     IF(J.EQ.3) T2=DATA(27)
       C
       C             FORM MEASUREMENT PARAMETER.
       C
C00021     DATA(13)=-(DATA(13)-RCAL(1))/(RCAL(2)-RCAL(1))
       C
       C             APPLY TEMPERATURE FACTORS.
       C
C00026     DATA(13)=DATA(13)*(RPAR(5)*T1-RPAR(6)*T2)+RPAR(7)*T1+RPAR(8)*T2-
         *        RPAR(I+9)*DATA(28)-RPAR(I+11)*DATA(32)-RPAR(I+13)*
         *        DATA(46) - RPAR(15)*DATA(18)
       C
       C                  APPROXIMATE MISSING DATA
       C
       C

       C         APPROXIMATING PARAMETER
       C
C00062     C=0.00012*DATA(14)*DATA(14)
       C
       C         FOR HORIZONTAL POLARIZATION
       C
C00065     EST=DATA(13)*(1.0+C)/(1.0-C)
       C
       C         FOR VERTICAL POLARIZATION
       C
C00071     IF (I .EQ.1) EST = DATA (13)*(1.0-C)/(1.0+C)
       C         FORM ANTENNA TEMPERATURES
       C
C00100     DATA(13) = DATA(13) - EST*RPAR(I+3)
C00104     RETURN
C00105     END
```

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FIGURE A-15. FORTRAN LISTING FOR SUBROUTINE RCONV

2. Theory and Design

For non-relativistic speeds the two way doppler frequency shift is known to be given by

$$f_d = 2 (\bar{v} \cdot \bar{i}_r) \frac{f}{c} \tag{1}$$

where $\bar{i}_r$ = boresight unit vector

$\bar{v}$ = aircraft velocity

f = operating frequency

c = speed of light

Denote ϕ_c as the cross-track angle and θ as the incident angle (see subroutine ANGLE). Then the boresight vector is given by

$$\bar{i}_r = - \sin\theta \cos\phi_c \, \bar{i}_x + \sin\theta \sin\phi_c \, \bar{i}_y - \cos\theta \, \bar{i}_z \tag{2}$$

Also

$$\bar{v} = v \, \bar{i}_x \tag{3}$$

So

$$\bar{v} \cdot \bar{i}_r = - v \sin\theta \cos\phi_c \tag{4}$$

and

$$f_d = -2 \frac{f v}{c} \sin\theta \cos\phi_c \tag{5}$$

Expression (5) is the desired result.

Now the computer routine determines whether the doppler shift falls in the doppler bandwidth as defined by the upper and lower limits, SPAR(23) and SPAR(22), respectively. If f_d is between SPAR(22) and SPAR(23), f_d is divided by the doppler filter gain sample interval SPAR(24) and the result rounded off to determine the band index (IBAND) from the center frequency. When the shift is outside the bandpass, the band index is set at the appropriate extreme and a flag is set. An error message is also appended to the Conversion Report. A listing of DOPCHK is shown in Figure A-16. The variables employed by the routine are defined in Table A-7.

```
               SUBROUTINE DOPCHK (DATA,SPAR,IL,IBAND,LNPMOD,IFLAG)
        CDOPCHK                            CHECK DOPPLER SHIFT
        C            SUBROUTINE DOPCHK (DATA,SPAR,IL,IBAND,LNPMOD,IFLAG)
        C
        C            THIS PROGRAM WAS PREPARED BY
        C
        C               JOHN P. CLAASSEN
        C               GLEN E. ELLIOTT
        C
        C            UNIVERSITY OF KANSAS CENTER FOR RESEARCH
        C
        C
        C         THIS SUBROUTINE COMPUTES THE DOPPLER SHIFT INDUCED BY THE
        C         RELATIVE MOTION BETWEEN AIRCRAFT AND SEA. THE DOPPLER SHIFT
        C         IS COMPARED  WITH THE DOPPLER FILTER CHARACTERISTIC TO
        C         DETERMINE WHETHER SHIFT IS WITHIN THE BANDPASS AND WHEN
        C         IT IS TO SELECT THE DOPPLER FILTER GAIN  RELATIVE TO THE
        C         CALIBRATION SIGNAL.
        C
C00011         DIMENSION DATA(1), SPAR(1)
        C
C00011         DATA DEGRAD/0.0174532925/
        C
        C         INITIALIZE FLAG
        C
C00011         IFLAG=0
        C
        C         CONVERT AIRCRAFT SPEED TO METERS/SEC
        C
C00011         VEL=DATA (42)/3.048
        C
        C         CONVERT TO RADIANS
        C
000013         THETA = DATA (14)*DEGRAD
C00015         PHI=DATA(15)*DEGRAD
        C
        C            COMPUTE THE DOPPLER SHIFT
        C
C00017          DOP=-2.0*SPAR(1)*VEL/299793000.0*SIN(THETA)*COS(PHI)
        C
        C         IF DOPPLER SHIFT EXCESSIVE FORM FLAG
        C

C00036         IF(DOP.LT.SPAR(22)) GO TO 10
C00041         IF(DOP.GT.SPAR(23)) GO TO 20
        C
        C         FORM DOPPLER BAND INDEX
        C
000044         IBAND=-DOP/SPAR(24)+0.5
C00047         IF (DOP.GT.0.0)  IBAND= -DOP/SPAR(24)-0.5
C00053         RETURN
        C            FORM FLAG AND ASSIGN BAND
C00054   10    IBAND = -SPAR(22)/SPAR(24)
C00057         GO TO 30
C00060   20    IBAND = -SPAR(23)/SPAR(24)
C00063   30    IFLAG=1
C00064         IF(MOD(IL,LNPMOD).EQ.0) WRITE (6,40) IL,DATA(42),DATA(14),DOP
000115   40    FORMAT (I6,5X,1H*,1X,17HEXCESSIVE DOPPLER,21X,1H*,5X,
             *         13HAIRCRAFT SPD=,F5.1,5X,11HVIEW ANGLE=,F5.1,5X,
             *         14HDOPPLER SHIFT=,F6.0)
C00115         RETURN
000116         END
```

FIGURE A-16. FORTRAN LISTING OF SUBROUTINE DOPCHK

Table A-7 Definition of Variables

IFLAG	=	Flag for Excessive Doppler
VEL	=	Aircraft Ground Velocity
THETA	=	Incident Angle
PHI	=	Cross-track Angle
DOP	=	Doppler Shift
IBAND	=	Doppler Band Index
SPAR(22)	=	Lower Doppler Filter Limit
SPAR(23)	=	Upper Doppler Filter Limit
SPAR(24)	=	Doppler Filter Sample Interval

H. Subroutine SCONV

1. Introduction

SCONV converts scatterometer output measurements into a normalized input power. The scatterometer transfer function is employed to perform the conversion. The transfer function is developed below. Certain significant simplifications arise when SCAT normal calibrations are employed.

2. Theory and Design

The block diagram for the RADSCAT scatterometer is shown in Figure A-17. The front-end elements have been decomposed into a calibration element G_c, transmission elements G_{VT}, G_{HVT}, G_{HT}, and G_{VHT} and reception elements G_{VR}, G_{HVR}, G_{HR} and G_{VHR} for ease in analysis and reduction of data. The transfer functions account for mis-match and loss. Calibration attenuators A_1 through A_4 are employed to calibrate the output channels 1 through 4, respectively.

During calibration transmitter power is routed sequentially through A_1, A_2, A_3 and A_4 and the respective channel output is noted. The resulting output voltage for the i^{th} channel is thus given by

$$V_i^{(c)} = d^2 P_x G_c G_R A_i \alpha_i I_i \tau_c \qquad (1)$$

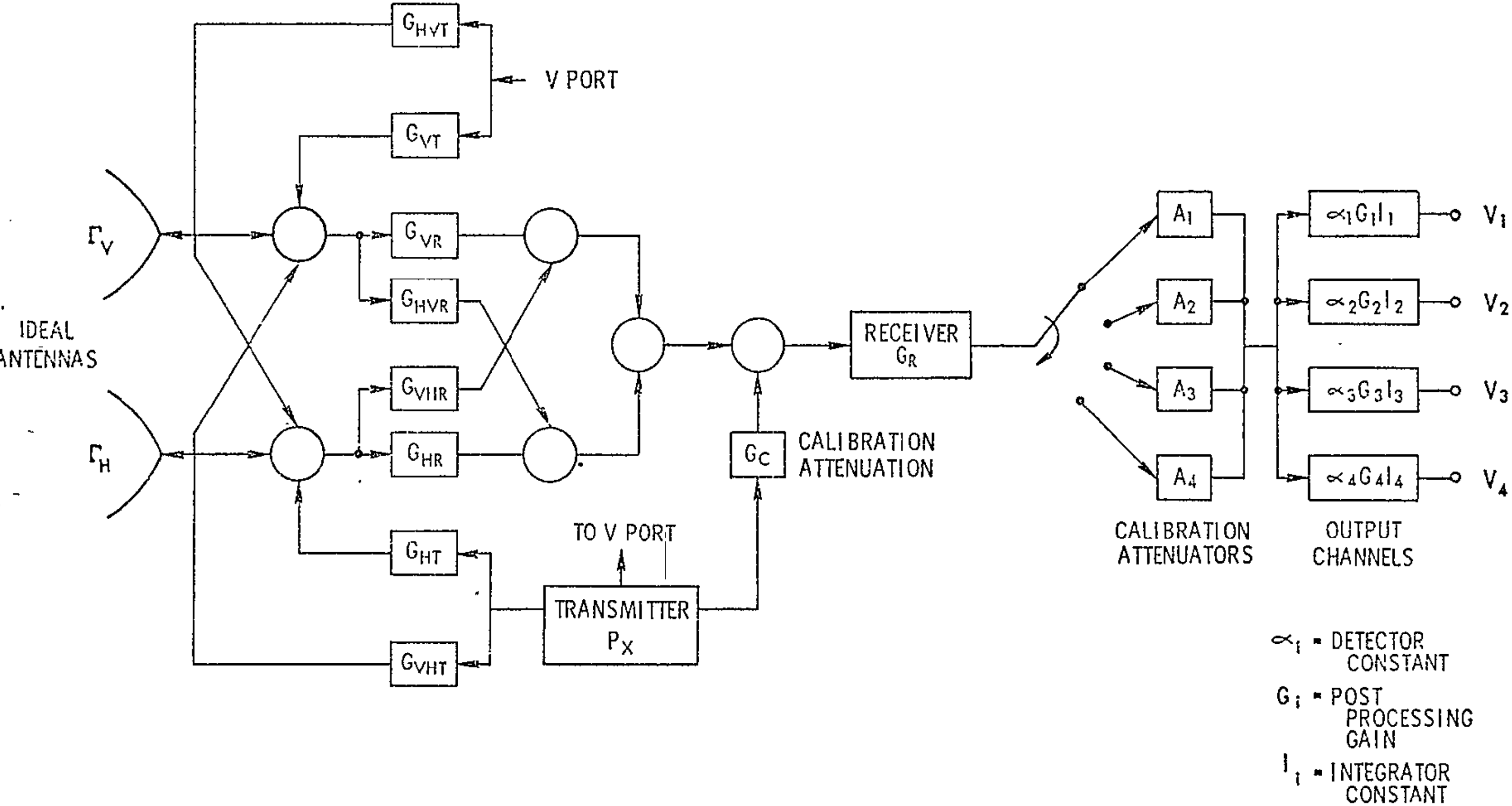

FIGURE A-17. BLOCK DIAGRAM FOR SCATTEROMETER where d = the effective duty factor

P_x = transmitter peak power

τ_c = calibration integration period

The factor d^2 occurs in the above expression since only the center frequency of the power spectrum is sampled by the receiver. The calibrations thus serve as a measure of the transmitted power

$$P_x = \frac{V_i^{(c)}}{d^2 G_c G_R A_i \alpha_i G_i I_i \tau_c} \quad (2)$$

During measurements at VV polarization and incident angle θ_o the power arriving at the receiver input is given by

$$P_{VV}(\theta_o) = \frac{\lambda^2}{(4\pi)^3} d^2 P_x [G_{VV} \Gamma_V I_{VV}(\theta_o) \Gamma_V G_{VT}$$

$$+ G_{VHR} \Gamma_H I_{HV}(\theta_o) \Gamma_V G_{VT} + G_{HVR} \Gamma_H I_{HH}(\theta_o) \Gamma_H G_{HVT}$$

$$+ G_{VR} \Gamma_V I_{VH}(\theta_o) \Gamma_H G_{HVT}] \quad (3)$$

where

$$I_{mn} = \iint_{4\pi} \frac{P_m(\chi, \psi) P_n(\chi, \psi) \sigma_{mn}(\theta)}{R^4} dA \quad (4)$$

σ_{mn} = normalized scattering coefficient for transmission at polarization n and reception at polarization m

R = range to scattering element dA

P_m = normalized antenna pattern

T_m = antenna directivity at polarization m

λ = operating wavelength

Similarly for observations at HH polarization the power at the receiver input is given by

$$P_{HH}(\theta_o) = \frac{\lambda^2}{(4\pi)^3} d^2 P_x [G_{HR} \Gamma_H I_{HH}(\theta_o) \Gamma_H G_{HT}$$

$$+ G_{HVR} \Gamma_V + I_{VH}(\theta_o) \Gamma_H G_{HT} + G_{VHR} \Gamma_V I_{VV}(\theta_o) \Gamma_V G_{VHT}$$

$$+ G_{HR} \Gamma_H I_{HV}(\theta_o) \Gamma_V G_{VHT}] \quad (5)$$

The latter three terms in expressions (3) and (5) may be neglected since products such as $G_{HVR} I_{VH}$; $G_{VHR} G_{VHT}$, $I_{HV} G_{VHT}$, etc., are extremely small. Therefore (3) and (5) simplify to:

$$P_{VV}(\theta_o) = \frac{\lambda^2 d^2 G_x}{(4\pi)^3} G_{VR} \Gamma_V I_{VV}(\theta_o) \Gamma_V G_{VT} \tag{6}$$

and

$$P_{HH}(\theta_o) = \frac{\lambda^2 d^2 G_x}{(4\pi)^3} G_{HR} \Gamma_H I_{HH}(\theta_o) \Gamma_H G_{HT} \tag{7}$$

The corresponding on-scale output voltage for these measurements occur on say, channels j and k, respectively. The outputs are given by

$$V_{jm} = P_{VV}(\theta_o) \; G_R \alpha_j \; G_j \; I_j \; \tau_m \tag{8}$$

and

$$V_{km} = P_{HH}(\theta_o) \; G_R \; \alpha_k \; G_k \; I_k \; \tau_m \tag{9}$$

where τ_m = measurement integration time

$m = 1, 2, \ldots, 7$

A subscript is employed on τ to identify the different integration periods associated with six angle indicators (1 through 6) for the ALTERNATING and FIXED ANGLE MODES and the integration period τ_7 unique to the SHORT SCAT mode.

Now equations (8) and (9) may be employed to express the receiver input power. Thus we may write

$$\frac{V_{jm}}{G_R \alpha_j G_j I_j \tau_m} = \frac{\lambda^2 d^2 P_x}{(4\pi)^3} G_{VR} G_{HT} \Gamma_V^2 I_{VV}(\theta_o) \tag{10}$$

$$\frac{V_{km}}{G_R \alpha_j G_j I_j \tau_m} = \frac{\lambda^2 d^2 P_x}{(4\pi)^3} G_{HR} G_{HT} \Gamma_H^2 I_{HH}(\theta_o) \tag{11}$$

Now P_x may be replaced by expression (2) for the corresponding output channel to yield the desired results

$$I_{VV}(\theta_o) = \frac{V_{jm}}{V_i^{(c)}} \frac{\tau_c}{\tau_m} \frac{G_c A_j}{G_{VR} G_{VT} \Gamma_V^2} \frac{(4\pi)^3}{\lambda^2} \tag{12}$$

and

$$I_{HH}(\theta_o) = \frac{V_{km}}{V_k^{(c)}} \frac{\tau_c}{\tau_m} \frac{G_c A_k}{G_{HR} G_{HT} \Gamma_H^2} \frac{(4\pi)^3}{\lambda^2} \tag{13}$$

It is noted that the receiver gain terms have dropped out.

Subroutine SCONV implements the algebraic expressions for I_{VV} and I_{HH}. Actually the SCAT channel selection routine in CRUNCH applies the factors A_m and $V_m^{(c)}$ (m = j or k) since they are channel dependent. Missing from these algebraic expressions is the doppler filter gain factor which is a function of the doppler frequency shift. The gain is normalized with respect to the gain at zero doppler since the calibrations are made there. An equally spaced sample version of this filter characteristic must appear in the lower part of SPAR. The filter gain at zero doppler must appear at SPAR(50). Down doppler filter gains must be stored in entries between SPAR(51) and SPAR(85) whereas entries for the up-doppler gain must appear between SPAR(34) and SPAR(50). Presently the gain function is sampled at 250 Hz intervals. To compensate the measurement the relative doppler gain must divide the measurement, DATA(8).

The FORTRAN coding for SCONV is shown in Figure A-18. The variables are defined in Table A-8.

Table A-8 Definition of Variables

DATA(8)	=	Selected Channel Output, V_{jm}
INT	=	Integration Period Index
IDATA(3)	=	RADSCAT Mode
SPAR(3)	=	Calibration Period
SPAR(INT+3)	=	Measurement Period
SPAR(IBAND+50)	=	Relative Doppler Filter Gain
SPAR(17)	=	Calibration Attenuation, G_c

```
              SUBROUTINE SCONV (DATA,IDATA,SPAR,IBAND)
        CSCONV                        SCAT CONVERSION
        C                SUBROUTINE SCONV (DATA,IDATA,SPAR,IBAND)
        C
        C                THIS PROGRAM WAS PREPARED BY
        C
        C                    JOHN P. CLAASSEN
        C                    GLEN E. ELLIOTT
        C
        C             UNIVERSITY OF KANSAS CENTER FOR RESEARCH
        C
        C
        C           THIS SUBROUTINE CONVERTS A SCATTEROMETER NORMALIZED OUTPUT
        C           VOLTAGE TO THE SCATTERING INTEGRAL.  THE RESULT IS LEFT
        C           IN DATA(8).
        C
C00007        DIMENSION DATA(1), IDATA(1), SPAR(1)
C00007        DATA PI/3.1415927/
        C
        C
        C
        C           APPLY CONVERSION PARAMETERS
        C
C00007        DATA(8)= DATA(8)*(4.*PI)**3/(299793000./SPAR(1))**2
        C
        C           SET INTEGRATION TIME INDEX
        C
C00014        INT = IDATA (5)
C00015        IF (IDATA (3) .EQ. 1) INT =7
        C
        C           COMPENSATE FOR INTEGRATION TIMES
        C
C00020        DATA(8)= DATA(8)*SPAR(3)/SPAR(INT+3)
        C
        C           SET POLARIZATION INDICES
        C
C00024        IXMIT =IDATA (6)
C00025        IREC = IDATA (7)
        C
        C           COMPENSATE FOR DOPPLER FILTER CHARACTERISTIC
        C
C00027        DATA(8)= DATA(8)/SPAR(IBAND+50)

        C
        C                 APPLY GAIN FACTORS
        C
C00031        DATA(8)=DATA(8)*SPAR(17)/(SPAR(IXMIT+11)*SPAR(IXMIT+25)*
             *          SPAR(IREC+15)*SPAR(IREC+25))
C00041        RETURN
C00042        END
```

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FIGURE A-18. SOURCE LISTING FOR SUBROUTINE SCONV

Table A-8 Definition of Variables (Continued)

IXMIT	=	Transmit Polarization Index
IREC	=	Receive Polarization Index
SPAR(IXMIT+11)	=	Transmit Transfer Function
SPAR(IREC+15)	=	Receive Transfer Function
SPAR(IXMIT+25)	=	Transmit Antenna Gain
SPAR(IREC+25)	=	Receive Antenna Gain

V. SPECIAL ROUTINES

A. Tape Read Routines

FUNCTION subroutine IREAD and subroutine READ1 are employed to read the Input Raw Data records. IREAD permits CRUNCH to read records from either file code 01 or 08. IREAD calls READ1 to unblock records from file code 01. The records on the scratch unit (08) are not blocked and so can be read from IREAD. A second entry point in READ1 permits subroutine CALIB to backspace one physical record (DATA). Read functions on unit 1 may be performed by simply calling READ1. The source listings for IREAD and READ1 are shown in Figures A-19 and A-20, respectively.

B. Tape Write Routine

Subroutine WRITE2 performs WRITE functions on file code 02. Output records (IARRAY) are accumulated in IBLOCK until it is full at which time IBLOCK is written to file code 02. A second entry point in WRITE2 performs the END OF FILE function. However, the remainder of IBLOCK is first filled with zeros before putting an EOF mark on file code 02. See the listing for WRITE2 in Figure A-21 for further insight.

C. Subroutine ABORT

To purposely stop the execution of the program and abort the job, an abort function was provided. The circumstances underwhich an abort is executed are described in Section III B. If the system has an abort routine available that dumps more registers and memory than this fatal execution will, it is advisable to replace the one provided. A listing of subroutine ABORT is shown in Figure A-22.

```
                 FUNCTION IREAD(IFC)                                            00000379
         C
         C            THIS PROGRAM WAS PREPARED BY
         C                  GLEN E. ELLIOTT
         C            UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.
         C
         C            THIS ROUTINE PERMITS SUBROUTINE CRUNCH TO READ FROM FILE
         C            CODE 1 OR 8.  RECORDS ON FILE UNIT 1 ARE BLOCKED IN
         C            GROUPS OF 10 PHYSICAL RECORDS.  EACH RECORD CONSISTING
         C            OF 50 WORDS.  SUBROUTINE READ1 UNBLOCKS THE RECORDS.
         C.           ON THE OTHERHAND THOSE RECORDS ON FILE UNIT 8 ARE NOT
         C            BLOCKED AND AS A CONSEQUENCE A SIMPLE BINARY READ
         C            IS EMPLOYED.
         C
C00003           LOGICAL EOF1                                                   00000380
C00003           COMMON /INPUT/ EOF1,DATA(50)                                   00000381
C00003           IREAD=0                                                        00000382
C00003           IF(IFC.EQ.8) GO TO 1                                           00000383
C00006           CALL READ1                                                     00000384
C00007           IF(EOF1) IREAD=1                                               00000385
C00013           RETURN                                                         00000386
C00015     1     READ(8) DATA                                                   00000387
C00022           IF(EOF,8) 2,3                                                  00000388
C00026     2     IREAD=1                                                        00000389
C00027     3     RETURN                                                         00000390
C00031           END                                                            00000391
```

ORIGINAL PAGE IS OF POOR QUALITY

FIGURE A-19. LISTING FOR IREAD

```
                 SUBROUTINE READ1
           C
           C               THIS PROGRAM WAS PREPARED BY
           C                     GLEN E. ELLIOTT
           C               UNIVERSITY OF KANSAS CENTER FOR RESEARCH,INC.
           C
           C               THIS SUBROUTINE READS BLOCKS OF 10 PHYSICAL RECORDS AND
           C               SEPARATES THEM. RECORDS FILLED WITH 99999. ARE BY-PASSED
           C               UNTIL AN EOF IS ENCOUNTERED.  A SECONDARY ENTRY POINT
           C               IS PROVIDED TO PERMIT BACKSPACING INDIVIDUAL RECORDS
           C               WITHIN A BLOCK.
           C
000002           COMMON/INPUT/IEOF,DATA(50)
000002           LOGICAL IEOF
000002           DIMENSION BLOCK(50,10)
000002           DATA NDX,NUT/0,1/
000002           IEOF=.FALSE.
000003           IF(NDX.NE.0) GO TO 10
000004           NDX=1
000005           READ(NUT) BLOCK
000012           IF(EOF,NUT) 100,10
000015     10    IF(BLOCK(1,NDX) .EQ. 99999.) GO TO 90
000022           DO 20 I = 1,50
000023     20    DATA(I) = BLOCK(I,NDX)
000033           NDX=NDX+1
000034           IF(NDX.GT.10) NDX=0
000037           RETURN
000040     90    READ(NUT)
000043           IF(EOF,NUT) 100, 90
000046    100    IEOF=.TRUE.
000047           NDX=0
000050           RETURN
000051           ENTRY BCKSP1
000056           IF(NDX.LT.1) NDX=11
000062           NDX=NDX-1
000063           RETURN
000064           END
```


FIGURE A-20. LISTING FOR READ1

```
                SUBROUTINE WRITE2 (IARRAY)                                        C0000418
          C
          C             THIS PROGRAM WAS PREPARED BY
          C                  GLEN E. ELLIOTT
          C             UNIVERSITY OF KANSAS CENTER FOR RESEARCH,INC.
          C
          C             THIS ROUTINE BLOCKS 20 WORD RECORDS INTO 20 RECORD
          C             GROUPS (BLOCKS) AND WRITES THE BLOCK OUT TO FILE UNIT
          C             02.  WHEN INSUFFICIENT RECORDS EXIST TO FILL A BLOCK
          C             THE REMAINING PORTION IS FILLED WITH ZEROES AS PROVIDED
          C             AT THE SECONDARY ENTRY POINT.  AN EOF IS APPENDED
          C             TO THE FILE THEREAFTER.
          C
C00003          DIMENSION IBLOCK(20,20), IARRAY(1)                                00000419
C00003          DATA INDEX /1/                                                    C0000420
C00003          DO 20 I = 1,20                                                    C0000421
C00005     20   IBLOCK(I,INDEX) = IARRAY(I)                                       00000422
000015          INDEX = INDEX + 1                                                 00000423
C00016          IF (INDEX .LE. 20)  RETURN                                        00000424
C00021          WRITE (2) IBLOCK                                                  00000425
C00026          INDEX = 1                                                         C0000426
000027          RETURN                                                            C0000427
C00030          ENTRY ENDF2                                                       C0000428
C00036          IF (INDEX .LE. 1)   GO TO 30                                      C0000429
C00042          DO 25 I = INDEX,20                                                C0000430
C00043          DO 25 J= 1,20                                                     C0000431
C00044     25   IBLOCK(J,I) = 0                                                   00000432
C00054          WRITE (2)  IBLOCK                                                 00000433
C00061          INDEX=1                                                           00000434
C00062    30    ENDFILE 2                                                         00000435
000064          RETURN                                                            C0000436
C00065          END                                                               C0000437
```


FIGURE A-21. LISTING FOR WRITE2

```
                SUBROUTINE ABORT(A)
          C     HALT PROGRAM IN CASE OF ERROR
000003          DIMENSION IEOR(2)
000003          DATA IEOR/10HEND OF REE,1HL/
000003          WRITE (6,100) A
000011      100 FORMAT (10X,10HABORT CODE,1X,A10)
000011          CALL ENDF2
000012          WRITE(2) IEOR,(I,I=3,9)
000024          B=A/0.0+1.0
000030          STOP
000032          END
```


FIGURE A-22. LIST FOR SUBROUTINE ABORT

APPENDIX B

OUTPUT PROGRAM

I. INTRODUCTION

The output program (OUTPUT) lists groups of output files produced by the conversion program. External directives permit the user to select file types to be listed. This appendix describes the operation of OUTPUT. In the description below it will be helpful to refer to the logic diagram of Figure B-1 and the listing of Figure B-2.

II. DESIGN AND OPERATION

Upon entry into OUTPUT a control card is read. The format and content of the control card is treated in Section III C. The card content is printed and its validity is checked. An invalid command terminates the program. The tape on unit 2 is also rewound. The file label is read and compared with the validated directive. If the file label does not agree with the label, the file is bypassed and a bypass message is printed. The search continues until the appropriate file is found; if in the search the end of reel is encountered, a message to that effect is printed and another control card is read (statement 1).

Specified file types are listed 80 records at a time. Each record is identified with a record number. The listing continues until the file is exhausted (EOF) at which time another file of the same type is sought.

The variables employed in OUTPUT are defined in Table B-1.

Table B-1 Definition of Variables

MISSD	=	Directed Mission Number
FLTD	=	Directed Flight Number
LIND	=	Directed Line Number
RUND	=	Directed Run Number

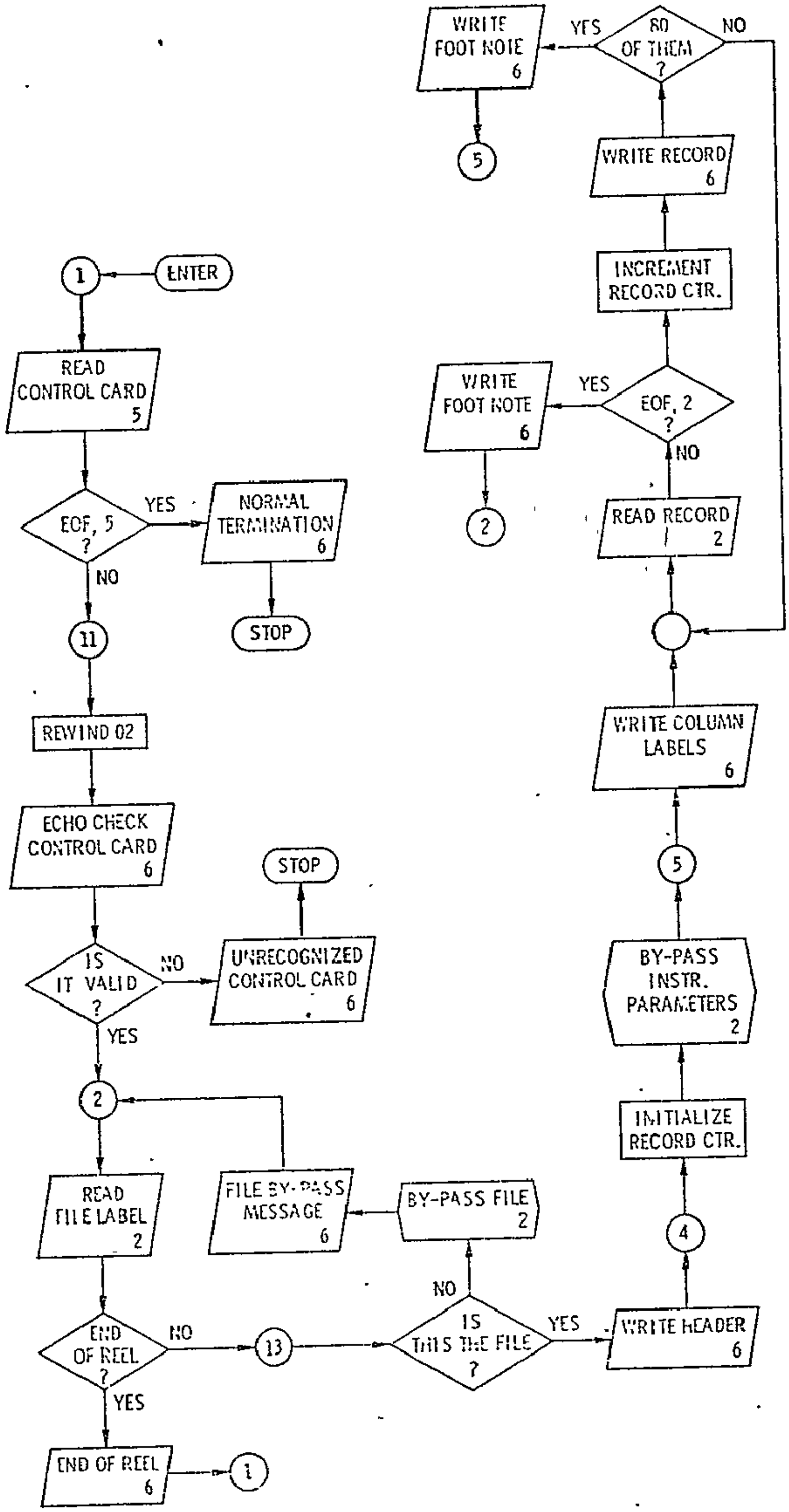

FIGURE B-1. DESCRIPTIVE LOGIC DIAGRAM FOR OUTPUT PROGRAM

```
                 PROGRAM OUTPUT(INPUT,OUTPUT,TAPE2,TAPE5=INPUT,TAPE6=OUTPUT)
          COUTPUT                          OUTPUT PROGRAM
          C
          C            THIS PROGRAM WAS PREPARED BY
          C
          C                 JOHN P. CLAASSEN
          C                 GLEN E. ELLIOTT
          C
          C            UNIVERSITY OF KANSAS CENTER FOR RESEARCH
          C
000003           INTEGER FLTD, RUND, FLT, RUN
000003           DIMENSION DATA(20),DATE(3)
000003           DIMENSION LSTYP(4), IMODE(4), IPL(2)
000003           DIMENSION IEOR(2)
000003           LOGICAL EOF2
000003           EQUIVALENCE (MODE,DATA(2)),
               *   (IP1,DATA(5)),(IP2,DATA(6))
000003           DATA IEOR/10HEND OF REE,1HL/
000003           DATA IMODE/4HR.C.,4HS.S.,4HF.A.,4HA.A./, IPL/1HH,1HV/
000003           DATA LSTYP/6HFLTLIN,6HMISFLT,6HSPECIF,3HALL/
          C                                    GET DIRECTIVE AND FILE ID.
000003     1     READ(5,100) LTYPE, MISSD,FLTD,LIND,RUND
000021   100     FORMAT(A6,4X,4I5)
000021           IF(EOF,5) 10,11
000024    11     REWIND 2
000026           WRITE(6,200) LTYPE, MISSD, FLTD, LIND, RUND
000044   200     FORMAT(1H1,///10X13HCONTROL CARD=,3X,A6,4X,4I5//)
000044           DO 20 I = 1,4
000046    20     IF(LTYPE.EQ.LSTYP(I)) GO TO 2
000052           WRITE(6,700)
000055   700     FORMAT(1H1,///10X22HUNRECOGNIZED DIRECTIVE)
000055           STOP
          C                                    FIND THE FILE.
000057     2     CONTINUE
000057           WRITE(6,300)
000063   300     FORMAT(1H1)
000063           READ(2) MISS, FLT, DATE, LIN, RUN, FREQ, FEED
000104           IF(MISS.NE.IEOR(1)) GO TO 13
000106           IF(FLT.NE.IEOR(2)) GO TO 13
000110           WRITE(6,400)
000114   400     FORMAT(///10X10(1H*),11HEND OF REEL,10(1H*)///)
000114           GO TO 1

000115    13     CONTINUE
000115           IF(LTYPE.EQ.LSTYP(4)) GO TO 4
000117           IF(MISS.NE.MISSD) GO TO 3
000121           IF(FLT.NE.FLTD) GO TO 3
000123           IF(LTYPE.EQ.LSTYP(2)) GO TO 4
000125           IF(LIN.NE.LIND) GO TO 3
000127           IF(LTYPE.NE.LSTYP(3)) GO TO 4
000131           IF(RUN.EQ.RUND) GO TO 4
000133           WRITE(6,500) MISS, FLT, LIN, RUN
000146   500     FORMAT(//10X13HBYPASSED FILE,4I5)
000146     3     READ(2)
000151           IF(EOF,2) 2,3
          C                                    FOUND IT, OUTPUT HEADINGS.
000154     4     CONTINUE
000154     9     WRITE(6,604)
000160   604     FORMAT(1H1,53X,14HMICROWAVE DATA)
000160           LINEN=0
          C                                    BYPASS IC RECORD.
000161           READ(2) ICSET, ID1, ID2, ID3
000174     5     WRITE(6,600) MISS, FLT, DATE, LIN, RUN, FREQ, FEED,
               *   ICSET, ID1, ID2, ID3
000226   600     FORMAT(/9H MISSION-,I3,5H  FLIGHT-,I3,
               *        7H  DATE-,2I3,I5,2X,11H  FLT LINE-,1X,I6,6H  RUN-,I3,
               *        13H   FREQUENCY-,F5.1,7H  FEED-,2X,A6,8H   IPAR=,I2,3I3/)
000226           WRITE(6,605)
000232   605     FORMAT(/
               * 62H RECORD  TIME      MODE  INCID  CROSS    XMIT  REC    S INT
               * 53HSCAT        SCAT        RAD    DEPOL    S/R     ALTITUDE,
               * 11H    FLT     /,
               * 62H NO.                        ANGLE  ANGLE     POL    POL    TIME
               * 52H         DB               FACTOR   CODE                ,
               * 11H    DIRECT  /,
               * 62H                            (DEG)   (DEG)                (SEC)
               * 53H                        (DEG K)                  (FEET),
               * 12H   (DEG)     //)
          C                                    OUTPUT ONE DOUBLE COMPUTER PAGE.
000232           DO 6 I=1,60
000234           CALL READ2(DATA,EOF2)
000236           IF(EOF2) GO TO 7
000240    12     LINEN=LINEN+1
000242           MODE=IMODE(MODE+1)
000243           IP1=IPL(IP1+1)
000245           IP2=IPL(IP2+1)
```


FIGURE B-2. SOURCE LISTING FOR PROGRAM OUTPUT

```
C00246     6     WRITE(6,601) LINEN,(DATA(I), I = 1,14)
C00264   601     FORMAT
         C                                   MATCH HEADING WITH FORMATS.
         *       * LINE      TIME       MODE    INCID   CROSS     XMIT   REC      S INT      *,
         *       * NO.                          ANGLE   ANGLE     POL    POL      TIME       *,
         *       *                              (DEG)   (DEG)                     (SEC)      *,
              * (1X,I4, 2X,F8.1,3X, A6, F5.1,2X, F5.1,6X, A5, A1,4X, F5.3,2X,
         C
         *       *SCAT        SCAT        RAD   DEPOL   S/R      ALTITUDE*,
         *       *            DB                FACTOR  CODE              *,
         *       *                      (DEG K)                    (FEET)*,
              * E11.4, 2X,F6.1,2X, F7.1, F8.3,    I9,    F10.0,
         C
         *       *   FLT      */,
         *       *   DIREC    */,
         *       *   (DEG)     *)
              * F9.1)
         C
         C                                   FOOT PAGE WITH CODE KEY.
C00264           WRITE(6,602)
C00270   602     FORMAT(//14H KEY TO CODES-/,
              *              25X,32H    0 NO FLAG                         *,5X,
              *              21H  1000 POLAR REVERSAL/,
              *              25X,*    1 POSSIBLY OUTSIDE RANGE GATE*,5X,
              *              22H 10000 EXCESSIVE DEPOL/,
              *              25X,32H  10 OUTSIDE DYNAMIC RANGE         ,5X,
              *              24H100000 REC TEMP ABNORMAL/,
              *              25X,* 100 EXCESSIVE DOPPLER              *,4X,
              *               *1000000 WARM LOAD TEMP ESTIMATED*/,
              *              25X,37H      COMBINATIONS OF FLAGS CAN OCCUR./,1H1)
C00270           GO TO 5
         C                                   FOOT PARTIAL PAGE
C00271     7     WRITE(6,602)
C00275           IF(LTYPE.EQ.LSTYP(3)) GO TO 1
C00277           GO TO 2
C00300    10     STOP
C00302           END
```


igure B-2. (Continued)

Table B-1 Definition of Variables (Continued)

MISS	=	File Mission Number
FLT	=	File Flight Number
LIN	=	File Line Number
RUN	=	File Run Number
LTYPE	=	Control Directive
LSTYPE	=	Program Recognized Directives
IEOR	=	10H End of Reel
DATA	=	Output Data
EOF2	=	EOF Indicator on File Code 02

III. SUBROUTINE READ2

READ2 performs the record retrieval function for OUTPUT. Output files are blocked in 20 record groups. READ2 retrieves these blocks and withdraws records as required by OUTPUT. The end of the file indicator EOF2 is generated by READ2. A listing for this routine appears in Figure B-3.

```
              SUBROUTINE READ2(IDATA,EOF2)
         C
         C              THIS PROGRAM WAS PREPARED BY
         C                      GLEN E. ELLIOTT
         C              UNIVERSITY OF KANSAS CENTER FOR RESEARCH,INC.
         C
         C              THIS ROUTINE UNBLOCKS 20 RECORD BLOCKS AND PROVIDES
         C              AN END OF FILE INDICATOR, EOF2.
         C
000005        DIMENSION IDATA(20), IBLOCK(20,20)
000005        LOGICAL EOF2
000005        DATA NDEX/0/
000005        EOF2=.FALSE.
000005        IF(NDEX.NE.0) GO TO 10
000006        NDEX=1
000007        READ(2) IBLOCK
000014        IF(EOF,2) 100,10
000020   10   IF(IBLOCK(1,NDEX).EQ.0) GO TO 90
000023        DO 20 I=1,20
000025   20   IDATA(I)=IBLOCK(I,NDEX)
000035        NDEX=NDEX+1
000036        IF(NDEX.GT.20) NDEX=0
000041        RETURN
000042   90   READ(2)
000045        IF(EOF,2) 100,90
000051  100   EOF2=.TRUE.
000052        NDEX=0
000053        RETURN
000054        END
```


FIGURE B-3. SOURCE LISTING FOR SUBROUTINE READ2

APPENDIX C

INSTRUMENT CHARACTERISTICS MAINTENANCE PROGRAM (ICHAR)

I. INTRODUCTION

Program ICHAR maintains a historical file of RADSCAT instrument characteristics. New sets of instrument parameters may be submitted to ICHAR for storage; old sets may be printed or punched. The design and operation of ICHAR is treated in this appendix. The reader will find it helpful to refer to the logic diagram (Figure C-1) and listing (Figure C-2) for ICHAR.

II. DESIGN AND OPERATION

The files on the historical parameter tape are identified numerically. So upon entry into the program the file pointer is initialized to zero. An instruction is read and echo checked. The instruction is then identified as one of three types. If the instruction is INITIALIZE, the file appendage counter (NNC) is set equal to one and four subsets of instrument parameters are read and transferred to file code 02. The format and entry for the parameters were described in Section III D of the text. The program is then halted.

If the historical tape had been initialized already and the command was APPEND, the old historical tape would have been rewound (Statement 5) and the contents of that tape transferred to another one (Statements between 5 and 18). Once transferred, the new set would be appended to the new file (Statements 26 through 23). When insufficient parameters are presented to fill the new file, the program is aborted. Otherwise the next control card is read; if it is APPEND, the process is repeated until all APPEND commands have been executed.

If the (next) command had been PRINT or PUNCH, the program would have advanced to statement 6 and executed the instruction. The program continues until all control cards have been exhausted.

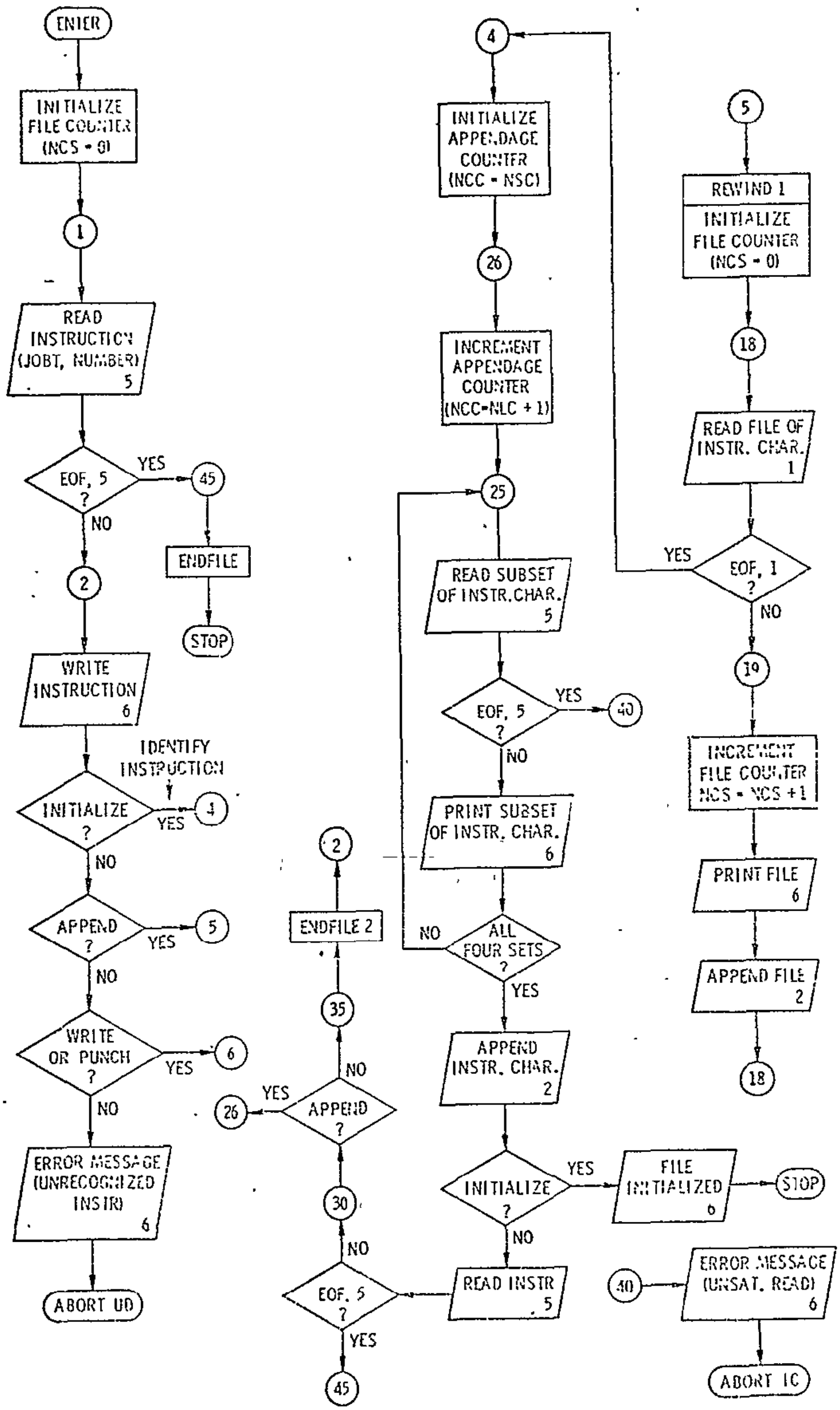

FIGURE C-1. DESCRIPTIVE FLOW CHART FOR PROGRAM ICHAR

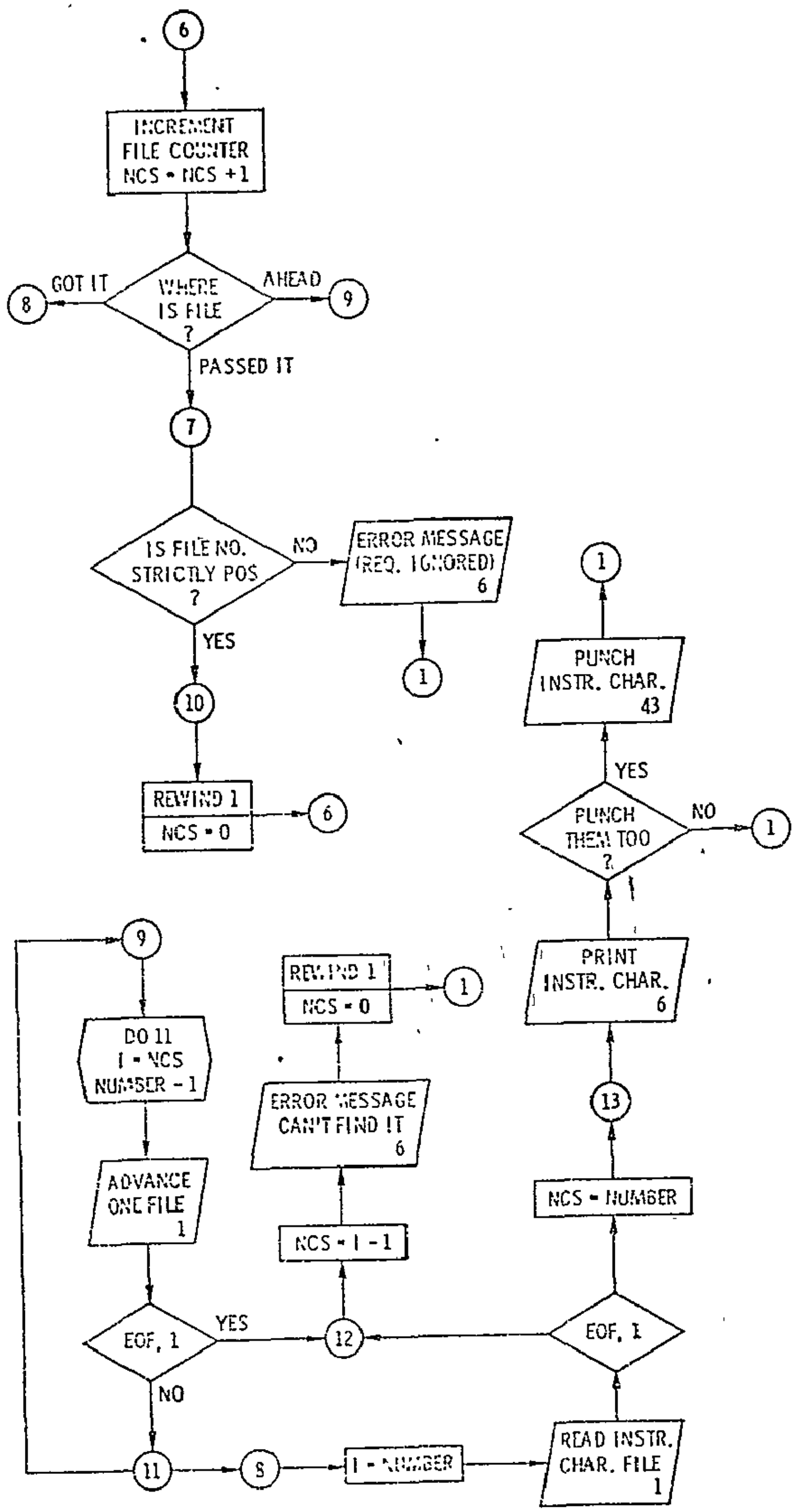

FIGURE C-1. (continued)

```
              PROGRAM ICHAR(INPUT,OUTPUT,PUNCH,TAPE1,TAPE2,
             * TAPE5=INPUT,TAPE6=OUTPUT,TAPE4 )=PUNCH)
        CICHAR        MAINTAIN ICHAR FILE.
        C
        C             THIS PROGRAM WAS PREPARED BY
        C
        C                  JOHN P. CLAASSEN
        C                  GLEN E. ELLIOTT
        C
        C             UNIVERSITY OF KANSAS CENTER FOR RESEARCH,INC.
        C
        C             THIS PROGRAM WILL STORE RADSCAT INSTRUMENT
        C             CHARACTERISTICS ON A HISTORICAL TAPE. THE HISTORICAL
        C             TAPE IS INITIALLY PREPARED BY USING THE DIRECTIVE
        C             *INITIALIZE* .  TO APPEND NEW SETS OF CHARACTERISTICS THE
        C             COMMAND *APPEND* WILL TRANSFER OLD SETS FROM TAPE UNIT
        C             1 TO TAPE UNIT 2 AND APPEND THE NEW SET .  NEW SETS ARE
        C             READ FROM CARDS.  PREVIOUSLY STORED SETS MAY
        C             BE PRINTED OR PUNCHED BY USING THE COMMANDS PRINT OR
        C             PUNCH RESPECTIVELY.  THE SET NO. MUST BE DESIGNATED .
        C             THE SETS WILL HAVE BEEN STORED NUMERICALLY IN ORDER ON
        C             THE TAPE.     TO MAINTAIN THE INSTRUMENT CHARACTERISTICS
        C             IT IS ADVISABLE TO RETAIN THE OLD TAPE WHEN A
        C             NEW ONE ONE IS PREPARED.  OLDER VERSIONS MAY BE DISCARDED.
        C             IT IS ADVISABLE ALSO TO USE A TAPE COMPARISON UTILITY
        C             PROGRAM TO VERIFY THE TRANSFER.
        C
        C             NCS = FILE COUNTER FOR THE OLD TAPE ALSO SERVES AS
        C             A FILE POINTER ON UNIT 1
        C             NCC = FILE COUNTER FOR THE APPENDED SETS
        C             JOBT = EXTERNAL DIRECTIVE. SEE DATA STATEMENT
        C             NUMBER = NUMBER OF THE REQUESTED FILE
        C             PAR = INSTRUMENT PARAMETERS
        C             IDAT = DATE
        C             NUM2 = SET NO. AS READ FROM TAPE
        C
000003        DIMENSION PAR(160,4), IDAT(3), IOPT(4)
000003        DATA IOPT/10HINITIALIZE,6HAPPEND,5HPRINT,5HPUNCH/, NCS/0/
        C                                 READ DIRECTIVE AND SET NUMBER.
000003   1    READ(5,500) JOPT, NUMBER
000013        IF (EOF,5) 45,2
000016  500   FORMAT(A10,I5)


000016   2    WRITE(6,600) JOPT,NUMBER
000026  600   FORMAT(1H1,///* DIRECTIVE IS *,A10,I5)
        C                                 CHECK DIRECTIVE
000026        DO 3 N=1,4
000030        IF(JOPT.EQ.IOPT(N)) GO TO(4,5,6,6),N
000041   3    CONTINUE
000043        WRITE(6,601)
000047  601   FORMAT(//* UNRECOGNIZED DIRECTIVE*//)
000047        CALL ABORT(2HUD)
        C                 FIND FILE
000051     6  NCS = NCS+1
000053        IF(NUMBER-NCS) 7,8,9
000055   7    IF(NUMBER.GE.1) GO TO 10
000060        WRITE(6,602) NUMBER
000065  602   FORMAT(//* IC SET NUMBER*,I5,* DOES NOT EXIST.*,
             * * REQUEST IGNORED.*//)
000065        GO TO 1
000066  10    REWIND 1
000070        NCS = 0
000071        GO TO 6
000072    12  NCS = I-1
000074        WRITE (6,608)  NCS,NUMBER
000104   608  FORMAT (//* THERE ARE ONLY*I5,* FILES.*
             * * CANT FIND FILE*I5//)
000104        REWIND 1
000106        NCS = 0
000107        GO TO 1
        C                                 FORWARD SPACE TO CORRECT SET.
000110   9    NUM=NUMBER-1
000112        DO 11 I=NCS,NUM
000114        READ(1)
000117        IF(EOF,1) 12,11
000122  11    CONTINUE
        C                                 READ INSTRUMENT CHARACTERISTICS
000125     8  I = NUMBER
000127        READ(1) NUM2,IDAT,PAR
000140        IF(EOF,1) 12,13
000143  13    NCS=NUMBER
        C                                 WRITE INSTRUMENT CHARACTERISTICS.
000145        WRITE (6,610)
000150   610  FORMAT (1H1,///)
000150        DO 15 I=1,4
000152        WRITE(6,603) NUM2  ,IDAT,PAR(1,I),PAR(2,I),PAR(3,I)
```

FIGURE C-2. SOURCE LISTING FOR PROGRAM ICHAR

```
000174    603   FORMAT(//* SET*,I5,*  DATE*,3I5,F15.4,5X,A10,E15.4)
000174          DO 14 J=4,75,7                                                00001551
000176          L=J+6                                                         00001552
000200          IF(L.GT.75) L=75                                              00001553
000203    14    WRITE(6,604)(PAR(K,I),K=J,L)                                  00001554
000222    604   FORMAT(7E15.4)                                                00001555
000222          WRITE(6,603) NU(2  ,IDAT,PAR(76,I),PAR(77,I),PAR(78,I)
000245          DO 15 J=79,160,7                                              00001557
000247          L=J+6                                                         00001558
000251          IF(L.GT.160) L=160                                            00001559
000254    15    WRITE(6,604)(PAR(K,I),K=J,L)                                  00001560
000275          IF(N.EQ.3) GO TO 1                                            00001561
        C                                 PUNCH IC*S.                         00001562
000277          DO 17 I=1,4                                                   00001563
000301          LL=1                                                          00001564
000302          WRITE(43,4303)   NUM2,IDAT        ,PAR(1,I),PAR(2,I),PAR(3,I),
              *        NUMBER, I, LL                                          00001566
000333    4303  FORMAT(4I5,10X,E10.3,A10,E10.3,12X,I2,I1,I5)
000333          DO 16 J=4,75,7                                                00001568
000335          LL=LL+1                                                       00001569
000337          L=J+6                                                         00001570
000341    16    WRITE(43,4304)(PAR(K,I),K=J,L),NUMBER,I,LL                    00001571
000364    4304  FORMAT(7E10.3,2X,I2,I1,I5)
000364          LL=LL+1                                                       00001573
000366          WRITE(43,4303)   NUM2,IDAT        ,PAR(1,I),PAR(2,I),PAR(3,I),  000
              *        NUMBER, I, LL                                          00001575
000416          DO 17 J=79,160,7                                              00001576
000420          LL=LL+1                                                       00001577
000422          L=J+6                                                         00001578
000424    17    WRITE(43,4304)(PAR(K,I),K=J,L),NUMBER,I,LL                    00001579
000451          GO TO 1                                                       00001580
        C                                                                     00001583
        C                                 COPY OLD IC*S                       00001584
        C                                                                     00001581
000452    5     REWIND 1                                                      00001585
000454          NCS = 0
000455          WRITE(6,605)                                                  00001587
000461    605   FORMAT(1H1,* THE FOLLOWING IC SETS WERE COPIED FROM *,        00001588
              * *THE OLD FILE*,/                                              00001589
              * * SET NUMBER     ID NUMBER       DATE*)                       00001590
000461    18    READ(1) NUM2,IDAT,PAR                                         00001591
000472          IF(EOF,1) 4,19                                                00001592
000475     19   NCS = NCS+1


000477          WRITE(6,606) NCS,NUM2,IDAT
000510    606   FORMAT(3X,I5,9X,I5,3X,3I5)                                    00001594
000510          WRITE(2) NUM2,IDAT,PAR                                        00001595
000521          GO TO 18                                                      00001597
        C                                 READ NEW SETS.                      00001598
000522     4    NCC = NCS
000524     26   NCC = NCC+1
000526          WRITE(6,607)
000531    607   FORMAT(1H1/* THE FOLLOWING IC SETS WERE APPENDED TO *
              * *THE OUTPUT FILE.*)                                           00001601
000531    25    DO 23 I=1,4                                                   00001602
000533          READ(5,4303) NUMBER,IDAT,PAR(1,I),PAR(2,I),PAR(3,I)           00001603
000555          IF(EOF,5) 40,20
000560    20    WRITE(6,603) NCC,IDAT,PAR(1,I),PAR(2,I),PAR(3,I)
000603          DO 21 J=4,75,7                                                00001606
000605          L=J+6                                                         00001607
000607          IF(L.GT.75) L=75                                              00001608
000612          READ(5,4304)(PAR(K,I),K=J,L)                                  00001609
000627          IF(EOF,5) 40,21
000632    21    WRITE(6,604)(PAR(K,I),K=J,L)                                  00001611
000651          READ(5,4303) NUMBER,IDAT,PAR(76,I),PAR(77,I),PAR(78,I)        00001612
000674          IF(EOF,5) 40,22
000677    22    WRITE(6,603) NCC,IDAT,PAR(76,I),PAR(77,I),PAR(78,I)
000722          DO 23 J=79,160,7                                              00001615
000724          L=J+6                                                         00001616
000726          IF(L.GT.160) L=160                                            00001617
000731          READ(5,4304)(PAR(K,I),K=J,L)                                  00001618
000746          IF(EOF,5) 40,23
000751    23    WRITE(6,604)(PAR(K,I),K=J,L)                                  00001620
        C                                 APPEND IC*S                         00001582
000772          WRITE(2) NCC,IDAT,PAR
001003          IF(JOPT.NE.IOPT(1)) GO TO 29
001005          WRITE(6,800)
001011    800   FORMAT(//10X*FILE INITIALIZED*//)
001011          STOP
001013    29    READ(5,500)  JOBT, NUMBER
001023          IF (EOF,5)  45,30
001026     30   IF( JOBT .EQ. IOPT(2) )  26,35
001033     35   ENDFILE 2
001035          GO TO 2
001036     40   WRITE (6,609)
001042    609   FORMAT (//* UNSATISFIED READ.*,
              * * INCOMPLETE SET OF CHARACTERISTICS*//)
```

Figure C-2. (continued)

```
001042          CALL ABORT (2HIC)
001044      45  ENDFILE 2
001046          STOP                                            00001622
001050          END                                             00001623
```

```
                SUBROUTINE ABORT(A)
          C
          C     HALT PROGRAM IN CASE OF ERROR
          C
000003          WRITE (6,100) A
000011     100  FORMAT (10X,10HABORT CODE,1X,A10)
000011          ENDFILE 2
000013          B=A/0.0+1.0
000017          STOP
000021          END
```

Figure C-2. (Continued)

III. DEFINITION OF VARIABLES

The variables employed by ICHAR are defined in Table C-1.

Table C-1 Definition of Variables

NSC	=	File Pointer for File Code 01
NCC	=	File Pointer for File Code 02
JOBT	=	Job Instruction
NUMBER	=	File Number to be Printed or Punched
IOPT	=	Array of Recognized Instructions
IDAT	=	Date in Parameters
NUM2	=	Set Number as Read from File Code 01
PAR	=	Set of Instrument Parameters

APPENDIX D

PROGRAM TDUPE

I. INTRODUCTION

Program TDUPE is a translation and duplication program which prepares an integer version of the output tape. It is intended that copies of the integerized tape be sent to the investigators upon request for use on other computing machines. A utility program may be used to prepare additional copies. This appendix describes the design and operation of TDUPE. Helpful to the reader are the flow charts of Figure D-1 and the program listing of Figure D-2.

II. DESIGN AND OPERATION

Action in TDUPE is initiated by an external control card specifying the files, by mission and flight, which are to be copied. A file counter is initialized, file unit 1 is rewound, and the instruction is listed. The labels on the files are examined and compared with the instruction. Files not having the designated mission and flight are bypassed until one is found. At this time a record counter is initialized. Then the instrument parameters are read, scaled, and integerized. The file heading and instrument parameters are transferred to file unit 2. The file heading is also listed on the printer and the file counter is incremented.

Consecutive records are then read, scaled and integerized. In each instance the record counter is incremented. The records are accumulated in blocks by subroutine WRITE2 and transferred to tape unit 2 when the block is filled. The terminating block is filled with integer zeroes when there are insufficient records to fill it. When the file has been exhausted, an EOF is appended to the transferred file and a message is given to indicate the number of records which have been transferred.

The search for additional files continues until the end of the reel is encountered. At this point another instruction is sought. The program terminates

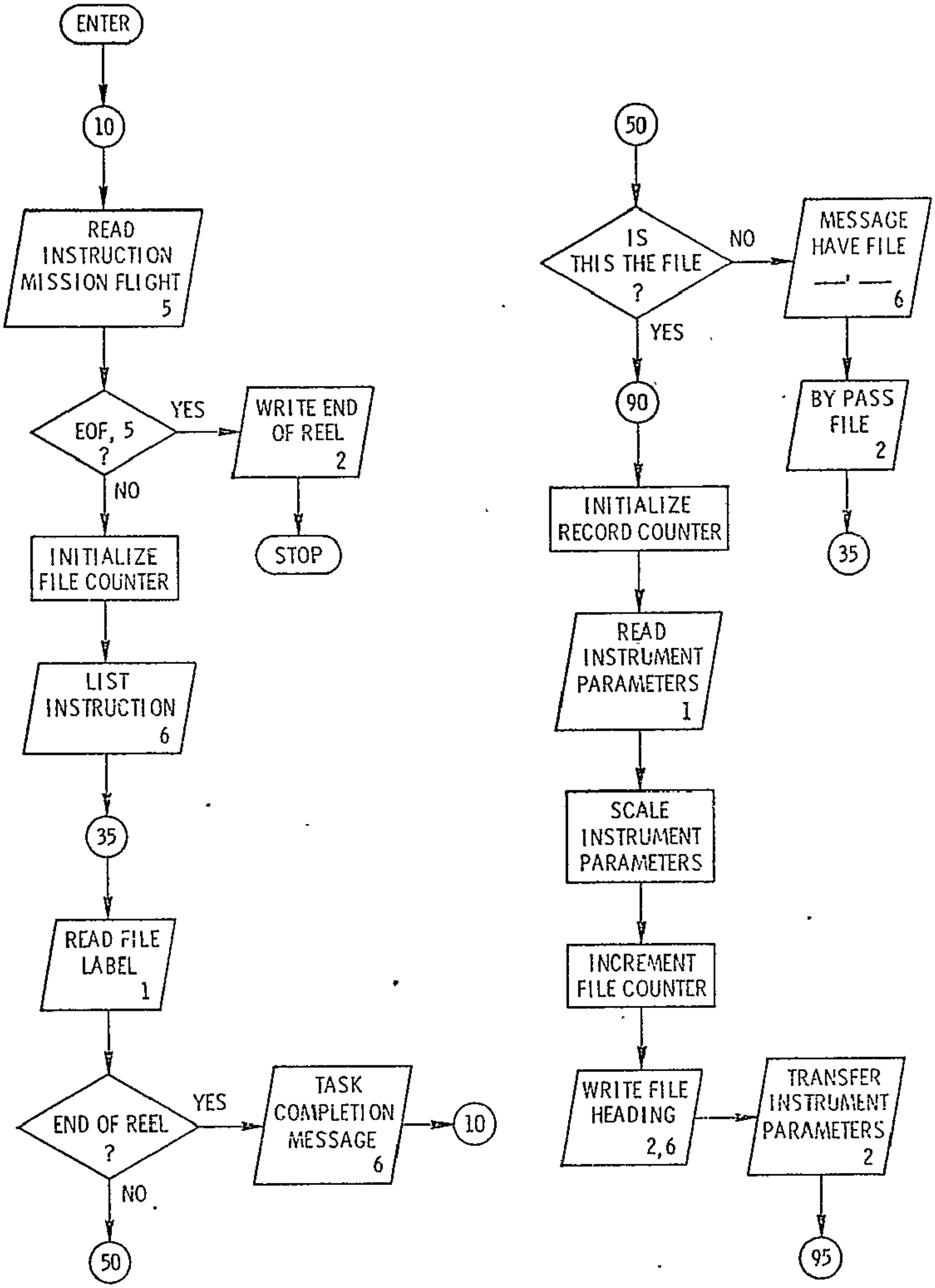

FIGURE D-1. DESCRIPTIVE LOGIC DIAGRAM FOR PROGRAM TDUPE

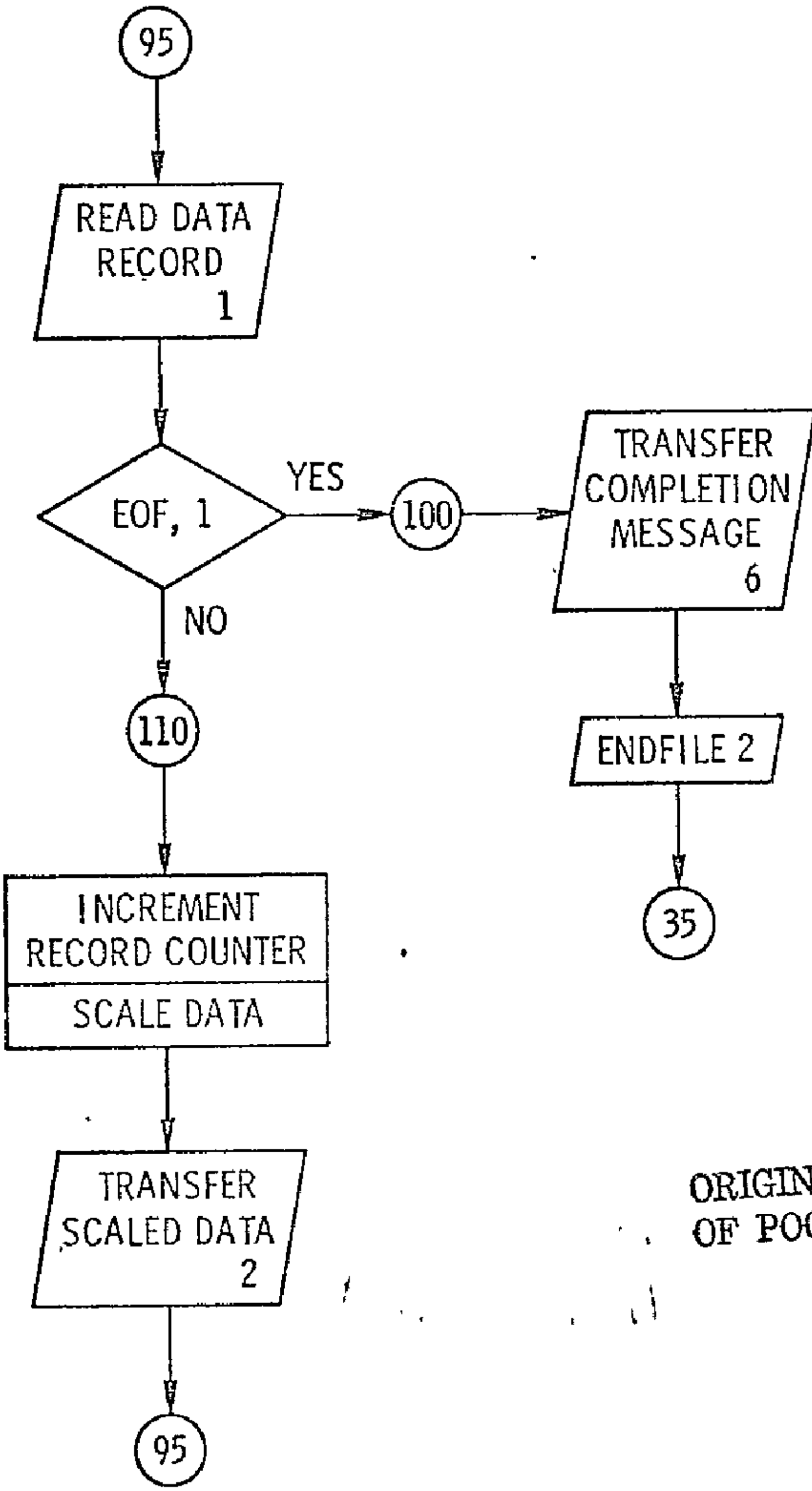

FIGURE D-1. (continued)

```
                PROGRAM TDUPE(INPUT,OUTPUT,TAPE1,TAPE2,TAPE5=INPUT,TAPE6=OUTPUT)
          C
          C           TAPE TRANSLATION AND DUPLICATION ROUTINE
          C
          C           THIS PROGRAM WAS PREPARED BY
          C
          C                JOHN P. CLAASSEN
          C
          C           UNIVERSITY OF KANSAS
          C           CENTER FOR RESEARCH
          C
          C
          C           THIS PROGRAM PREPARES A MASTER DUPLICATE TAPE OF THE
          C           RADSCAT OUTPUT TAPE FOR USE ON OTHER MACHINES.  OTHER
          C           COPIES OF THE MASTER DUPLICATE TAPE MAY BE PREPARED
          C           BY USING AN IN-HOUSE UTILITY PROGRAM.  THE OUTPUT DATA
          C           RECORDS ARE TRANSLATED TO INTEGER FORMAT AFTER
          C           MULTIPLICATION BY AN APPROPRIATE SCALE FACTOR.
          C           MESSAGES ARE LISTED TO INDICATE THE STATE OF THE
          C           TRANSFER.
          C
          C           CONTROL PARAMETERS
          C
          C           MISFLT  = MISSION AND FLT DATA TO BE DUPLICATED
          C
          C           INPUT/OUTPUT PARAMETERS
          C
          C           IHEAD = FILE HEADING
          C           LCHAR = INSTRUMENT PARAMETER LABEL
          C           ICHAR = INSTRUMENT CHARACTERISTICS
          C           DATA = INPUT RECORDS
          C           IDATA = INTEGER EQUIVALENT OF DATA
          C           IARRAY = OUTPUT RECORDS
          C
          C           WORKING PARAMETERS
          C
          C           NOF = NO. OF FILES
          C           IREC = NO. OF RECORDS IN A FILE
          C           IEOR = *END OF REEL*
          C
          C
000003          DIMENSION IHEAD(9), ICHAR(160), DATA(20), IDATA(20),

               * IARRAY(20), IEOR(2), MISFLT(2), LCHAR(4)
000003          DIMENSION RPAR(75), SPAR(85), SFACT(15)
000003          LOGICAL EOF1
000003          EQUIVALENCE (ICHAR(1),RPAR(1)),(ICHAR(76),SPAR(1))
000003          EQUIVALENCE (DATA(1), IDATA(1))
000003          DATA SFACT/1.0E10, 1.0, 1.0E5, 1.0E7, 1.0E9, 3*1.0, 4*10.0,
               * 1.0E3,2*100.0/
000003          DATA IEOR/10HEND OF REE,1HL/
          C
          C           READ THE DIRECTIVE
          C
000003       10 READ (5,1000)        MISFLT
000011     1000 FORMAT (2I10)
000011          IF (EOF,5) 20,30
          C
          C           WRITE *END OF REEL*
          C
000014       20 WRITE (2) IEOR, (I,I=3,9)
000026          STOP
          C
          C           INITIALIZE FILE COUNT
          C
000030       30 NOF = 0
000031          REWIND 1
000033          WRITE (6,2000) MISFLT
000041     2000 FORMAT (1H1,11X, *WILL PREPARE COPY OF DATA FROM MISSION*I5,* AND
               * FLT*I3///)
000041       35 READ (1) IHEAD
          C
          C           CHECK FOR END OF REEL
          C
000046          DO 40 I = 1,2
000050       40 IF(IHEAD(I) .NE. IEOR(I)) GO TO 50
000054          WRITE (6,3000) NOF
000061     3000 FORMAT (//11X,I5* FILES HAVE BEEN TRANSFERRED *///)
000061          GO TO 10
          C
          C           CHECK FOR FILE NAME
          C
000062       50 DO 60 I=1,2
000064       60 IF (IHEAD(I) .NE. MISFLT(I)) GO TO 70
000070          GO TO 90
000070       70 WRITE(6,4000) (IHEAD(I),I=1,2), MISFLT
```

FIGURE D-2. SOURCE LISTING FOR TDUPE

```
000104     4000  FORMAT (11X, *FILE HEADING * 2I5 * DOES NOT AGREE WITH DIRECTIVE
                * *2I5)
          C
          C                BY-PASS UNWANTED FILE
          C
000104       80  READ (1)
000107           IF (EOF,1) 35,80
          C
          C                INITIALIZE RECORD COUNT
          C
000112       90  IPEC = 0
000113           READ (1) LCHAR, ICHAR
          C
          C                SCALE AND TRANSFER INSTR. PARAMETERS
          C
000122           ICHAR(1)=RPAR(1)*1.0E-6
000125           DO 91 I=3,20
000127      91   ICHAR(I)=RPAR(I)*1.0E4
000134           ICHAR(21)=RPAR(21)*10.0
000137           ICHAR(22)=RPAR(22)*10.0
000142           DO 92 I=23,75
000143      92   ICHAR(I)=RPAR(I)*1.0E4
000150           ICHAR(76)=SPAR(1)*1.0E-6
000153           DO 93 I=3,16
000155      93   ICHAR(I+75)=SPAR(I)*1.0E4
000162           DO 96 I=17,31
000164      96   ICHAR(I+75)=SPAR(I)*SFACT(I-16)
000171           DO 97 I=32,85
000173      97   ICHAR(I+75)=SPAR(I)*1.0E4
000200           WRITE (6,5000) (IHEAD(I),I=1,7)
000212     5000  FORMAT (/11X,*HAVE MISSION*I5,*  FLT*I4,* DATE*3I5*  FLT LINE*A6,
                * *  RUN*I3)
          C
          C                UPDATE FILE COUNTER.
          C
000212           NOF = NOF + 1
000214           WRITE(2) IHEAD
000221           WRITE(2) LCHAR, ICHAR
000230      95   CALL READ1(DATA,EOF1)
000232           IF(.NOT.EOF1) GO TO 110
000234     100   WRITE (6,6000) IREC,NOF
000244     6000  FORMAT (//11X,I4* RECORDS HAVE BEEN TRANSFERRED FROM FILE* I3///)
000244           CALL ENDF2


000245           GO TO 35
          C
          C                UPDATE RECORD COUNTER.
          C
000246     110   IREC = IREC + 1
          C
          C                SCALE AND TRANSFER RADSCAT MEASUREMENTS.
          C
000250           IARRAY(1)=DATA(1)*100.0
000253           IARRAY(2)=IDATA(2)
000254           IARRAY(3)=DATA(3)*100.0
000257           IARRAY(4)=DATA(4)*100.0
000261           IARRAY(5)=IDATA(5)
000263           IARRAY(6)=IDATA(6)
000264           IARRAY(7)=DATA(7)*10000.0
000267           IF (DATA(8) .LT. 1.0E-03) GO TO 120
000272           IARRAY(8) = DATA(8)*1.0 E06
000275           IARRAY(9)=1000000
000276           GO TO 130
000277     120   IARRAY(8)=DATA(8)*1.0E+09
000302           IARRAY(9)= 1000000000
000304     130   IARRAY(10)=DATA(9)*100.0
000307           IARRAY(11)=DATA(10)*100.0
000312           IARRAY(12) = DATA(11)*10000.0
000315           IARRAY(13)=IDATA(12)
000316           IARRAY(14)=DATA(13)*10.0
000321           IARRAY(15)=DATA(14)*100.0
000324           IARRAY(16)=DATA(15)*100.0
000327           CALL WRITE2(IARRAY)
000330           GO TO 95
000331           END
```

Figure D-2. (Continued)

```
                SUBROUTINE READ1(IDATA,EOF1)
000005          DIMENSION IDATA(20), IBLOCK(20,20)
000005          LOGICAL EOF1
000005          DATA NDEX/0/
000005          EOF1=.FALSE.
000005          IF(NDEX.NE.0) GO TO 10
000006          NDEX=1
000007          READ(1) IBLOCK
000014          IF(EOF,1) 100,10
000020    10    IF(IBLOCK(1,NDEX).EQ.0) GO TO 90
000023          DO 20 I=1,20
000025    20    IDATA(I)=IBLOCK(I,NDEX)
000035          NDEX=NDEX+1
000036          IF(NDEX.GT.20) NDEX=0
000041          RETURN
000042    90    READ(1)
000045          IF(EOF,1) 100,90
000051    100   EOF1=.TRUE.
000052          NDEX=0
000053          RETURN
000054          END
```

```
                SUBROUTINE WRITE2 (IARRAY)
000003          DIMENSION IBLOCK(20,20), IARRAY(1)
000003          DATA INDEX /1/
000003          DO 20 I = 1,20
000005     20   IBLOCK(I,INDEX) = IARRAY(I)
000015          INDEX = INDEX + 1
000016          IF (INDEX .LE. 20)  RETURN
000021          WRITE (2) IBLOCK
000026          INDEX = 1
000027          RETURN
000030          ENTRY ENDF 2
000036          IF (INDEX .LE. 1)   GO TO 30
000042          DO 25 I = INDEX,20
000043          DO 25 J= 1,20
000044     25   IBLOCK(J,I) = 0
000054          WRITE (2)  IBLOCK
000061          INDEX=1
000062    30    ENDFILE 2
000064          RETURN
000065          END
```


Figure D-2. (Continued)

when there are no additional instructions. However, before terminating an end of reel statement is written on file unit 2.

The variables are defined in Table D-1.

Table D-1 Definition of Variables

IHEAD	=	File Label
LCHAR	=	Instrument Parameters Label
ICHAR	=	Instrument Parameters
DATA	=	Input Records
IDATA	=	Integer Equivalent
IARRAY	=	Output Records
IEOR	=	11HEND of Reel
SFACT	=	Scale Factors

APPENDIX E

SPECIAL PROGRAMS

I. INTRODUCTION

Two special engineering routines WIDTH and GAIN prepare several antenna parameters essential to the reduction of the scatterometer data. WIDTH computes the equivalent beamwidth of the RADSCAT antenna; whereas GAIN computes the antenna directivity. Other parameters of special interest to antenna engineers are also computed in GAIN. These programs are provided with the realization that the antenna pattern may eventually change through an alteration of the antenna. In this case the equivalent beamwidth and gain should then be recomputed based on new pattern information and the instrument parameters changed accordingly.

Each of the programs are described below. Operating instructions are given in Section IV F of the main text.

II. PROGRAM WIDTH

The theory for this program was described in Appendix A, Section III B. In that development it is apparent that the equivalent beamwidth is given by

$$\theta_{eq} = \sqrt{\frac{4}{\pi} \int_0^{2\pi} \int_0^{\pi} P^2(\theta,\phi) \sin\theta \; d\theta \; d\phi} \tag{1}$$

where $P(\theta \phi)$ is the normalized power pattern function described in the standard spherical coordinate system (r , θ , ϕ). When the pattern is elliptically symmetric, the integration may be limited to one quadrant in which case

$$\theta_{eq} = \sqrt{\frac{16}{\pi} \int_0^{\pi} \int_0^{\pi/2} P^2(\theta,\phi) \; \sin\theta \; d\theta \; d\phi} \tag{2}$$

Here it is assumed that the main beam lies on the x-axis as shown in Figure E-1. It is convenient to work in terms of elevation angle ϵ rather than polar angle in which case

$$\theta_{eq} = \sqrt{\frac{16}{\pi} \int_0^{\pi} \int_0^{\pi/2} P^2(\theta,\phi) \cos\epsilon \; d\epsilon \; d\phi} \tag{3}$$

Since quadrature techniques usually require rectangular domains of integration, it is necessary to apply the transformation

$$\psi = \sin \epsilon \tag{4}$$

so that

$$\theta_{eq} = \sqrt{\frac{16}{\pi} \int_0^{\pi} \int_0^{1} P^2(\psi,\phi) \; d\psi \; d\phi} \tag{5}$$

The full limits of integration are not necessary since the integral converges rapidly over the main beam. Program WIDTH whose listing is shown in Figure E-2 use this property to advantage. As shown in the driver routine, the upper limits of integration are progressively increased by 1/2 degree intervals in ϵ. The convergence of the equivalent beamwidth can then be observed as the domain increases to include more of the beam.

A Gaussian-Legendre quadrature technique is employed to perform the double integration. This technique is embodied in RINTEG. The reader is referred to Klerer and Korn* or any other advanced text on numerically techniques for a discussion of this technique.

The main beam of the RADSCAT antenna pattern is functionally represented in the FUNCTION subroutine FUN. RINTEG calls FUN repeatedly to evalute the pattern function squared.

*Klerer, M. and Korn, G. A., "Digital Computer User's Handbook," McGraw-Hill Book Company, 1970.

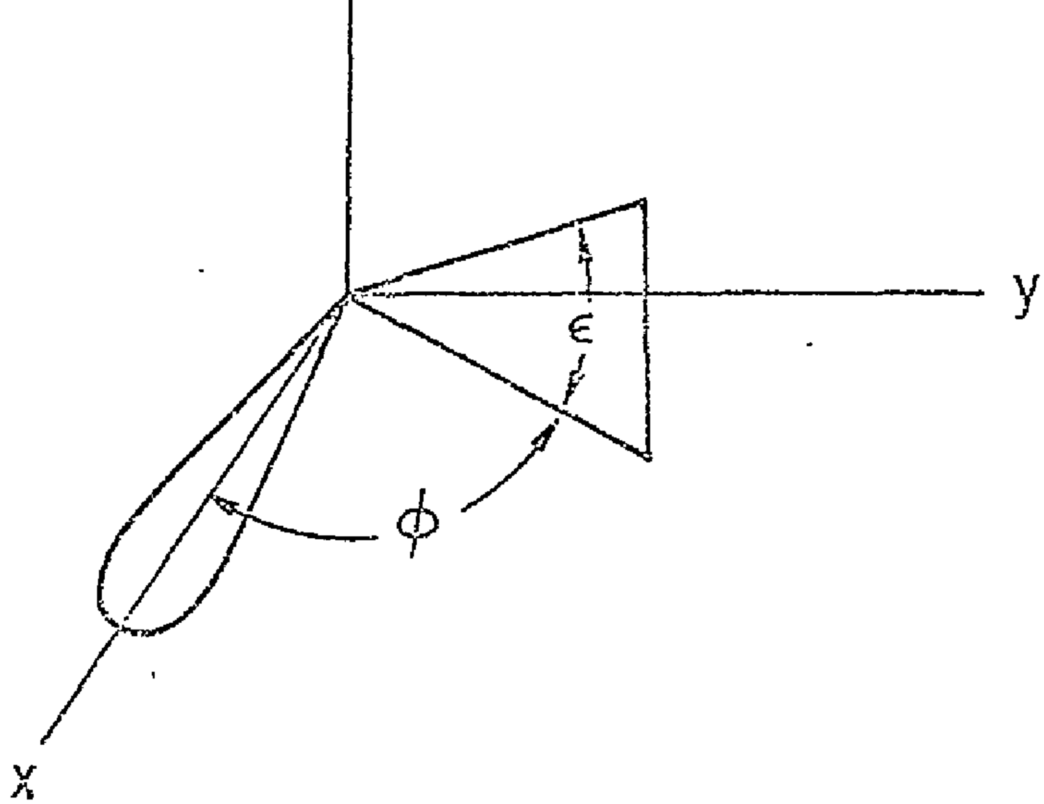

FIGURE E-1. ANTENNA PATTERN GEOMETRY FOR WIDTH

```
              PROGRAM WIDTH(OUTPUT,TAPE6=OUTPUT)
        C
        C              THIS ROUTINE DETERMINES THE EQUIVALENT (PENCIL)
        C              BEAMWIDTH
        C              BEAMWIDTH FOR AN ANTENNA WHOSE PATTERN IS SPECIFIED
        C              IN SUBROUTINE FUN.  SUBROUTINE RINTEG INTEGRATES
        C              THE PATTERN BY A QUASSIAN (LEGENDRE) QUADRATURE METHOD.
        C              INTEGRATION ARE REPETIVELY PERFORMED AT ONE DEGREE
        C              INTERVALS OUT TO SIX DEGREES.  THE EQUIVALENT
        C              BEAMWIDTH IS CHOSEN FROM THE LISTING AT THE POINT AT
        C              WHICH THE VALUES BEGIN TO CONVERGE
        C
        C              THIS PROGRAM WAS PREPARED BY
        C
        C               JOHN P. CLAASSEN
        C
        C              UNIVERSITY OF KANSAS
        C              CENTER FOR RESEARCH.
        C
000003        EXTERNAL FUN
000003        DATA PI/3.14159265/
000003        WRITE (6,300)
000007    300 FORMAT (1H1//)
000007        WRITE (6,100)
000013    100 FORMAT(30X,5(1H*),*SEARCH FOR THE EQUIVALENT BEAMWIDTH*5(1H*)//)
000013        DO 20 I=1,6
000015        X2 = 0.0174532925*FLOAT(I)*0.50
000017        Y2 = X2
000021        X2 = SIN(X2)
000023        X1 = 0.0
000024        Y1 = 0.0
000025        IX = 10*I
000030        CALL RINTEG (FUN, Z, X2, X1, Y2, Y1, IX, IX, 4, 4)
000041        BEAM = SQRT (16.0*Z/PI)/0.0174532925
000047        WRITE (6,200)     I ,BEAM
000056    200 FORMAT (10X,*ACTIVE BEAMWIDTH IS *I3,* DEGREES, WHEREAS*,
             * * THE EQUIVALENT BEAMWIDTH IS*F5.2,* DEGREES*)
000056     20 CONTINUE
000060        STOP
000062        END


000056        DO 30 I = 1,MP
000057        SY(I) = SAMPLE(MP,I)*HDELY
000066     30 CONTINUE
000070        DO 50 I = 1,NP
000071        DO 40 J = 1,MP
000072        C(I,J) = COEF(NP,I)*COEF(MP,J)
000106     40 CONTINUE
000110     50 CONTINUE
000112        DO 90 N=1,NX
000114        X1=X2
000116        X2=X1+DELX
000120        XM = X1 + HDELX
000121        Y2 = Y1P
000122        DO 80 M=1,MY
000124        Y1 = Y2
000126        Y2 = Y1 + DELY
000130        YM = Y1 + HDELY
000131        DO 70 I=1,NP
000133        X=SX(I)+XM
000136        DO 60 J=1,MP
000137        Y=SY(J)+YM
000142        SUM = SUM+C(I,J)*FUN(X,Y)
000160     60 CONTINUE
000162     70 CONTINUE
000164     80 CONTINUE
000167     90 CONTINUE
000171        ZZ  = SUM*DELX*DELY*0.250
000174        RETURN
000175        END
```

FIGURE E-2. SOURCE LISTING FOR WIDTH

```
              SUBROUTINE RINTEG (FUN,ZZ,X2P,X1P,Y2P,Y1P,NNX,MMY,NNP,MMP)
        C              THIS ROUTINE EMPLOYS A QUASSIAN LEGENDER QUADRATURE
        C              INTEGRATION PROCEDURE.  INTEGRATION OVER X-Y SEGMENTS
        C              ARE PERFORMED AFTER TRANSLATION TO (-1,1)X(-1,1).
        C              FUN= INTEGRAND FUNCTION
        C              ZZ = EITHER A PARAMETER FOR FUN OR THE INTEGRATED RESULT
        C                  OR BOTH
        C              X2P,X1P = UPPER AND LOWER LIMITS ON X
        C              Y2P,Y1P = UPPER AND LOWER LIMITS ON Y
        C              NX,MY = SEGMENTS IN X AND Y, RESPECTIVELY
        C              NP,MP = DEGREE OF PRECISION IN X AND Y, RESPECTIVELY
000015        DIMENSION SAMPLE(5,5),COEF(5,5),SX(5),SY(5),C(5,5),SV(25),CV(25)
000015        EQUIVALENCE (SV(1),SAMPLE(1,1)), (CV(1),COEF(1,1))
000015        DATA SV/
             * 1.0, -0.577350269, -0.774596669, -0.861136312, -0.906179846,
             * 1.0, 0.577350269, 0.0, -0.339981044, -0.538469310,
             * 1.0, 0.0, .774596669, 0.339981044, 0.0,
             * 1.0, 0.0, 0.0, 0.861136312, 0.538469310,
             * 1.0, 0.0, 0.0, 0.0, 0.906179846/
000015        DATA CV/
             * 1.0, 1.0, 0.555555556, 0.347854845, 0.236926885,
             * 1.0, 1.0, 0.888888889, 0.652145155, 0.478628670,
             * 1.0, 0.0, 0.555555556, 0.652145155, 0.568888888,
             * 1.0, 0.0, 0.0,         0.347854845, 0.478628670,
             * 1.0, 0.0, 0.0, 0.0,                 0.236926885/
000015        SUM = 0.0
000016        X1 = X1P
000017        X2 = X2P
000020        Y1 = Y1P
000021        Y2 = Y2P
000022        NX = NNX
000023        MY = MMY
000025        NP = NNP
000026        MP = MMP
000030        DELX = (X2-X1)/FLOAT(NX)
000033        DELY =  (Y2-Y1)/FLOAT(MY)
000037        HDELX = DELX*0.50
000041        HDELY = DELX*0.50
000042        X2 = X1
000043        DO 20 I = 1,NP
000045        SX(I) = SAMPLE(NP,I)*HDELX
000054     20 CONTINUE
```

```
              FUNCTION   FUN (XX,YY)
        C               THIS ROUTINE DEFINES THE SQUARE OF THE ANTENNA
        C               PATTERN OVER THE MAIN BEAM.
000005        ESP = XX
000005        ESP = ATAN(ESP,SQRT(1.0-ESP*ESP))
000015        PHIP =YY
000020        AMXEP = AMAX1 (ESP,PHIP)
000024        IF (AMXEP .LE. 0.0291 ) GO TO 10
000027        IF (AMXEP .LE. 0.0349 ) GO TO 20
000031        IF (AMXEP .LE. 0.0611 ) GO TO 30
000034        IF (AMXEP .LE. 0.105 ) GO TO 40
000036        IF (AMXEP .LE. 0.628) GO TO 50
000041        FUN = 10.0E-38
000042     10 FUN = EXP ( -4690.*ESP*ESP -3280.*PHIP*PHIP )
000050        FUN = FUN*FUN
000052        RETURN
000052     20 FUN = EXP(-121.1*ESP-3280.*PHIP*PHIP)
000060        FUN = FUN*FUN
000062        RETURN
000062     30 FUN = 0.0398*EXP(-821.*ESP*ESP-1072.*PHIP*PHIP)
000071        FUN = FUN*FUN
000073        RETURN
000073     40 FUN = 0.0159*EXP(-486.*ESP*ESP-53.6*PHIP)
000102        FUN = FUN*FUN
000104        RETURN
000104     50 FUN =0.000159*EXP(-8.59*SQRT(ESP*ESP+PHIP*PHIP))
000114        FUN = FUN*FUN
000116        RETURN
000116        END
```

Figure E-2. (Continued)

III. PROGRAM GAIN

A. Introduction

Program GAIN computes the antenna directivity, beam solid angle and, antenna efficiency. The theory and design of the program is described below.

B. Theory

The antenna beam solid angle is given by

$$\Omega = \int_0^{2\pi} \int_0^{\pi} P(\theta, \phi) \sin\theta \, d\theta \, d\phi \tag{6}$$

where

$P(\theta,\phi)$ = normalized antenna pattern

θ = polar angle

ϕ = azimuthal angle

$p(\theta,\phi)$ represents the normalized power in the antenna pattern. It can be shown that the antenna directivity Γ is related to Ω by the following expression

$$\Gamma = \frac{4\pi}{\Omega} \tag{7}$$

The antenna efficiency, on the otherhand, is the ratio of the power in the main beam to that in the entire pattern. Clearly then, the efficiency is given by

$$\eta_i = \int_0^{2\pi} \int_0^{\theta_i} P(\theta, \phi) \sin\theta \, d\theta \, d\phi \tag{8}$$

where θ_i is a polar angle which subdivides the main beam. In the above expression it is tacitly assumed that the main beam lies on the positive z axis as illustrated in Figure E-3. θ_i is chosen somewhat arbitrarily. Commonly θ_i is chosen at the −3 dB point or at the first null of the antenna pattern. For narrow beam antenna, the latter is most appropriate for radiometric work.

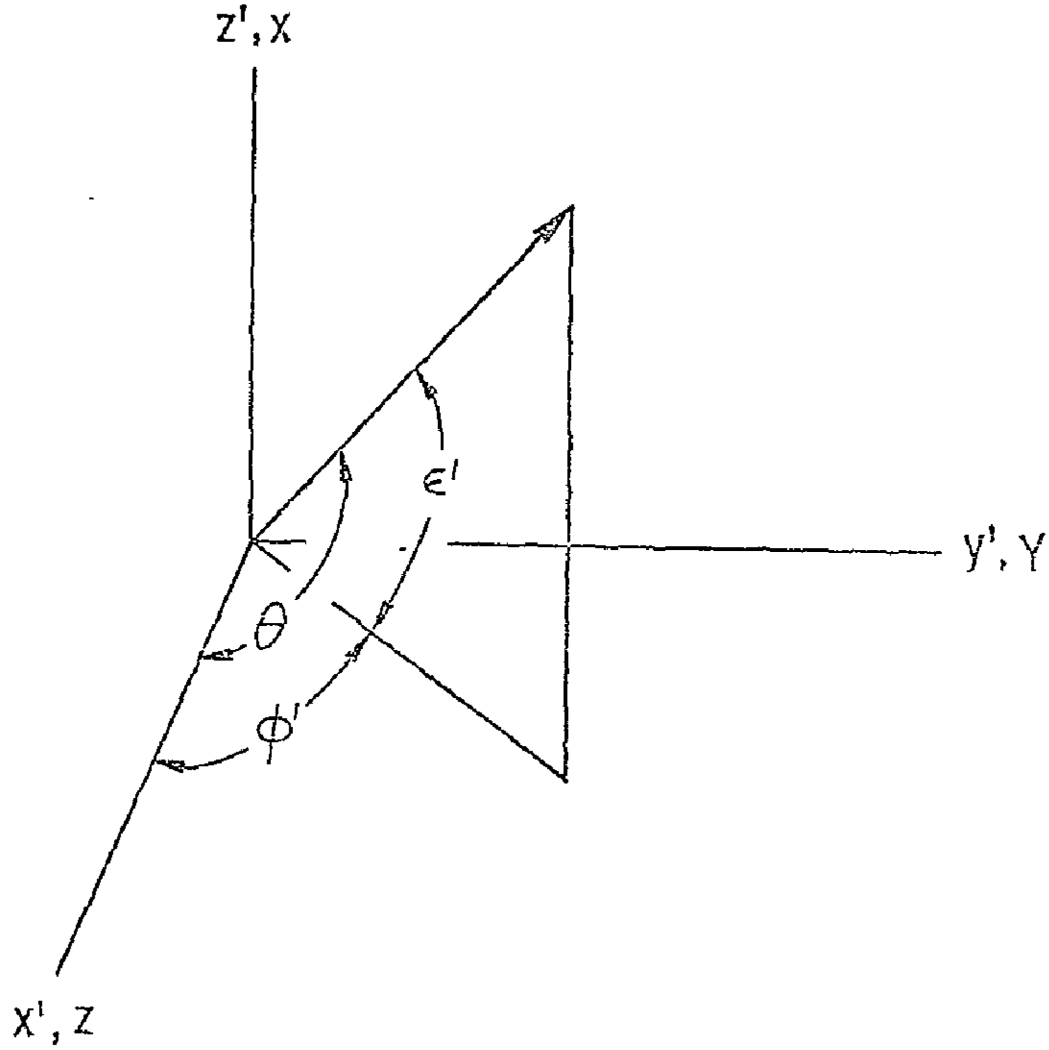

FIGURE E-3. ANTENNA PATTERN GEOMETRY FOR GAIN

C. Design and Operation of GAIN

In the discussion which follows it will be helpful to examine the FORTRAN listing for GAIN as shown in Figure E-4. Upon entry into GAIN, an array BEAM in which various polarized beam solid angle factors will be stored, is cleared. The main beam solid angles are then computed for various θ_i spaced at 1/2 degree intervals. The integration of the antenna pattern is performed by RINTEG which in turn calls for polarized pattern information from FUN1. The results are stored in BEAM. The accumulated solid beam angle is stored in TOTAL. The remainder of the polarized beam solid angle is then computed in the following statements.

At this point the antenna gain is computed and the gain and beam solid angle are printed.

In the remainder of the program the power content in the cross-polarized pattern (FUN2) is computed and added to TOTAL. A DO loop terminating on 30 then computes the antenna efficiency at one degree intervals out to 8 degrees. The result is listed.

Finally, the total beam solid angle, including polarized and cross-polarized contributions, is printed.

D. Subroutines FUN1 and FUN2

The antenna patterns described in FUN1 and FUN2 are actually represented in terms of another coordinate system. The relationship between the two coordinate systems is illustrated in Figure E-3. In the primed system the pattern is described in terms of the elevation angle ϵ and azimuth ϕ as shown in Figure E-1. The necessary transformations between the two are performed in the opening statements of FUN1 and FUN2. The latter statements simply evaluate the pattern over one of six domains in FUN1 and over five domains in FUN2.

```
                PROGRAM GAIN (OUTPUT,TAPE6=OUTPUT)
          C
          C     THIS PROGRAM COMPUTES THE ANTENNA GAIN AND EFFECIENCY FROM
          C     ANTENNA (POWER) PATTERNS DESCRIBED IN FUN1 AND FUN2.
          C     FUN1 DESCRIBES THE POLARIZED PATTERN WHEREAS FUN2 DESCRIBES THE
          C     CROSS-POLARIZED PATTERN.
          C
          C             THIS PROGRAM WAS PREPARED BY
          C
          C              JOHN P. CLAASSEN
          C
          C             UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.
          C
000003          DIMENSION BEAM(10), EFF(10)
000003          EXTERNAL FUN1
000003          EXTERNAL FUN2
000003          DATA PI/3.14159265/
000003          DATA FACTOR/0.0174532925/
000003          WRITE (6,500)
000007      500 FORMAT (1H1//)
000007          TOTAL = 0.0
000010          DO 10 I = 1,10
000012          BEAM(I) = 0.0
000013       10 CONTINUE
000015          Y2 = PI/2.0
000016          Y1 = 0.0
000017          WRITE (6,100)
000023      100 FORMAT(30X,*ANTENNA GAIN AND EFFICIENCY FACTORS*//)
          C
          C             COMPUTE THE MAIN BEAM SOLID ANGLE
          C
000023          DO 20 I = 1,8
000025          X1 = COS(FLOAT(I)*FACTOR*0.50)
000031          X2 = COS(FLOAT(I-1)*FACTOR*0.50)
000040          CALL RINTEG (FUN1, Z, X2, X1, Y2, Y1, 2, 90, 3, 3)
000051          BEAM (I+1) = BEAM (I) + 4.0*Z
000055          TOTAL = TOTAL + 4.0*Z
000057       20 CONTINUE
          C
          C             COMPUTE THE REMAINDER BEAM SOLID ANGLE
          C
000061          X2 = COS(4.0*FACTOR)

000064          X1 = COS(120.0*FACTOR)
000071          CALL RINTEG (FUN1, Z, X2, X1, Y2, Y1, 115, 90, 3, 3)
000102          TOTAL = TOTAL + 4.0*Z
          C
          C             COMPUTE GAIN
          C
000105          GAIN1 = 4.0*PI/TOTAL
000107          GAIN2 = 10.0*ALOG10(GAIN1)
000113          WRITE ( 6,200) TOTAL, GAIN1, GAIN2
000124      200 FORMAT ( 5X,*POLARIZED BEAM SOLID ANGLE=*E14.6/
               * 5X,*POLARIZED GAIN=*E14.6,* OR*F6.1,* DB*//)
          C
          C             COMPUTE THE CONTRIBTION FROM THE CROSS PATTERN
          C
000124          Y2 = 1.0
000125          X1 = COS (FACTOR*5.0)
000132          CALL RINTEG(FUN2,Z,X2,X1,Y2,Y1,5,90,4,4)
000143          TOTAL = TOTAL + 4.0*Z
          C
          C             COMPUTE BEAM EFFICIENCY
          C
000146          DO 30 I = 1,8
000150          EFF(I) = BEAM(I+1)/TOTAL
000152          WRITE (6,300) I, EFF(I)
000162      300 FORMAT(5X,*ACTIVE BEAMWIDTH IS *I3,* DEGREES.*,
               * *  CORRESPONDING EFFICIENCY IS*F6.3*   .*)
000162       30 CONTINUE
          C
          C             WRITE THE BEAM SOLID ANGLE
          C
000164          WRITE (6,400)  TOTAL
000172      400 FORMAT (/5X,*TOTAL BEAM SOLID ANGLE=*E14.6)
000172          STOP
000174          END
```

FIGURE E-4. SOURCE LISTING FOR GAIN

```
              SUBROUTINE RINTEG (FUN, ZZ,X2P,X1P,Y2P,Y1P,NNX,MMY,NNP,MMP)
        C             THIS ROUTINE EMPLOYS A QUASSIAN LEGENDRE QUADRATURE
        C             INTEGRATION PROCEDURE.  INTEGRATION OVER X-Y SEGMENTS
        C             ARE PERFORMED AFTER TRANSLATION TO (-1,1)X(-1,1).
        C             FUN= INTEGRAND FUNCTION
        C             ZZ = EITHER A PARAMETER FOR FUN OR THE INTEGRATED RESULT
        C                 OR BOTH
        C             X2P,X1P = UPPER AND LOWER LIMITS ON X
        C             Y2P,Y1P = UPPER AND LOWER LIMITS ON Y
        C             NX,MY = SEGMENTS IN X AND Y, RESPECTIVELY
        C             NP,MP = DEGREE OF PRECISION IN X AND Y, RESPECTIVELY
000015        DIMENSION SAMPLE(5,5),COEF(5,5),SX(5),SY(5),C(5,5),SV(25),CV(25)
000015        EQUIVALENCE (SV(1),SAMPLE(1,1)), (CV(1),COEF(1,1))
000015        DATA SV/
            * 1.0, -0.577350269, -0.774596669, -0.861136312, -0.906179846,
            * 1.0, 0.577350269, 0.0, -0.339981044, -0.538469310,
            * 1.0, 0.0, .774596669, 0.339981044, 0.0,
            * 1.0, 0.0, 0.0, 0.861136312, 0.538469310,
            * 1.0, 0.0, 0.0, 0.0, 0.906179846/
000015        DATA CV/
            * 1.0, 1.0, 0.555555556, 0.347854845, 0.236926885,
            * 1.0, 1.0, 0.888888889, 0.652145155, 0.478628670,
            * 1.0, 0.0, 0.555555556, 0.652145155, 0.568888888,
            * 1.0, 0.0, 0.0,          0.347854845, 0.478628670,
            * 1.0, 0.0, 0.0, 0.0,                  0.236926885/
        C
        C             CLEAR SUMMING VARIABLE
        C
000015        SUM = 0.0
        C
        C             RE-ASSIGN INPUT ARGUMENTS
        C
000016        X1 = X1P
000017        X2 = X2P
000020        Y1 = Y1P
000021        Y2 = Y2P
000022        NX = NNX
000023        MY = MMY
000025        NP = NNP
000026        MP = MMP
        C
        C             COMPUTE LENGTH OF CELL SIDES

        C
000030        DELX = (X2-X1)/FLOAT(NX)
000033        DELY =  (Y2-Y1)/FLOAT(MY)
000037        HDELX = DELX*0.50
000041        HDELY = DELX*0.50
        C
        C             FORM SAMPLE FACTOR FOR X
        C
000042        DO 20 I = 1,NP
000043        SX(I) = SAMPLE(NP,I)*HDELX
000052    20  CONTINUE
        C
        C             FORM SAMPLE FACTOR FOR Y
        C
000054        DO 30 I = 1,MP
000055        SY(I) = SAMPLE(MP,I)*HDELY
000064    30  CONTINUE
        C
        C             FORM GAUSSIAN WEIGHTS
        C
000066        DO 50 I = 1,NP
000067        DO 40 J = 1,MP
000070        C(I,J) = COEF(NP,I)*COEF(MP,J)
000104    40  CONTINUE
000106    50  CONTINUE
        C
        C             INTEGRATE IN STRIPS OF DELX
        C
000110        X2 = X1
000112        DO 90 N=1,NX
000113        X1=X2
000115        X2=X1+DELX
000117        XM = X1 + HDELX
        C
        C             INTEGRATE ALONG Y
        C
000120        Y2 = Y1P
000121        DO 80 M=1,MY
000123        Y1 = Y2
000125        Y2 = Y1 + DELY
000127        YM = Y1 + HDELY
        C
        C             TRANSFORM TO CELL (-1,1)X(-1,1)
```

Figure E-4. (Continued)

```
             C                                                                            00000303
000130               DO 70 I=1,NP                                                         00000304
000132               X=SX(I)*XM                                                           00000305
000135               DO 60 J=1,MP                                                         00000306
             C                                                                            00000308
             C                  FORM PARTIAL SUM                                          00000309
             C                                                                            00000310
000136               Y=SY(J)*YM                                                           00000307
000141               SUM = SUM+C(I,J)*FUN(X,Y)                                            00000311
000157          60   CONTINUE                                                             00000312
000161          70   CONTINUE                                                             00000313
000163          80   CONTINUE                                                             00000314
000166          90   CONTINUE                                                             00000315
             C                                                                            00000316
             C                  APPLY JACOBIAN                                            00000317
             C                                                                            00000318
000170               ZZ  = SUM*DELX*DELY*0.250                                            00000319
000173               RETURN                                                               00000320
000174               END                                                                  00000321


                     FUNCTION FUN1 (X,Y)                                                  00000322
             C                                                                            00000323
             C                       POLARIZED PATTERN                                    00000324
             C                THIS FUNCTION SUBROUTINE EVALUATES THE PATTERN INTENSITY    00000325
             C                IN THE PRIMED COORDINATE SYSTEM.  THE PATTERN IS            00000326
             C                EXPRESSED IN TERMS OF ELEVATION AND AZIMTH IN THAT          00000327
             C                COORDINATE SYSTEM. THE INPUT ARGUMENTS, HOWEVER, ARE        00000328
             C                DESCRIBED IN AN UNPRIMED COORDINATE SYSTEM RELATED          00000329
             C                TO THE PRIMED SYSTEM BY A ROTATION ABOUT THE                00000330
             C                Y AXIS.  THE BORE SIGHT IS ON THE X-PRIME AXIS IN           00000331
             C                THE PRIMED SYSTEM AND ON THE Z AXIS IN THE UNPRIMED         00000332
             C                SYSTEM.                                                     00000333
             C                                                                            00000334
             C                                                                            00000335
             C                TRANSFORM TO PATTERN COORDINATES                            00000336
             C                                                                            00000337
000005               SINX = SQRT(1.0 - X*X)                                               00000338
000013               COSY = COS(Y)                                                        00000339
000016               SINY=SQRT(1.0-COSY*COSY)                                             00000340
000022               COSTP =-SINX*COSY                                                    00000341
000024               SINTP = SQRT(1.0-COSTP*COSTP)                                        00000342
000031               THETAP=ATAN2(SINTP,COSTP)                                            00000343
000034               PHIP=  ATAN2(SINX*SINY,X)                                            00000344
000045               APHIP = ABS(PHIP)                                                    00000345
000046               AESPP = ABS(1.57079633-THETAP)                                       00000346
000051               ESQ = AESPP*AESPP                                                    00000347
000052               PSQ = PHIP*PHIP                                                      00000348
             C                                                                            00000349
             C                EVALUATE THE PATTERN FUNCTIONS                              00000350
             C                                                                            00000351
000054               AMXEP = AMAX1(AESPP,PHIP)                                            00000352
000057               IF (AMXEP .LE. 0.0291 ) GO TO 100                                    00000353
000062               IF (AMXEP .LE. 0.0349 ) GO TO 200                                    00000354
000064               IF (AMXEP .LE. 0.0611 ) GO TO 300                                    00000355
000067               IF (AMXEP .LE. 0.105 ) GO TO 400                                     00000356
000071               IF (AMXEP .LE. 0.628 ) GO TO 500                                     00000357
000074               XI = -SINTP*COS(PHIP)                                                00000358
000077               XI = ATAN2(SQRT(1.0-XI*XI),XI)                                       00000359
000106               XID = XI*57.2957796                                                  00000360
000110               IF (XID .LT. 100. .AND. XID .GT. 60. ) GO TO 600                     00000361
000123               FUN1 = 0.0                                                           00000362
000124               RETURN                                                               00000363
000124         100   FUN1 = EXP ( -4690.*ESQ -3280.*PSQ )                                 00000364
000133               RETURN                                                               00000365
000133         200   FUN1 =EXP(- 121.1*AESPP-3280.*PSQ)                                   00000366
000142               RETURN                                                               00000367
000142         300   FUN1 = 0.0398*EXP(-820.7*ESQ-1072.*PSQ)                              00000368
000152               RETURN                                                               00000369
000152         400   FUN1 = 0.0159*EXP(-486.*ESQ-53.6*APHIP)                              00000370
000162               RETURN                                                               00000371
000162         500   FUN1 = 0.000159*EXP(-8.59*SQRT(ESQ+PSQ))                             00000372
000173               RETURN                                                               00000373
000173         600   TANPSI = SINTP/COSTP*SIN(PHIP)                                       00000374
000177               PSI = ATAN(TANPSI)                                                   00000375
000201               COSPS = COS(PSI)**2                                                  00000376
000204               SINPS = SIN(PSI)**2                                                  00000377
000207               FUN1 = (3.16E-05*COSPS + 6.31E-06*SINPS)*                            00000378
                    * EXP(-(XID-80.)**2/(106.*COSPS + 36.*SINPS))                         00000379
000224               RETURN                                                               00000380
000225               END                                                                  00000381
```

Figure E-4. (Continued)

```
                FUNCTION FUN2 (X,Y)
         C
         C                       CROSS-POLARIZED PATTERN
         C                  THIS FUNCTION SUBROUTINE EVALUATES THE PATTERN INTENSITY
         C                  IN THE PRIMED COORDINATE SYSTEM.  THE PATTERN IS
         C                  EXPRESSED IN TERMS OF ELEVATION AND AZIMTH IN THAT
         C                  COORDINATE SYSTEM. THE INPUT ARGUMENTS, HOWEVER, ARE
         C                  DESCRIBED IN AN UNPRIMED COORDINATE SYSTEM RELATED
         C                  TO THE PRIMED SYSTEM BY A ROTATION ABOUT THE
         C                  Y AXIS.  THE BORE SIGHT IS ON THE X-PRIME AXIS IN
         C                  THE PRIMED SYSTEM AND ON THE Z AXIS IN THE UNPRIMED
         C                  SYSTEM.
         C
         C
         C                  TRANSFORM TO PATTERN COORDINATES
         C
000005          SINX = SQRT(1.0 - X*X)
000013          COSY = COS(Y)
000016          SINY=SQRT(1.0-COSY*COSY)
000022          COSTP =-SINX*COSY
000024          SINTP = SQRT(1.0-COSTP*COSTP)
000031          THETAP=ATAN2(SINTP,COSTP)
000034          PHIP=  ATAN2(SINX*SINY,X)
000045          APHIP = ABS(PHIP)
000046          AESPP = ABS(1.57079633-THETAP)
000051          ESQ = AESPP*AESPP
000052          PSQ = PHIP*PHIP
         C
         C                  EVALUATE THE PATTERN FUNCTIONS
         C
000054          AMXEP = AMAX1(AESPP,PHIP)
000057          IF (AMXEP .LE. 0.0291 ) GO TO 100
000062          IF (AMXEP .LE. 0.0349 ) GO TO 200
000064          IF (AMXEP .LE. 0.0611 ) GO TO 300
000067          IF (AMXEP .LE. 0.105 ) GO TO 400
000071          FUN2 = 0.0
000072          RETURN
000073      100 FUN2 = 0.0063*EXP (-4690.*ESQ-3280.*PSQ)
000103          RETURN
000103      200 FUN2 = 0.0063*EXP ( -4690.*ESQ -3280.*PSQ )
000113          RETURN
000113      300 FUN2 = 0.00025*EXP(-821.*PSQ-821.*ESQ)

000123          RETURN
000123      400 FUN2 = 0.00025*EXP(-821.*PSQ-821.*ESQ)
000133          RETURN
000133          END
```


Figure E-4. (Continued)

CRINC LABORATORIES

Chemical Engineering Low Temperature Laboratory

Remote Sensing Laboratory

Flight Research Laboratory

Chemical Engineering Heat Transfer Laboratory

Nuclear Engineering Laboratory

Environmental Health Engineering Laboratory

Information Processing Laboratory

Water Resources Institute

Technology Transfer Laboratory

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