CLARENDON LABORATORY

Atmospheric Physics

The Selective Chopper Radiometer on Nimbus IV

Archived Data

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The Nimbus IV satellite launched in April 1970 carried an infra-red radiometer to make remote measurements of the atmospheric temperature structure at levels up to 50 km altitude. The instrument, known as a selective chopper radiometer (SCR), has been described by Houghton & Smith (1970) and Abel et al (1970). Details of the instrument may be found in these and other published papers (see references). (Calibration procedures are described by Barnett et al (1972).)

This paper describes the format of the archive tapes, containing frame by frame radiances and other relevant data, which have been prepared for the National Space Science Data Center. A list of events, including those which have a bearing on the quality of the data, is also provided (Appendix 3).

In general, the Nimbus IV SCR performed in a very consistent manner. The archive tapes have been carefully tested and documented. However, during its 2½ years of operation various changes occurred (see Appendix 3) and certain peculiarities have been noted. Should any problems arise, would users please contact the Department of Atmospheric Physics, Clarendon Laboratory, Oxford University.

Tape Format

Introduction

The Nimbus 4 archive tape is a 7 track magnetic tape written at 800 b.p.i.. Each tape contains data for approximately 15 'days' where a 'day' refers to the daily transmission of data from NTCC to Oxford. This normally includes data acquired by the ground station between 0000Z and 2400Z the previous day.

Each tape begins with a file summarizing its contents. Subsequent files provide detailed day by day and orbit by orbit information. An orbit is usually a readout orbit from the spacecraft tape recorder but can also represent one or more sections of real time data. The tape ends with a repeat of the summary file.

The structure of an archive tape is summarized in Table I.

TABLE I

Record	Orbit grouping	File / day grouping
Summary header record		Summary file Volume table of contents
Summary day records 1 to N where N = number of days on the tape		Summary file Volume table of contents
End of file (tape mark)		Summary file Volume table of contents
Day header file		repeated for each day
EOF		repeated for each day
Orbit header record	repeated for each orbit	repeated for each day
Cal/Hsk record	repeated for each orbit	repeated for each day
Data records 1 to M where M=(No.of major frames-1)/14+1	repeated for each orbit	repeated for each day
End of orbit record	repeated for each orbit	repeated for each day
EOF	repeated for each orbit	repeated for each day
End of day file		repeated for each day
EOF		repeated for each day
Copy of summary file		
EOF mark		
EOF		

Detailed description

In general, for all tables, numbers in the column headed CONTENTS are octal and other numbers decimal. Exceptions are indicated by the subscripts 8 or 10 for octal or decimal.

Each file consists of a series of records and is terminated by a tape mark. Each record is a series of 12-bit integers, each represented by 2 6-bit tape characters with ODD parity, the most significant half of the word appearing first on the tape. The format of a record is as follows:

Word	Contents
0,1	7106, 7106
2	Length L
3	Record Number
4	Identifier
5 to L-3	Data words
L-2	EOR mark
L-1	Checksum

'Length' is the number of 12-bit words in the record from the first 7106_8 up to and including the checksum.

The record number starts at 1 at the beginning of the file and is increased by 1 for each successive record Modulo 4096.

The identifier is a unique code associated with the data content of the record.

The end of record (EOR) mark has one of the following values:

5252	last record of file
5225	file containing one record
6453	last record on the tape
4421	all other records.

The checksum is the 12-bit 1's complement sum of words 0 to N-2 of the record.

Summary Head Record		No. of words	Note
Word	Contents		
0,1	7106, 7106	2	
2	10	1	
3	1	1	
4	4200	1	
5	No. of days on tape	1	
6	EOR	1	
7	Checksum	1	1

Summary Day Record

0,1	7106, 7106	2	
2	Length	1	
3	Record no.	1	
4	4201	1	
5	'day'	1	
6	'year'	1	
7	No. of orbits	1	
8,9	Orbit no.	2	
10	Hdrss	1	2
11	Day	1	3
12,13	Time	2	3
14	No. of major frames	1	
15	No. of bad checksums	1	
16	No. of 1st good m.f.	1	
17	No. good THIR records	1	4
18	Flagword	1	5
	.		
	.		
	EOR		
	Checksum		

Items 8-18 are repeated for each orbit in a 'day'.

Day Header File

Word	Contents	No. of words	Note
0,1	7106, 7106	2	
2	11	1	
3	1	1	
4	4202	1	
5	Day	1	
6	Year	1	
7	EOR	1	
8	Checksum	1	

Orbit Header Record

Word	Contents	No. of words	Note
0,1	7106, 7106	2	
2	16	1	
3	Record No.	1	
4	4203	1	
5,6	Orbit No.	2	
7	Hdrss	1	2
8	Day	1	3
9,10	Time	2	3
11	No. of major frames	1	
12	EOR	1	
13	Checksum	1	

Calibration and Housekeeping Record

Word	Contents	No. of words	Note
0,1	7106, 7106	2	
2	407	1	
3	Record No.	1	
4	4204	1	
5	Ignore	1	
6	Ignore		
7-25	Calibration parameters	19	6
26	No. bad checksums	1	
27,28	Spare	2	
29-104	Max.Housekeeping Fns.	76	7
105-180	Min. " "	76	7
181-256	Mean " "	76	7
257-260	Spare	4	
261	EOR	1	
262	Checksum	1	

Data Record

Word	Contents	No. of words	Note
0,1	7106,7106	2	
2	3501	1	
3	Record No.	1	
4	4205	1	
5	No.of internal records (Max. 16)*	1	
6	204	1	
7,8	Orbit No.	2	
9	Hdrss	1	
10	Transmitted Record No.	1	8
11	Major Frame No.	1	8
12	Day	1	12
13,14	Time	2	12
15	Latitute x 8_{10}	1	14
16	Longitude x 8_{10}	1	14
17-70	Thir (raw-packed)	54	8
71,72	Housekeeping Averages	2	8
73,74	Thir Bolometer (unpacked)	2	8
75	Altitude	1	9
76-78	Thir max, min,mean	3	12
79,80	Flags	2	10
81,87	Radiances x 16_{10}	7	11
88,89	Ch.A,B rads imbalance corrected	2	11
90-138	Analogue Housekeeping	49	13
	.		
	.		
	EOR	1	
	Checksum	1	

Items 7-138 are repeated for each internal record.

*Rate: no. of internal records can be zero on some tapes.

End of Orbit Record

Word	Contents	No. of words
0,1	7106, 7106	2
2	7	1
3	Record No.	1
4	4206	1
5	EOR	1
6	Checksum	1

End of Day File

0,1	7106, 7106	2
2	7	1
3	1	1
4	4207	1
5	EOR	1
6	Checksum	1

End of Tape Record

Copy of Summary File.

Notes

1. The Checksum is the 12-bit 1's complement sum of all preceding numbers in the block.

2. Hdrss: This 12 bit word gives

   (a) in the most significant 6 bits a BCD code indicating the recorder used in transmission which may be A or B, or R indicating a real time transmission (see Appendix 1).

   (b) in the least significant 6 bits the Data Acquisition Station which is usually A=Alaska or R=Rosman.

3. This is the day number and time taken from spacecraft clock of the start of the first good major frame in integer seconds from midnight.

4. In a bad THIR record, THIR MAX is set to O(see Data Record).

5. Flagword: Bit 2^x is set to 1 when the following conditions are satisfied at any time during the orbit:

x=0	RTTS interference this orbit		
1	IRLS "	"	"
2	HDRSS "	"	"
3	THIR switched on	"	"
4	No channel C,D	"	"
5	No channel E,F.		

6. These numbers represent factors used in the calculation of the radiances. They are:

7-13	g=20/gain(20°C) where gain is in volts/unit radiance (see note 11).
14-20	Space signal in bits. 1 bit=6.25 mV.
21,22	Gain at balance for Ch.A,B.
23	Space amplitude - maximum correction for Ch.E; Ch. F corrected by approx. 0.4 of this amount. This correction has increased as a function of time.
24,25	lat x 8 at night,day; day,night crossings.

For details of the calibration techniques, see Barnett et al (1972).

7. For each of max, min, mean housekeeping functions there are:

0	Spare
1	Spare
2	+8.2 V DC Housing 1
3	-8.2 " "
4	Spare
5	+8.2 V DC Housing 2
6	-8.2 " "
7	Spare
8	+8.2 V DC Housing 3
9	-8.2 " "
10	3.5 V DC
11	4 V DC
12	9 V DC
13	-9 V DC
14,15	Spare
16-21	BB thermistors direct
22-27	BB thermistors amplified
28-33	Bolometer temps.
34-39	Calib mirror temps.
40-45	Radiometer body temps.
46-49	Fixed mirror temps.
50-55	Chopper amplitudes.
56-71	Signal gains and zero settings.
72-75	Module temps.

A method for calculating housekeeping temperatures is given in Appendix 2.

8. Taken from raw data. Transmitted record no. is incremented for each transmitted record even if the same major frame is sent more than once.

9. Altitude is (altitude of spacecraft-1000 km) x 8.

10. Flags: Bit 2^x is set to 1 if the following are satisfied:

Word 1:	x=0	End of orbit detected.
	1	Mag tape checksum error
	2	SCR record checksum error
	3	Bad EOF on SCR record
	4	Bad attitude
	5	Earth view
	6	Space view
	7	BB view
	8	Ch 3 normal (i.e. Ch.C)
	9	Ch 3 ground (i.e. Ch.G)
	10	Ch A,B normal filter
	11	Ch A,B imbalance filter

10. (contd.)

Word 2: x=0 Inconsistent digital B information
1 Spike detected on SCR signals
2 THIR on
3 RTTS "
4 MUSE "
5 SIRS "
6 BUV "
7 IDCS "
8 IRIS "
9 IRLS "
10 S band A on
11 " B "

11. Order of channels is A,B,C,D,F,E.G.

1 radiance unit = 1 $mWm^{-2}ster^{-1}(cm^{-1})^{-1}$.

12 bit integers on magnetic tape are radiance values which have been multiplied by 16.

e.g. 100_{10} radiance units is written on tape as $1600_{10}(3100_8)$

Radiances are set to zero in a particular channel if at least 8 samples are rejected in that channel. During space and black body view, radiances are set to noise which is calculated according to

$$8 \times \left[\frac{1}{N}\sum_{i=1}^{N}\left(x_i-\bar{x}\right)^2\right]^{\frac{1}{2}}$$ where N = number of good samples.

12. Time of start of major frame (see note 3).

13. This section contains:

4 x Roll
4 x Pitch
Yaw) Items 2-13 of list in note 7, sub-
Code) commutated code is slot number, i.e. 2-13.
Corresponding voltage)
6 BB thermistors direct
6 BB thermistors amplified
6 Bolometer temps.
6 Calib mirror temps.
6 Radiometer body temps.
4 Fixed mirror temps.
6 Chopper amplitudes
4 Module temps.

14. Latitude and longitude are in eighths of degrees north and east respectively, e.g. $10^{o}S$, $300^{o}E$ is 4016, 2400 . Latitude is a signed integer. Longitude is unsigned.

APPENDIX 1

BCD Code

Symbol	Octal	Symbol	Octal
A	61	T	23
B	62	U	24
C	63	V	25
D	64	W	26
E	65	X	27
F	66	Y	30
G	67	Z	31
H	70	Ø	12
I	71	1	01
J	41	2	02
K	42	3	03
L	43	4	04
M	44	5	05
N	45	6	06
O	46	7	07
P	47	8	10
Q	50	9	11
R	51	SPACE	00
S	22		

APPENDIX 2

Housekeeping Temperatures

Housekeeping temperatures (for all but the 6 amplified thermistors) can be found using the following cubic fit:

$$T = a + bV + cV^2 + dV^3 \quad (^oK)$$

where a = 360.7

b = 29.21

c = 4.20

d = 0.3378

V is in Telemetry Volts (TMV)
= -0.025 x 8 bit digital value.

Black Body Radiances

The temperatures of the six internal black bodies is found by examining the output from the amplified black body thermistors (function numbers 15n05). The temperature is then given by the formula

$$T = \frac{E}{\ln\left(\frac{AV + B}{CV + D}\right)} \quad ^oK$$

where V = VIP sample in volts (range 0 to -6.25) and A,B,C,D,E are given according to the following table:

Channel	A	B	C	D	E
A	25635.9	-34774.4	-2.561_{10}^{-3}	-0.97874	3444.57
B	"	-34743.0	"	-0.983903	"
C	"	-35434.8	"	-0.972863	"
D	"	-32048.3	"	-0.946499	"
F	"	-34776.8	"	-0.98093	"
E	"	-34620.2	"	-0.978345	"

APPENDIX 2 (continued)

From the temperature the corresponding radiance can be found by substituting into the Planck equation. Alternatively the radiance can be found directly from the amplified black body thermistor output by means of the following numerical approximation:

$$B = \frac{1 + cV + dV^2}{a + bV} \text{ radiance units}$$

where V = volts 0 to -6.25, and a,b,c,d are given in the following table:

Channel	Wave No.	a	b	c	d
A	668 cm^{-1}	$5.01_{10}{-3}$	$-1.875_{10}{-3}$	-0.1815	$-2.661_{10}{-3}$
B	668	$5.002_{10}{-3}$	$-1.872_{10}{-3}$	-0.1815	$-2.662_{10}{-3}$
C	668	$5.046_{10}{-3}$	$-1.863_{10}{-3}$	-0.1796	$-2.621_{10}{-3}$
G	935	$6.183_{10}{-3}$	$-2.497_{10}{-3}$	-0.1463	$-2.836_{10}{-3}$
D	675	$4.954_{10}{-3}$	$-1.964_{10}{-3}$	-0.1886	$-2.856_{10}{-3}$
F	712	$5.065_{10}{-3}$	$-1.921_{10}{-3}$	-0.1757	$-2.716_{10}{-3}$
E	697	$5.037_{10}{-3}$	$-1.908_{10}{-3}$	-0.1781	$-2.708_{10}{-3}$

APPENDIX 3

Historical Information

It has proved difficult to collect precise information on all events which occurred which might affect the SCR data as details from different sources concerning the same event are not always consistent. In some instances the same source produces contradictory statements. It is safe to assume the data is true in the main but to treat fine detail with some caution.

Event	Orbit	Date	Day
Launch 08.17.57Z		8 April	98/70
SCR turned on	6A	8 April	98/70
SCR heater duty cycle established by	86	14 April	102/70
Latitude & longitude apparently correct by	176	21 April	111/70
Balance temp.of channel B dropped below 17 C	1000	21 June	172/70
Wallops test June to September 1970			
Channel 3 ground last used	1378	19 July	200/70
Nimbus 4 archive data available		27 July 70	208/70
HDRSS A first failed temporarily (used sparingly until orbit 4678)	3707	9 Jan	9/71
THIR first failed	3731	11 Jan	11/71
THIR re-started	3983	29 Jan	29/71
RTTS flag believed defined		10 March	69/71
Channel 5 & 6 failed first	4619	18 March	77/71
HDRSS A again in full action	4678	22 March	81/71
First gyro failed and produced attitude errors.			
Between orbits 4959 & 5356 spacecraft was travelling backwards most of the time.	4905	8 April	98/71
SCR turned off (connected with above)	4936	10 April	100/71
THIR failed again	4973	13 April	103/71
SCR turned on again	4975	13 April	103/71
Ch.5 & 6 showed significant improvement	5022	17 April	107/71
HDRSS A finally failed	5081	17 April	107/71

Continued

APPENDIX 3 (continued)

	Orbit	Date	Day
THIR (which had worked intermittently since orbit 4973) finally failed	5145	26 April	116/71
Ch.5 and 6 good	5266	5 May	125/71
Spacecraft turned and travelled forwards	5356	12 May	132/71
Attitudes reported as good 15 May			
Ch.5 and 6 bad		3 July	184/71
Ch.5 and 6 good again		19 July	200/71
Second loss of attitude, spacecraft travelled backwards.		6 Feb	37/72
Details not known but our records return to normal by		28 Feb.	59/72
Channels 3 and 4 failed		17 April	108/72
Ch. 5 & 6 occasionally bad or marginal from		23 Aug	236/72
Data transmissions alternate days only from		7 Sept.	251/72
Routine transmissions discontinued from		1 Dec.	336/72
Nimbus V launched		11 Dec.	346/72

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