

CRS Files

(Celestial Reference System Files)

I. Input Data Tapes:

A. Univac Binary Tapes:

CRS tapes for Voyager encounters with Saturn are:

CRS009	Voyager 1 at Titan
CRS010	Voyager 1 at Saturn (including rings)
CRS32-1	Voyager 2 at Saturn (including rings)

UK0015 appears to be the best trajectory for the Voyager 2 Uranus encounter. See a later section in this file for information on format of the input data tapes

Tapes in the NK series cover early Voyager 2 Neptune Operational Readiness Tests.

B. ASCII Format Tapes:

CRS tapes in the NJ series contain ASCII data; these cover the later Voyager 2 Neptune ORT's and the encounter itself.

II. Format of JPL Univac Binary Tapes:

The following documentation is adapted from 618-782 Rev A ("DPTRAJ and ODP Interfaces and File Format Descriptions", JPL Navigation Software Group, Section 314, 1 August 1980) and from "Univac 1108 Multi-processor System: System Description," Sperry-Rand Corporation, 1968.

CRS tapes contain position and velocity data for spacecraft. Each file contains two header records, an unlimited number of data records, and (possibly) an end-of-file record.

The size of the CRS file depends on the length of the trajectory processed, the frequency at which records are written, and the number of bodies for which data have been requested.

A hexadecimal dump of the first four records of tape UK0015 (the Voyager 2 Uranus flyby "final" trajectory) follows this discussion. That dump is followed by some specific examples of how to unpack the data from those records. Appendix A contains additional information.

A. Bit Patterns for Character, Integer, and Floating Point Numbers:

Tapes were created by a Univac 1108 computer. The Univac uses 6-bit bytes, 6-byte integers, and 12-byte (double precision) floating point numbers. Storage is in most significant byte first (MSB) order.

CHARACTER data require one 6-bit byte per character; they are BCD coded. Translations are given in Figure 1. Note that we have translated codes only for the SPACE character and the upper case letters A-Z.

CHARACTER CODE					
CPU INTERNAL CODE (OCTAL)	80-COLUMN PUNCHED CARD CODE	HIGH SPEED PRINTER SYMBOL	CPU INTERNAL CODE (OCTAL)	80-COLUMN PUNCHED CARD CODE	HIGH SPEED PRINTER SYMBOL
00	7-8	@	40	12-4-8)
01	12-5-8	[41	11	-
02	11-5-8]	42	12	+
03	12-7-8	#	43	12-6-8	<
04	11-7-8	Δ	44	3-8	=
05	(Blank)	(Space)	45	6-8	>
06	12-1	A	46	2-8	&
07	12-2	B	47	11-3-8	\$
10	12-3	C	50	11-4-8	*
11	12-4	D	51	0-4-8	(
12	12-5	E	52	0-5-8	%
13	12-6	F	53	5-8	:
14	12-7	G	54	12-0	?
15	12-8	H	55	11-0	!
16	12-9	I	56	0-3-8	, (comma)
17	11-1	J	57	0-6-8	\
20	11-2	K	60	0	0
21	11-3	L	61	1	1
22	11-4	M	62	2	2
23	11-5	N	63	3	3
24	11-6	O	64	4	4
25	11-7	P	65	5	5
26	11-8	Q	66	6	6
27	11-9	R	67	7	7
30	0-2	S	70	8	8
31	0-3	T	71	9	9
32	0-4	U	72	4-8	' (apostrophe)
33	0-5	V	73	11-6-8	;
34	0-6	W	74	0-1	/
35	0-7	X	75	12-3-8	. (period)
36	0-8	Y	76	0-7-8	⊠
37	0-9	Z	77	0-2-8	‡ (or stop)

Figure 1. Univac character codes
(from Univac 1108 Multi-Processor System Reference Card)

INTEGER (I) data require 36 bits of storage. The most significant bit (msb) is the sign bit; it is 0 for positive integers, 1 for negative integers. The remaining 35 bits contain a binary integer. If msb is 1, the 35 bit binary integer is the two's complement of its positive value.

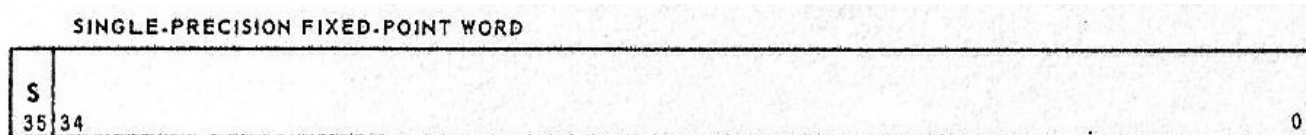


Figure 2. Univac bit assignments for 36-bit integers.
(from *Univac 1108 Multi-Processor System Reference Card*)

DOUBLE PRECISION (DP) floating point numbers require 72 bits of storage. The most significant bit (msb) is the sign bit; it is 0 for positive numbers, 1 for negative numbers. The next 11 bits contain the exponent value, a binary number between 0 and 2047. Exponents are applied to a base of 2. The exponent value is biased by 1024. Binary exponents and equivalent (true) decimal values are shown below

Binary Exponent	True (decimal) Value
0	-1024
11111111111	1023

The positive fixed point part (mantissa) occupies the remaining 60 bits. This is normally assumed to be in the (decimal) range 0.5-1.0. Such a value places a 1 bit in the most significant location (bit 59). When this condition exists, the floating point number is said to be normalized. A negative fixed point part causes the entire floating point word (exponent plus mantissa) to be two's complemented, and a 0 appears in bit 59. The range of a double precision floating point number is approximately 10^{-308} to 10^{307} with 18 digit accuracy.

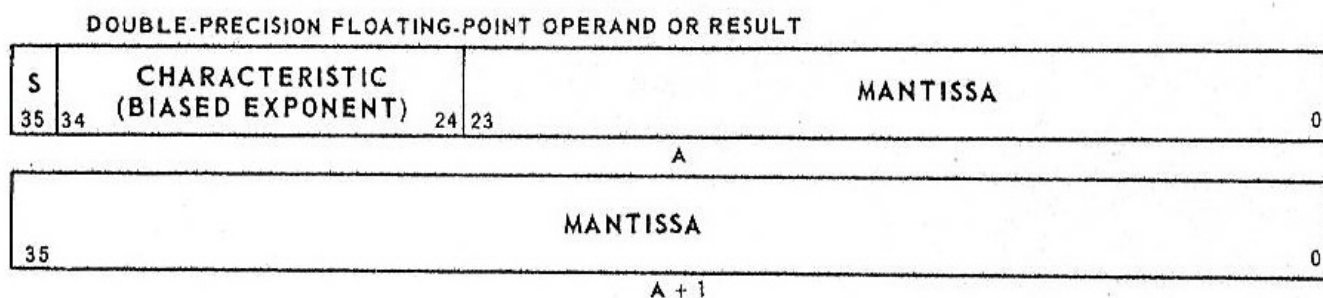


Figure 3. Univac bit assignments for 72-bit floating point numbers.
(from *Univac 1108 Multi-Processor System Reference Card*)

B. Detailed File Format:

Word 0 in each record is not described in original documentation. It may be a label, a byte count, or an identifier for the content of the remainder of the record. It does not appear to be important, and we ignore it here. "Word" as used here means 36 bits; words are counted starting from 0.

Word #	Name	Dimension	Type	Value	Definition
0	--	1	?	?	Record label (?)
1	NWRDSH	1	I	61	Number of words in record
2-24	FNGRPR	23	BCD		Fingerprints (identification of DPTRAJ run, other information)
25-62	LABL	38	BCD		Label (comment array)

Table 2: Record 0 contains bookkeeping information.

The second record tells how many bodies are described in the data records and names those bodies.

Word #	Name	Dimension	Type	Value	Definition
0	--	1	?	?	Record label(?)
1	NWRDS	1	I	NBODL	Number of bodies in record (number of solar system bodies which have position and velocity vectors written in each data record)
2- (NBODL+1)	KBODL	NBODL	BCD		Names of those solar system bodies.

Table 3: Bodies list in Record 1.

The order in which bodies are written in the data record is the same as the order in the KBODL array. The list of valid names (as of 1980) is given below

MERCUR	JUPITE	SATURN	URANUS
	IO	MIMAS	ARIEL
VENUS	EUROPA	ENCELA	UMBRIE
	GANYME	TETHYS	TITANI
EARTH	CALLIS	DIONE	OBERON
MOON	AMALTH	RHEA	MIRAND
	HIMALI	TITAN	
MARS	ELARA	HYPERI	NEPTUN
PHOBOS	PASIPH	IAPETU	TRITON
DEIMOS	SINOPE	PHOEBE	NEREID
	LYSITH	JANUS	
	CARME		PLUTO
	ANANKE		
	LEDA		SUN
	JXIV		

Records 2 and following contain position and velocity vectors. For each of m time points, the data record will contain the following

Word #	Name	Dimension	Type	Value	Definition
0	--		?	?	Record label(?)
1	NWRDSD	1	I	$9+12*\text{NBODL}$	Number of words contained in the data array (record)
2-3	SP1950	1	DP		Seconds (ET) past 0 hrs 1 January 1950
4-5	JULDAT	1	DP		Julian date (days)
6-7	GRE DAT	2	I		Gregorian calendar date (two integer words which represent the vigesimal date)
8-9	ETMUTC	1	DP		ET-UTC time difference
10	IRECFL	1	I		Record flag and body indication =0 TDT (time, delta time) event =K Planet or satellite periapsis =-K Planet or satellite apoapsis (where K is a pointer to the location of the body in the KBODL list)
11- (10+12*NBODL)	POSSCB	(6, NBODL)	DP		Position and velocity vectors
11-12	X1	1	DP		X-position of the first body in the KBODL list (km)
13-14	Y1	1	DP		Y-position of first body (km)
15-16	Z1	1	DP		Z-position of first body (km)
17-18	VX1	1	DP		X-velocity of first body (km/s)
19-20	VY1	1	DP		Y-velocity of first body (km/s)
21-22	VZ1	1	DP		Z-velocity of first body (km/s)
23-24	X2	1	DP		X-position of second body (km)
25-26	Y2	1	DP		Y-position of second body (km)
27-28	Z2	1	DP		Z-position of second body (km)
29-30	VX2	1	DP		X-velocity of second body (km/s)
				...	
	VZn	1	DP		Z-velocity of nth body (km/s)

Table 4: State vectors in Records 2 and later.

VZn appears in words $(9+12*\text{NBODL})$ and $(10+12*\text{NBODL})$. Note that all positions and velocities are given with respect to the spacecraft and are geometric -- that is, they are the actual positions/velocities at time SP1950 (without compensation for finite light time travel).

The last record (record $m+3$) may or may not exist. If it does, it contains three integer words (at most) which signify end of data.

C. Hexadecimal Dump: First Four Records of Tape UK0015

The first entry on each line is the number of the first 16-bit word (in hexadecimal). Each four digit number following represents the contents of a 16-bit word. Note that this dump was created on a "big-endian" (most significant

byte first, MSB) computer reading data from tape; most computers today (ca. 2024) use "little-endian" (least significant byte first, LSB) disk storage. For an annotated LSB dump, see Appendix A.

File	0	Record	0	378 (17A Hex) bytes				
0000	000F	8100	1000	0000	3D29	364A	5C52	1761
0008	5518	1451	4514	54C6	6D84	8514	5145	145C
0010	35C7	6E36	C70D	37CB	5C32	C77E	34C7	1CB3
0018	D781	4514	5145	2176	1551	8645	1451	4514
0020	5145	1451	4514	5145	1451	4514	5145	1451
0028	4514	5145	1451	4514	5145	1451	4514	5145
0030	1451	4514	5145	1451	4514	5145	1451	4514
0038	5A28	A056	9150	8405	A28A	0584	5508	645E
0040	3514	5145	1451	4514	5145	1451	4514	5145
0048	1451	4514	5145	1451	4514	5145	1451	4514
0050	5145	1451	4514	5145	1451	4514	5145	1451
0058	4514	5145	1451	4514	5145	1451	4514	5145
0060	1451	4514	5145	1451	4514	5145	1451	4514
0068	5145	1451	4514	5145	1451	4514	5145	1451
0070	4514	5145	1451	4514	5145	1451	4514	5145
0078	1451	4514	5145	1451	4514	5145	1451	4514
0080	5145	1451	4514	5145	1451	4514	5145	1451
0088	4514	5145	1451	4514	5145	145F	88EE	6092
0090	000F	8100	1000	0000	0000	0000	0000	0000
0098	0000	0000	0000	0000	0000	0000	0000	0000
***** Duplicate of above data *****								
00B8	0000	0000	0000	0000	0000
File	0	Record	1	126 (7E Hex) bytes				
0000	0001	4100	1000	0000	0461	A4C5	1452	865D
0008	9345	6971	9369	848E	5C64	C93C	61F7	FF00
0010	0014	1001	0000	0000	0000	0000	0000	0000
0018	0000	0000	0000	0000	0000	0000	0000	0000
***** Duplicate of above data *****								
0038	0000	0000	0000	0000	0000	0000	0000
File	0	Record	2	378 (17A Hex) bytes				
0000	000E	8100	1000	0000	3941	F87A	C662	E5EB
0008	605A	4169	551D	C55F	CC4C	6C07	6601	BA80
0010	537A	B9A9	406D	CBD6	C0C0	8DB6	5F00	0000
0018	0004	1E8B	085D	4936	1544	E420	9910	ACBB
0020	514B	E034	1F85	273B	29DC	C26A	CBFC	1433
0028	4513	6321	81D4	0581	C24D	AE32	BE75	0403
0030	F0F5	5BD6	0304	5834	1DEF	020F	E78B	C264
0038	D420	9FC1	EEDF	11FF	9DF4	1F8A	F4F1	3C77
0040	DE98	1BF9	7D99	EFBD	E911	7334	00EC	DF73
0048	5843	A73F	0400	E5F4	8AC1	A2B5	2604	11F8

```

0050    9F10  15F1  FBFB  5BED  33AF  D9F3  9949  BC7B
0058    EE75  5392  F4E8  CA6D  0BFF  40A6  EA90  2A9D
0060    9694  04EB  336C  D7EB  6E86  8403  D8A4  7A7C
0068    383A  AD54  0F80  31C3  82CB  7B30  4BED  5537
0070    9B71  98FB  A12B  EE04  7C59  E0FC  7478  ABFD
0078    0303  EAE3  D402  30E4  04E3  17BE  0BBA  5AB9
0080    D404  C9EC  DFAB  4EE1  8A75  F00D  C68B  000E
0088    8100  1000  0000  0000  0000  0000  0000  0000
0090    0000  0000  0000  0000  0000  0000  0000  0000

```

***** Duplicate of above data *****

```

00B8    0000  0000  0000  0000  0000  ....  ....  ....

```

File 0 Record 3 378 (17A Hex) bytes

```

0000    000E  8100  1000  0000  3941  F87A  C671  E5EB
0008    605A  4169  551D  C576  8DB8  8207  6601  BA80
0010    5399  3E29  406D  CBD6  C0E8  D0C2  6700  0000
0018    0004  1E8B  084F  76ED  0252  8420  9910  B456
0020    3B22  3284  1F85  2742  3968  AABA  1BFC  1407
0028    1C11  16C6  FEF4  0581  D460  88C9  E93D  5403
0030    F10D  DA35  1E16  6A14  1DEF  0195  A57A  54F6
0038    2420  9FC1  EF4E  99B5  9D04  1F8A  F4F2  1461
0040    707B  ABF9  7D94  D567  C996  A034  00EE  FDD2
0048    2A95  C7F9  0400  E6A8  B181  3128  FC84  11F8
0050    720D  F124  508D  BBED  3568  FC33  B90D  B83B
0058    EE76  E9DE  4A4C  1EA1  0BFF  3F45  A366  1527
0060    41B4  04EB  5794  6EC7  8A6C  4403  D8BC  FAD2
0068    B866  2A84  0EF9  015A  23D3  E6DF  8BED  56E1
0070    5FC1  D3FD  681B  EE07  7236  11AB  746B  5BFD
0078    04F0  28AC  45FF  20F4  04E3  0F13  91C5  11A7
0080    3404  CA44  28C3  9B8F  FA36  056E  31C9  000E
0088    8100  1000  0000  0000  0000  0000  0000  0000
0090    0000  0000  0000  0000  0000  0000  0000  0000

```

***** Duplicate of above data *****

```

00B8    0000  0000  0000  0000  0000  ....  ....  ....

```

Table 5: Hexadecimal dump showing bytes in the order in which they were written.

D. Example: Unpacking the data from the UK0015 records

Table 5 shows that physical record 0 contains 378 bytes (or 3024 bits). The logical record is shorter, so the physical record is padded to the end with 0's.

We ignore the first 36 bits (the record label). The second 36 bits give us NWRDSH, the number of words in the (logical) record. This integer has decimal value 61, as the documentation says it should. There appear, however, to be 65 actual words in the record, 63 of which follow NWRDSH. The remainder of

the record contains BCD characters which we decode as follows, after converting to octal

```
octal  12 23 31 12 27 05 10 27 30 25 24 30 05 05 05 05 05 05 23 06 33 30 ...
BCD    E  N  T  E  R      C  R  S  P  O  S                N  A  V  S  ...
```

Record 1 has a physical length of 126 bytes, but the logical record is shorter. We ignore the first 36 bits (record label). The second 36 bits contains the decimal integer 4, the number of bodies on the tape. The remainder of the record gives the names of the four bodies on the tape. After converting the hexadecimal values to octal, we decode as follows:

```
octal  30 32 23 05 05 05  12 06 27 31 15 05  32 27 06 23 32 30  22 16 27 06 23 11
BCD    S  U  N                E  A  R  T  H          U  R  A  N  U  S  M  I  R  A  N  D
```

Thus the vectors in the data records will be position and velocity of the Sun, position and velocity of the Earth, position and velocity of Uranus, and position and velocity of Miranda -- all with respect to the Voyager 2 spacecraft

Record 2 contains 378 bytes, but the logical record is shorter so there is padding with 0's. We ignore the first 36 bits (record label). The next 36 bits tell us that there should be (decimal) 57 words of data following. The next 72 bits contain the double precision floating point time in seconds (SP1950). The translation is as follows

```
Hexadecimal:      41F87AC662E5EB605A

Binary:
Sign              0
Exponent         10000011111
Mantissa        100001111010110001100110001011100101111010110110000001011010

Decimal:
Sign             +
Exponent        31 (after removing bias)
Mantissa        .5299743...
```

Converted Number = 1138111255.184982468 seconds

Deeper within record 2 we can locate the y-position of Uranus, a negative number. Because the number is negative, we must take the two's complement before we decode. We proceed as follows:

```
Original hexadecimal number:  BED33AFD9F39949BC7

Binary (after two's complement):
Sign              -
Exponent         10000010010
Mantissa        110011000101000000100110000011000110011010110110010000111001

Decimal:
Sign             -
Exponent        18 (after removing bias)
Mantissa        .798...
```

Reconstructed number = -209216.594506910 km

IV. Format of JPL ASCII Tapes:

The following documentation is adapted from JPL Document 618-505, Vol III, Rev B, Appendix A -- an interface agreement between NAV and RSST, dated 20 July 1988 and assigned Control No. NAV-37.

Each file in the ASCII version of the CRS tapes contains several logical records blocked into physical records of 7200 bytes each. There are no special delimiters between logical records in a physical record and there is not necessarily any relationship between logical record boundaries and physical record boundaries.

The size of the CRS file depends on the length of the trajectory processed, the frequency at which records are written, and the number of bodies for which data have been requested.

A hexadecimal dump of parts of the first two records of tape NJ0015 (the Voyager 2 Neptune ORT4 trajectory) follows. Since the dump includes an ASCII translation, no special examples of unpacking are included here.

A. Logical Record 1:

This record identifies and describes the file. Its format is (3I10,3(2X,A8),20X).

Content -----	Type ----	Description -----
NRECS	I	Number of time-tagged vector sets in file
SCID	I	Spacecraft identification number (e.g., 32 for VGR 2)
NBODIS	I	Number of planetary bodies in file (no greater than 4)
CRDATE	C*8	Date of file creation (e.g., 04/06/88)
NAVID	C*8	Nav Team ID for this file (e.g., T880401)
PFID	C*8	Nav Team ID for source P-file

Table A: File identification

B. Logical Record 2:

This record describes the coordinate system and time difference. Format is (A38,D26.18,16X)

Content -----	Type ----	Description -----
LABEL	C*38	Text definition of coordinate system
ETMUTC	DP	Difference between Ephemeris Time and UTC (secs)

Table B: Space and time references

C. Logical Record 3:

This record gives the name of the first body on the tape and several constants that describe it. Its format is (16X,A6,D26.18,2D26.8,5D16.8,3D26.18,2X)

Content -----	Type ----	Description -----
BODY	C*6	Name of planetary body
GM	DP	GM of body
REQ	SP	Mean equatorial radius from oblate spheroid model (km)
RPOL	SP	Polar radius from oblate spheroidal model (km)
RREF	SP	Reference radius for gravity field coefficients (km)
J2	SP	Gravity field coefficient
J4	SP	Gravity field coefficient
J6	SP	Gravity field coefficient
J8	SP	Gravity field coefficient
XNPOL	DP	X component of unit vector to north pole
YNPOL	DP	Y component of unit vector to north pole
ZNPOL	DP	Z component of unit vector to north pole

Table C: Body identification

D. Logical Records 4, 5, 6 (optional):

These records may or may not be present on the tape, depending on how many bodies are represented (NBODIS). There is one record per body; here we have assumed the maximum of 4 bodies in addition to the spacecraft. Format of Logical Records 4-6 is the same as in Logical Record 3.

E. Logical Record 7:

This record gives the Ephemeris Time of the first set of data records. It has format (2I4,2I3,F8.4,D26.18,32X).

Content -----	Type ----	Description -----
YR	I	Ephemeris Time -- year
DOY	I	Ephemeris Time -- day of year
HR	I	Ephemeris Time -- hour
M	I	Ephemeris Time -- minute
S	SP	Ephemeris Time -- seconds
ETSP50	DP	Ephemeris Time -- secs past 0h 1 Jan 1950

Table E: Ephemeris Time

F. Logical Record 8:

This record contains position and velocity vectors for the first body listed (the body described in Logical Record 3) with respect to the reference (spacecraft). It has format (6(3D26.18)).

Content -----	Type ----	Description -----
X	DP	X component of position vector of body (km)
Y	DP	Y component of position vector of body (km)
Z	DP	Z component of position vector of body (km)
DX	DP	X component of velocity vector of body (km)
DY	DP	Y component of velocity vector of body (km)
DZ	DP	Z component of velocity vector of body (km)

Table F: Body state vector

G. Logical Records 9, 10, 11 (optional):

Logical records 9, 10, and 11 give position and velocity information for the bodies described in Logical Records 4, 5, and 6, respectively. If fewer than 4 bodies have been described, only the corresponding data records (position/velocity) will appear. Formats are the same as given for Logical Record 8.

H. Additional Logical Records:

Logical Records 7-11 repeat as needed to fill out the time covered by the CRS tape.

J. Hexadecimal Dump from ASCII CRS Tape:

The following is part of a hexadecimal dump from ASCII CRS tape NJ0015. The first entry on each line is the number of the first word (in hexadecimal). Each four digit number following represents the contents of a 16-bit word. On the right-hand side is an ASCII translation of the line.

By comparing the dump with the descriptions above you can see that this tape contains 1801 data records for Voyager 2; position and velocity vectors are given for 4 bodies -- the Sun, Earth, Neptune, and Triton. The file was created on 7/7/89 from Nav Team P-file I2228. Physical constants are given for the four bodies. The first data record has time tag 1989:218 13:00:56.1831, or 1249563656.18312693 seconds past 1950.0

File	0	Record	0	7200 (1C20 Hex) bytes					
0000	2020	2020	2020	3138	3031	2020	2020	2020	1801
0008	2020	3332	2020	2020	2020	2020	2034	2020	32 4
0010	3037	2F20	372F	3839	2020	5438	3930	3630	07/ 7/89 T89060
0018	3220	2020	4932	3232	3820	2020	2020	2020	2 I2228
0020	2020	2020	2020	2020	2020	2020	2020	2020	
0028	5350	4143	4543	5241	4654	2043	454E	5445	SPACECRAFT CENTE
0030	5245	4420	454D	4535	3020	434F	4F52	4449	RED EME50 COORDI
0038	4E41	5445	5320	2020	2E35	3631	3833	3132	NATES .5618312
0040	3639	3335	3230	3237	3130	302B	3030	3220	69352027100+002
0048	2020	2020	2020	2020	2020	2020	2020	2020	
		*****	Duplicate of above data			*****			
0058	5355	4E20	2020	2020	202E	3133	3237	3132	SUN .132712
0060	3433	3938	3030	3930	3936	3035	2B30	3132	439800909605+012
0068	2020	202E	3639	3630	3030	3030	2B30	3036	.69600000+006
		*****	Duplicate of above data			*****			
0078	2020	202E	3030	3030	3030	3030	2020	2020	.00000000
		*****	Duplicate of above data			*****			
00A0	2020	202E	3132	3139	3630	3331	3231	3238	.121960312128
00A8	3036	3730	3137	2B30	3030	2020	2D2E	3432	067017+000 -.42
00B0	3437	3836	3036	3130	3438	3530	3736	3930	4786061048507690
00B8	2B30	3030	2020	202E	3839	3730	3430	3935	+000 .89704095

00C0	3537	3232	3333	3230	3031	2B30	3030	2020	5722332001+000
00C8	2020	2020	2020	2020	2020	2020	2020	2020	
00D0	4541	5254	4820	2020	202E	3339	3836	3030	EARTH .398600
00D8	3434	3230	3237	3739	3430	3538	2B30	3036	442027794058+006
00E0	2020	202E	3633	3738	3134	3030	2B30	3034	.63781400+004
00E8	2020	202E	3633	3536	3735	3532	2B30	3034	.63567552+004
00F0	2020	202E	3633	3738	3134	3030	2B30	3034	.63781400+004
00F8	2020	202E	3130	3832	3632	3730	2D30	3032	.10826270-002
0100	2020	2D2E	3136	3233	3334	3937	2D30	3035	-.16233497-005
0108	2020	202E	3534	3234	3837	3830	2D30	3036	.54248780-006
0110	2020	2D2E	3230	3737	3235	3534	2D30	3036	-.20772554-006
0118	2020	202E	3338	3437	3235	3439	3634	3035	.384725496405
0120	3733	3536	3132	2D30	3032	2020	2D2E	3137	735612-002 -.17
0128	3032	3437	3033	3331	3131	3038	3136	3931	0247033111081691
0130	2D30	3034	2020	202E	3939	3939	3932	3539	-004 .99999259
0138	3431	3232	3838	3636	3538	2B30	3030	2020	4122886658+000
0140	2020	2020	2020	2020	2020	2020	2020	2020	
0148	4E45	5054	554E	2020	202E	3638	3233	3436	NEPTUN .682346
0150	3936	3930	3037	3531	3236	3431	2B30	3037	969007512641+007
0158	2020	202E	3234	3738	3130	3030	2B30	3035	.24781000+005
0160	2020	202E	3234	3239	3238	3134	2B30	3035	.24292814+005
0168	2020	202E	3235	3232	3530	3030	2B30	3035	.25225000+005
0170	2020	202E	3335	3836	3931	3132	2D30	3032	.35869112-002
0178	2020	202E	3030	3030	3030	3030	2020	2020	.00000000

***** Duplicate of above data *****

0190	2020	202E	3335	3331	3138	3233	3731	3037	.353118237107
0198	3939	3231	3732	2B30	3030	2020	2D2E	3636	992172+000 -.66
01A0	3135	3832	3130	3438	3631	3733	3632	3938	1582104861736298
01A8	2B30	3030	2020	202E	3636	3135	3235	3937	+000 .66152597
01B0	3936	3338	3039	3936	3730	2B30	3030	2020	9638099670+000
01B8	2020	2020	2020	2020	2020	2020	2020	2020	
01C0	5452	4954	4F4E	2020	202E	3238	3030	3030	TRITON .280000
01C8	3030	3030	3030	3030	3030	3030	2B30	3034	000000000000+004
01D0	2020	202E	3135	3030	3030	3030	2B30	3034	.15000000+004

***** Duplicate of above data *****

01E0	2020	202E	3030	3030	3030	3030	2020	2020	.00000000
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***** Duplicate of above data *****

0208	2020	2D2E	3430	3633	3836	3332	3332	3733	-.406386323273
0210	3138	3139	3135	2B30	3030	2020	202E	3834	181915+000 .84
0218	3535	3431	3130	3436	3734	3333	3932	3934	5541104674339294
0220	2B30	3030	2020	2D2E	3334	3632	3830	3739	+000 -.34628079
0228	3435	3930	3731	3135	3934	2B30	3030	2020	4590711594+000
0230	3139	3839	2032	3138	2031	3320	2030	2035	1989 218 13 0 5
0238	362E	3138	3331	2020	202E	3132	3439	3536	6.1831 .124956
0240	3336	3536	3138	3331	3236	3933	2B30	3130	365618312693+010
0248	2020	2020	2020	2020	2020	2020	2020	2020	

***** Duplicate of above data *****

0258	2020	2D2E	3832	3332	3833	3535	3234	3637	-.823283552467
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0260	3834	3835	3630	2B30	3039	2020	202E	3430	848560+009	.40
0268	3830	3337	3133	3333	3933	3734	3137	3935	8037133393741795	
0270	2B30	3130	2020	202E	3136	3933	3239	3337	+010	.16932937
0278	3936	3832	3534	3835	3232	2B30	3130	2020	9682548522+010	
0280	2020	2D2E	3132	3538	3630	3337	3539	3630	-	.125860375960
0288	3731	3831	3230	2B30	3032	2020	202E	3133	718120+002	.13
0290	3133	3037	3833	3336	3835	3030	3635	3733	1307833685006573	
0298	2B30	3032	2020	202E	3439	3835	3437	3230	+002	.49854720
02A0	3538	3730	3032	3933	3736	2B30	3031	2020	5870029376+001	
02A8	2020	2D2E	3731	3838	3635	3839	3335	3639	-	.718865893569
02B0	3438	3437	3939	2B30	3039	2020	202E	3339	484799+009	.39
02B8	3739	3337	3832	3531	3933	3636	3035	3731	7937825193660571	
02C0	2B30	3130	2020	202E	3136	3439	3530	3437	+010	.16495047
02C8	3633	3633	3337	3932	3239	2B30	3130	2020	6363379229+010	
02D0	2020	202E	3835	3339	3131	3836	3232	3533		.853911862253
02D8	3636	3935	3830	2B30	3031	2020	202E	3331	669580+001	.31
02E0	3835	3331	3534	3339	3536	3433	3236	3936	8531543956432696	
02E8	2B30	3032	2020	202E	3133	3130	3338	3635	+002	.13103865
02F0	3338	3739	3137	3235	3438	2B30	3032	2020	3879172548+002	
02F8	2020	202E	3131	3736	3232	3731	3638	3139		.117622716819
0300	3437	3236	3435	2B30	3038	2020	2D2E	3232	472645+008	-.22
0308	3834	3832	3034	3831	3032	3838	3331	3331	8482048102883131	
0310	2B30	3038	2020	2D2E	3835	3534	3335	3535	+008	-.85543555
0318	3136	3033	3838	3437	3031	2B30	3037	2020	1603884701+007	
0320	2020	2D2E	3732	3837	3834	3532	3439	3431	-	.728784524941
0328	3234	3638	3333	2B30	3031	2020	202E	3134	246833+001	.14
0330	3134	3036	3436	3339	3530	3630	3834	3635	1406463950608465	
0338	2B30	3032	2020	202E	3532	3636	3936	3231	+002	.52669621
0340	3832	3438	3837	3139	3632	2B30	3031	2020	8248871962+001	
0348	2020	202E	3132	3037	3533	3732	3239	3633		.120753722963
0350	3635	3832	3635	2B30	3038	2020	2D2E	3232	658265+008	-.22
0358	3735	3339	3337	3335	3730	3137	3637	3531	7539373570176751	
0360	2B30	3038	2020	2D2E	3836	3931	3336	3938	+008	-.86913698
0368	3736	3538	3436	3337	3935	2B30	3037	2020	7658463795+007	
0370	2020	2D2E	3833	3135	3933	3039	3336	3733	-	.831593093673
0378	3039	3533	3030	2B30	3031	2020	202E	3132	095300+001	.12
0380	3131	3030	3438	3935	3736	3438	3535	3133	1100489576485513	
0388	2B30	3032	2020	202E	3135	3134	3937	3134	+002	.15149714
0390	3836	3533	3731	3235	3135	2B30	3031	2020	8653712515+001	
0398	3139	3839	2032	3138	2031	3320	2031	2035	1989 218 13 1 5	
03A0	362E	3138	3331	2020	202E	3132	3439	3536	6.1831	.124956
03A8	3337	3136	3138	3331	3236	3933	2B30	3130	371618312693+010	
03B0	2020	2020	2020	2020	2020	2020	2020	2020		

***** Duplicate of above data *****

03C0	2020	2D2E	3832	3332	3834	3330	3736	3330	-	.823284307630
03C8	3130	3934	3036	2B30	3039	2020	202E	3430	109406+009	.40
03D0	3830	3337	3231	3231	3738	3434	3233	3730	8037212178442370	
03D8	2B30	3130	2020	202E	3136	3933	3239	3430	+010	.16932940
03E0	3935	3935	3338	3039	3639	2B30	3130	2020	9595380969+010	
03E8	2020	2D2E	3132	3538	3630	3337	3736	3534	-	.125860377654
03F0	3638	3832	3939	2B30	3032	2020	202E	3133	688299+002	.13
03F8	3133	3037	3833	3439	3032	3237	3337	3836	1307834902273786	
0400	2B30	3032	2020	202E	3439	3835	3437	3230	+002	.49854720
0408	3930	3036	3531	3935	3137	2B30	3031	2020	9006519517+001	

0410	2020	2D2E	3731	3838	3635	3338	3132	3239	- .718865381229
0418	3536	3735	3631	2B30	3039	2020	202E	3339	567561+009 .39
0420	3739	3338	3031	3633	3133	3237	3734	3335	7938016313277435
0428	2B30	3130	2020	202E	3136	3439	3530	3535	+010 .16495055
0430	3439	3836	3837	3035	3035	2B30	3130	2020	4986870505+010
0438	2020	202E	3835	3338	3837	3836	3138	3237	.853887861827
0440	3034	3938	3436	2B30	3031	2020	202E	3331	049846+001 .31
0448	3835	3333	3834	3535	3835	3238	3233	3333	8533845585282333
0450	2B30	3032	2020	202E	3133	3130	3339	3635	+002 .13103965
0458	3033	3731	3130	3638	3939	2B30	3032	2020	0371106899+002
0460	2020	202E	3131	3736	3138	3334	3431	3132	.117618344112
0468	3630	3434	3131	2B30	3038	2020	2D2E	3232	604411+008 -.22
0470	3834	3733	3536	3337	3134	3739	3934	3539	8473563714799459
0478	2B30	3038	2020	2D2E	3835	3534	3033	3934	+008 -.85540394
0480	3938	3331	3831	3733	3733	2B30	3037	2020	9831817373+007
0488	2020	2D2E	3732	3837	3834	3433	3131	3430	-.728784431140
0490	3732	3733	3637	2B30	3031	2020	202E	3134	727367+001 .14
0498	3134	3036	3437	3231	3731	3037	3635	3638	1406472171076568
04A0	2B30	3032	2020	202E	3532	3636	3936	3138	+002 .52669618
04A8	3339	3831	3534	3839	3937	2B30	3031	2020	3981548997+001
04B0	2020	202E	3132	3037	3438	3733	3235	3432	.120748732542
04B8	3037	3435	3836	2B30	3038	2020	2D2E	3232	074586+008 -.22
04C0	3735	3332	3130	3738	3030	3338	3633	3535	7532107800386355
04C8	2B30	3038	2020	2D2E	3836	3931	3237	3839	+008 -.86912789
04D0	3430	3530	3334	3630	3533	2B30	3037	2020	4050346053+007
04D8	2020	2D2E	3833	3138	3830	3735	3830	3434	-.831880758044
04E0	3239	3632	3939	2B30	3031	2020	202E	3132	296299+001 .12
04E8	3130	3931	3833	3836	3337	3131	3030	3539	1091838637110059
04F0	2B30	3032	2020	202E	3135	3136	3233	3135	+002 .15162315
04F8	3633	3731	3031	3034	3338	2B30	3031	2020	6371010438+001
0500	3139	3839	2032	3138	2031	3320	2032	2035	1989 218 13 2 5
0508	362E	3138	3331	2020	202E	3132	3439	3536	6.1831 .124956
0510	3337	3736	3138	3331	3236	3933	2B30	3130	377618312693+010
0518	2020	2020	2020	2020	2020	2020	2020	2020	

***** Duplicate of above data *****

0528	2020	2D2E	3832	3332	3835	3036	3237	3932	-.823285062792
0530	3338	3034	3137	2B30	3039	2020	202E	3430	380417+009 .40
0538	3830	3337	3239	3039	3633	3134	3336	3737	8037290963143677
0540	2B30	3130	2020	202E	3136	3933	3239	3433	+010 .16932943
0548	3935	3038	3231	3336	3033	2B30	3130	2020	9508213603+010
0550	2020	2D2E	3132	3538	3630	3337	3933	3438	-.125860379348
0558	3833	3739	3338	2B30	3032	2020	202E	3133	837938+002 .13
0560	3133	3037	3833	3631	3139	3839	3230	3331	1307836119892031
0568	2B30	3032	2020	202E	3439	3835	3437	3231	+002 .49854721
0570	3231	3434	3332	3738	3838	2B30	3031	2020	2144327888+001
0578	2020	2D2E	3731	3838	3634	3836	3839	3034	-.718864868904
0580	3035	3036	3637	2B30	3039	2020	202E	3339	050667+009 .39
0588	3739	3338	3230	3734	3334	3237	3532	3637	7938207434275267
0590	2B30	3130	2020	202E	3136	3439	3530	3633	+010 .16495063
0598	3336	3130	3935	3936	3732	2B30	3130	2020	3610959672+010
05A0	2020	202E	3835	3338	3633	3836	3131	3036	.853863861106
05A8	3930	3432	3933	2B30	3031	2020	202E	3331	904293+001 .31
05B0	3835	3336	3134	3731	3837	3333	3031	3039	8536147187330109
05B8	2B30	3032	2020	202E	3133	3130	3430	3634	+002 .13104064

05C0	3638	3531	3231	3536	3036	2B30	3032	2020	6851215606+002
05C8	2020	202E	3131	3736	3133	3937	3134	3036	.117613971406
05D0	3239	3839	3036	2B30	3038	2020	2D2E	3232	298906+008 -.22
05D8	3834	3635	3037	3933	3236	3232	3236	3837	8465079326222687
05E0	2B30	3038	2020	2D2E	3835	3533	3732	3334	+008 -.85537234
05E8	3830	3631	3830	3835	3835	2B30	3037	2020	8061808585+007
05F0	2020	2D2E	3732	3837	3834	3333	3733	3635	-.728784337365
05F8	3435	3937	3935	2B30	3031	2020	202E	3134	459795+001 .14
0600	3134	3036	3438	3033	3837	3239	3637	3332	1406480387296732
0608	2B30	3032	2020	202E	3532	3636	3936	3134	+002 .52669614
0610	3936	3330	3735	3537	3538	2B30	3031	2020	9630755758+001
0618	2020	202E	3132	3037	3433	3734	3033	3934	.120743740394
0620	3637	3630	3339	2B30	3038	2020	2D2E	3232	676039+008 -.22
0628	3735	3234	3834	3235	3439	3331	3631	3231	7524842549316121
0630	2B30	3038	2020	2D2E	3836	3931	3138	3739	+008 -.86911879
0638	3238	3735	3536	3634	3739	2B30	3037	2020	2875566479+007
0640	2020	2D2E	3833	3231	3638	3336	3532	3635	-.832168365265
0648	3533	3332	3431	2B30	3031	2020	202E	3132	533241+001 .12
0650	3130	3833	3139	3839	3036	3036	3330	3530	1083198906063050
0658	2B30	3032	2020	202E	3135	3137	3439	3337	+002 .15174937
0660	3037	3138	3431	3534	3739	2B30	3031	2020	0718415479+001
0668	3139	3839	2032	3138	2031	3320	2033	2035	1989 218 13 3 5
0670	362E	3138	3331	2020	202E	3132	3439	3536	6.1831 .124956
0678	3338	3336	3138	3331	3236	3933	2B30	3130	383618312693+010
0680	2020	2020	2020	2020	2020	2020	2020	2020	

***** Duplicate of above data *****

0690	2020	2D2E	3832	3332	3835	3831	3739	3534	-.823285817954
0698	3636	3135	3932	2B30	3039	2020	202E	3430	661592+009 .40
06A0	3830	3337	3336	3937	3437	3834	3537	3134	8037369747845714
06A8	2B30	3130	2020	202E	3136	3933	3239	3436	+010 .16932946

... Continuation of Record 0 ...

0D48	2020	2D2E	3833	3336	3035	3533	3835	3734	-.833605538574
0D50	3139	3732	3636	2B30	3031	2020	202E	3132	197266+001 .12
0D58	3130	3430	3136	3835	3431	3631	3233	3132	1040168541612312
0D60	2B30	3032	2020	202E	3135	3233	3833	3533	+002 .15238353
0D68	3934	3530	3037	3632	3933	2B30	3031	2020	9450076293+001
0D70	3139	3839	2032	3138	2031	3320	2038	2035	1989 218 13 8 5
0D78	362E	3138	3331	2020	202E	3132	3439	3536	6.1831 .124956
0D80	3431	3336	3138	3331	3236	3933	2B30	3130	413618312693+010
0D88	2020	2020	2020	2020	2020	2020	2020	2020	

***** Duplicate of above data *****

0D98	2020	2D2E	3832	3332	3839	3539	3337	3636	-.823289593766
0DA0	3231	3939	3931	2B30	3039	2020	202E	3430	219991+009 .40
0DA8	3830	3337	3736	3336	3731	3336	3638	3639	8037763671366869
0DB0	2B30	3130	2020	202E	3136	3933	3239	3631	+010 .16932961
0DB8	3839	3835	3231	3333	3638	2B30	3130	2020	8985213368+010
0DC0	2020	2D2E	3132	3538	3630	3338	3935	3137	-.125860389517
0DC8	3530	3535	3638	2B30	3032	2020	202E	3133	505568+002 .13
0DD0	3133	3037	3834	3334	3332	3937	3533	3432	1307843432975342
0DD8	2B30	3032	2020	202E	3439	3835	3437	3233	+002 .49854723

0DE0	3039	3938	3836	3931	3237	2B30	3031	2020	0998869127+001
0DE8	2020	2D2E	3731	3838	3631	3739	3532	3533	-.718861795253
0DF0	3336	3633	3834	2B30	3039	2020	202E	3339	366384+009 .39
0DF8	3739	3339	3335	3431	3839	3236	3137	3231	7939354189261721
0E00	2B30	3130	2020	202E	3136	3439	3531	3130	+010 .16495110
0E08	3533	3638	3035	3030	3032	2B30	3130	2020	5368050002+010

File 0 Record 1 7200 (1C20 Hex) bytes

0000	2020	202E	3835	3337	3139	3835	3036	3232	.853719850622
0008	3331	3938	3037	2B30	3031	2020	202E	3331	319807+001 .31
0010	3835	3439	3935	3632	3336	3736	3631	3130	8549956236766110
0018	2B30	3032	2020	202E	3133	3130	3436	3632	+002 .13104662
0020	3534	3833	3532	3535	3931	2B30	3032	2020	5483525591+002
0028	2020	202E	3131	3735	3837	3733	3531	3830	.117587735180
0030	3237	3436	3232	2B30	3038	2020	2D2E	3232	274622+008 -.22
0038	3834	3134	3137	3239	3834	3432	3132	3232	8414172984421222
0040	2B30	3038	2020	2D2E	3835	3531	3832	3733	+008 -.85518273
0048	3734	3835	3236	3535	3733	2B30	3037	2020	7485265573+007
0050	2020	2D2E	3732	3837	3833	3737	3532	3437	-.728783775247
0058	3739	3737	3930	2B30	3031	2020	202E	3134	797790+001 .14
0060	3134	3036	3532	3935	3935	3330	3433	3431	1406529595304341
0068	2B30	3032	2020	202E	3532	3636	3935	3934	+002 .52669594
0070	3137	3734	3734	3236	3032	2B30	3031	2020	1774742602+001
0078	2020	202E	3132	3037	3133	3735	3132	3837	.120713751287
0080	3436	3833	3837	2B30	3038	2020	2D2E	3232	468387+008 -.22
0088	3734	3831	3236	3138	3938	3332	3936	3736	7481261898329676
0090	2B30	3038	2020	2D2E	3836	3930	3634	3032	+008 -.86906402
0098	3632	3333	3131	3535	3239	2B30	3037	2020	6233115529+007
00A0	2020	2D2E	3833	3338	3932	3739	3935	3637	-.833892799567
00A8	3238	3431	3635	2B30	3031	2020	202E	3132	284165+001 .12
00B0	3130	3331	3539	3631	3539	3936	3330	3438	1031596159963048
00B8	2B30	3032	2020	202E	3135	3235	3130	3939	+002 .15251099
00C0	3231	3032	3335	3632	3233	2B30	3031	2020	2102356223+001
00C8	3139	3839	2032	3138	2031	3320	2039	2035	1989 218 13 9 5
00D0	362E	3138	3331	2020	202E	3132	3439	3536	6.1831 .124956
00D8	3431	3936	3138	3331	3236	3933	2B30	3130	419618312693+010
00E0	2020	2020	2020	2020	2020	2020	2020	2020	

***** Duplicate of above data *****

00F0	2020	2D2E	3832	3332	3930	3334	3839	3238	-.823290348928
00F8	3536	3231	3832	2B30	3039	2020	202E	3430	562182+009 .40
0100	3830	3337	3834	3234	3536	3037	3332	3934	8037842456073294
0108	2B30	3130	2020	202E	3136	3933	3239	3634	+010 .16932964
0110	3838	3938	3034	3733	3232	2B30	3130	2020	8898047322+010
0118	2020	2D2E	3132	3538	3630	3339	3132	3132	-.125860391212

... Continuation of Record 1 ...

Table J: Hexadecimal dump from ASCII CRS tape NJ0015

Appendix A

A.I: Hexadecimal Dump: First Three Records of Tape UK0015 (byte order)

The first entry on each line is the number of the first byte (in decimal, starting from 0). Each two digit character following represents the contents of an 8-bit byte. Except for formatting, this is the same dump as in Table 5.

In Record 0, the first 36 bits contain the record label, the second 36 bits contain NWRDSH, and subsequent bits contain 6-bit "fingerprint" characters. Boundaries for the first 50 characters are shown below, highlighted in yellow in alternating groups of ten.

Begin Record 0

```

      record label          NWRDSH          fingerprints 1-10
0000000 00 0f 81 00 10 00 00 00 3d 29 36 4a 5c 52 17 61

      fingerprints 11-20          fingerprints 21-30
0000016 55 18 14 51 45 14 54 c6 6d 84 85 14 51 45 14 5c

      fingerprints 31-40          fingerprints 41-50          ...
0000032 35 c7 6e 36 c7 0d 37 cb 5c 32 c7 7e 34 c7 1c b3

0000048 d7 81 45 14 51 45 21 76 15 51 86 45 14 51 45 14

0000064 51 45 14 51 45 14 51 45 14 51 45 14 51 45 14 51

0000080 45 14 51 45 14 51 45 14 51 45 14 51 45 14 51 45

0000096 14 51 45 14 51 45 14 51 45 14 51 45 14 51 45 14

0000112 5a 28 a0 56 91 50 84 05 a2 8a 05 84 55 08 64 5e

0000128 35 14 51 45 14 51 45 14 51 45 14 51 45 14 51 45

0000144 14 51 45 14 51 45 14 51 45 14 51 45 14 51 45 14
```

```

0000160    51  45  14  51  45  14  51  45  14  51  45  14  51  45  14  51
0000176    45  14  51  45  14  51  45  14  51  45  14  51  45  14  51  45
0000192    14  51  45  14  51  45  14  51  45  14  51  45  14  51  45  14
0000208    51  45  14  51  45  14  51  45  14  51  45  14  51  45  14  51
0000224    45  14  51  45  14  51  45  14  51  45  14  51  45  14  51  45
0000240    14  51  45  14  51  45  14  51  45  14  51  45  14  51  45  14
0000256    51  45  14  51  45  14  51  45  14  51  45  14  51  45  14  51
0000272    45  14  51  45  14  51  45  14  51  45  14  5f  88  ee  60  92
0000288    00  0f  81  00  10  00  00  00  00  00  00  00  00  00  00  00
0000304    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
                ***** Duplicate of above data *****
0000368    00  00  00  00  00  00  00  00  00  00                                End Record 0

```

In Record 1, the first 36 bits contain the record label, the second 36 bits contain NWRDS, and subsequent bits contain 6-bit character strings identifying the bodies in the data records. For example, the name of target 1 is given by the hex string 0x61a4c5145. Converted to 6-bit strings, this is 011000 011010 010011 000101 000101 000101 or, using the conversions in Figure 1, "SUN ".

```

                                record label
Begin Record 1                00 01 41 00 10 00

NWRDS          target 1      target 2      target 3
0000384      00 00 04  61 a4 c5 14 52 86 5d 93 45  69 71 93 69

                                target 4
0000400      84 8e 5c 64 c9 3c 61 f7 ff 00 00 14 10 01 00 00

0000416      00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

                ***** Duplicate of above data *****

0000496      00 00 00 00 00 00 00 00                                End Record 1

```

In Record 2 and later, the first 36 bits contain the record label and the second 36 bits contain NWRDSD. Those and other fields are identified in the lines below, where alternating fields have been highlighted in yellow. Note that numeric fields often split 8-bit bytes; all 72-bit floating point position and velocity fields split a byte at both the beginning and end of their ranges.

```

                                record label          NWRDSD
Begin Record 2                00 0e 81 00 10 00 00 00

                                SP1950          JULDAT
0000512      39  41 f8 7a c6 62 e5 eb 60 5a 41 69 55 1d c5 5f

                                GREDAT1          GREDAT2
0000528      cc 4c 6c  07 66 01 ba 80 53 7a b9 a9  40 6d cb d6

                                ETMUTC          IRECFL          SUN-X
0000544      c0 c0 8d b6 5f 00 00 00 00 04 1e 8b 08 5d 49 36

                                SUN-y
0000560      15 44 e4 20 99 10 ac bb 51 4b e0 34 1f 85 27 3b

                                SUN-z          SUN-vx
0000576      29 dc c2 6a cb fc 14 33 45 13 63 21 81 d4 05 81

                                SUN-vy          SUN-vz
0000592      c2 4d ae 32 be 75 04 03 f0 f5 5b d6 03 04 58 34

                                EARTH-x          EARTH-y
0000608      1d ef 02 0f e7 8b c2 64 d4 20 9f c1 ee df 11 ff

```

0000624 *EARTH-z* *EARTH-vx*
9d f4 1f 8a f4 f1 3c 77 de 98 1b f9 7d 99 ef bd

0000640 *EARTH-vy*
e9 11 73 34 00 ec df f3 58 43 a7 3f 04 00 e5 f4

0000656 *EARTH-vz* *URANUS-x*
8a c1 a2 b5 26 04 11 f8 9f 10 15 f1 fb fb 5b ed

0000672 *URANUS-y* *URANUS-z*
33 af d9 f3 99 49 bc 7b ee 75 53 92 f4 e8 ca 6d

0000688 *URANUS-vx* *URANUS-vy*
0b ff 40 a6 ea 90 2a 9d 96 94 04 eb 33 6c d7 eb

0000704 *URANUS-vz*
6e 86 84 03 d8 a4 7a 7c 38 3a ad 54 0f 80 31 c3

0000720 *MIRANDA-x* *MIRANDA-y*
82 cb 7b 30 4b ed 55 37 9b 71 98 fb a1 2b ee 04

0000736 *MIRANDA-z* *MIRANDA-vx*
7c 59 e0 fc 74 78 ab fd 03 03 ea e3 d4 02 30 e4

0000752 *MIRANDA-vy* *MIRANDA-vz*
04 e3 17 be 0b ba 5a b9 d4 04 c9 ec df ab 4e e1

0000768 *undefined*
8a 75 f0 0d c6 8b 00 0e 81 00 10 00 00 00 00 00

0000784 *undefined*
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

***** Duplicate of above data *****

0000880 00 00

End Record 2

A.II: Hexadecimal Dump: First Three Records of Tape UK0015 (LSB 32-bit word order)

On an LSB computer -- which is by far the most common today (ca. 2024) -- bytes appear in different order when read into an array with 16 or 32 bit elements. The lines below show a hexadecimal dump of the first three records from UK0015 when presented as array contents assumed to be 32-bit integers.

Yellow highlighting shows the location of bits in the Record 0 record label (compare with the hex dump in Section A.I); semi-bytes (4 bits) in NWRDSH are underlined. Asterisks show the semi-bytes holding the sign bit (assuming these are 36-bit integers).

The value of NWRDSH (underlined) can be recovered by placing the bits in the order

abcdefghi = 00000003d

which has a value 61, as stated in Section II.D.

Begin Record 0:

		*	fgdebc a	hi	
0000000	00810f00	*	000000 <u>10</u>	4a36293d	6117525c
			-----	--	
0000016	51141855		c6541445	1485846d	5c144551
0000032	366ec735		cb370dc7	7ec7325c	b31cc734
0000048	144581d7		76214551	45865115	14455114
0000064	51144551		45511445	14455114	51144551
0000080	45511445		14455114	51144551	45511445
0000096	14455114		51144551	45511445	14455114
0000112	56a0285a		05845091	84058aa2	5e640855
0000128	45511435		14455114	51144551	45511445
0000144	14455114		51144551	45511445	14455114
0000160	51144551		45511445	14455114	51144551

0000176	45511445	14455114	51144551	45511445
0000192	14455114	51144551	45511445	14455114
0000208	51144551	45511445	14455114	51144551
0000224	45511445	14455114	51144551	45511445
0000240	14455114	51144551	45511445	14455114
0000256	51144551	45511445	14455114	51144551
0000272	45511445	14455114	5f144551	9260ee88
0000288	00810f00	00000010	00000000	00000000
0000304	00000000	00000000	00000000	00000000

***** Duplicate of above data *****

In Record 1, the highlighting and underlining is repeated for the record label and NWRDS. NWRDS can be reconstructed by arranging the semi-bytes in the order

abcdefghi = 000000004

which has value 4 – the number of bodies described in the data records.

Begin Record 1:

0000368	00000000	00000000	<u>0100</u> 0000	bc a 00 <u>100041</u> -- -
0000384	hifgde 61040000 -----	5214c5a4	45935d86	69937169
0000400	645c8e84	f7613cc9	140000ff	00000110
0000416	00000000	00000000	00000000	00000000

***** Duplicate of above data *****

In Record 2, the highlighting and underlining are repeated. The value of NWRDSD (underlined) can be extracted by rearranging the semi-bytes in the order

abcdefghi = 000000039

NWRDSD has decimal value 57, which agrees with the value in Table 4. Selected values are summarized in Table K.

Quantity	LSB ARRAY Contents		Extracted Hex	Decimal Equivalent
NWRDS	00000010	7af84139	000000039	57
SP1950	7af84139	ebe562c6 69415a60	41f87ac662e5eb605a	1138111255.184983
JULDAT	69415a60	5fc51d55 076c4ccc	4169551dc55fcc4c6c	2446455.083972
SUN-vx	3314fccb	21631345 8105d481	bfc14334513632181d	-7.3687414761870542

Table K: Selected values extracted from UK0015 record 2.

Begin Record 2

0000496			* * 00810e00	* fgdebc a 00000010 -----
0000512	hi 7af84139 --	ebe562c6	69415a60	5fc51d55
0000528	076c4ccc	80ba0166	a9b97a53	d6cb6d40
0000544	b68dc0c0	0000005f	8b1e0400	36495d08
0000560	20e44415	bbac1099	34e04b51	3b27851f
0000576	6ac2dc29	3314fccb	21631345	8105d481
0000592	32ae4dc2	030475be	d65bf5f0	34580403
0000608	0f02ef1d	64c28be7	c19f20d4	ff11dfee
0000624	8a1ff49d	773cf1f4	f91b98de	bdef997d

0000640	347311e9	f3dfec00	3fa74358	f4e50004
0000656	b5a2c18a	f8110426	f115109f	ed5bfbfb
0000672	f3d9af33	7bbc4999	925375ee	6dcae8f4
0000688	a640ff0b	9d2a90ea	eb049496	ebd76c33
0000704	0384866e	7c7aa4d8	54ad3a38	c331800f
0000720	307bcb82	3755ed4b	fb98719b	04ee2ba1
0000736	fce0597c	fdab7874	e3ea0303	e43002d4
0000752	be17e304	b95aba0b	ecc904d4	e14eabdf
0000768	0df0758a	0e008bc6	00100081	00000000
0000784	00000000	00000000	00000000	00000000

***** Duplicate of above data *****

Dick Simpson
orig: various 1985
rev: 10 Dec 1987
rev: 17 Aug 1989
rev: 12 Jun 2024