Interpretation and Use of Binary TRK-2-34 Data

This document (and its associated files) describes and illustrates extraction of values from binary files generated according to the NASA JPL Deep Space Network (DSN) Tracking System Data Archival Format Software Interface Specification (SIS):

[1] *TRK-2-34 DSMS Tracking System Data Archival Format, Deep Space Mission System (DSMS) External Interface Specification 820-013 (JPL D-16765), Revision B, released 2002-12-15.*

[2] *TRK-2-34 DSN Tracking System Data Archival Format, Deep Space Network (DSN) External Interface Specification 820-013 (JPL D-16765), Revision J-1, released 2008-02-29.*

[3] *TRK-2-34 DSN Tracking System Data Archival Format, Deep Space Network (DSN) External Interface Specification 820-013 (JPL D-16765), Revision N, released 2013-11-07.*

[4] *TRK-2-34 DSN Tracking System Data Archival Format, Deep Space Network (DSN) External Interface Specification 820-013 (JPL D-16765), Revision O, released 2015-10-27.*

[5] *TRK-2-34 DSN Tracking System Data Archival Format, Deep Space Network (DSN) External Interface Specification 820-013 (JPL D-16765), Revision P, released 2017-05-03.*

Being the most recent, [5] has been chosen for illustration here; the differences among the versions are small. Readers can examine the Change Log in each version for details; the Change Log is cumulative, so the Change Log in [5] is the most comprehensive. Readers should be aware, however, that documentation updates are not synchronized with changes in the radio tracking system hardware and software, though major upgrades would presumably trigger a new TRK-2-34 release. Revision P [5] is a 'best efforts' description of the system output as of approximately 2017-05-03.

Each TRK-2-34 data file (sometimes also known as a Tracking and Navigation File, or TNF) is binary. It consists of records of uplink, downlink, derived, interferometric, and/or filtered data in up to 18 different formats (data types 0 through 17), ordered chronologically and containing parameters of potential interest to different user communities. For archiving, the records have been sorted into blocks of constant data type; the blocks have then been concatenated into a new file, ordered by data type. Within each block of constant data type, the records remain in chronological order. The contents of the new and original files are identical except for the record order.

We have chosen an example TNF from the MAVEN mission; the data were collected on 2019-07-24 at DSS 65, near Madrid, Spain. The data file (*tnfp.dat*) contains blocks with data types 0, 1, 9, 16, and 17; this set of blocks is representative of the output from a nominal DSN tracking pass. The file is described by its detached PDS label (*tnfp.xml*), which specifies the file, block, record, and field structures. The same data file may be found in the PDS system under logical identifier (LID)

urn:nasa:pds:maven.rose.raw:data.tnf:mvn_rse_l0_tnf_20190724t113015

Software has been written to unpack records with these five data types; the unpacked values have been included here in five files in comma-separate variable (CSV) format; for example, *tnfp09.csv* contains the contents of all records with data type 9.

The general structure of a binary TRK-2-34 record is shown in Figure 1 below.

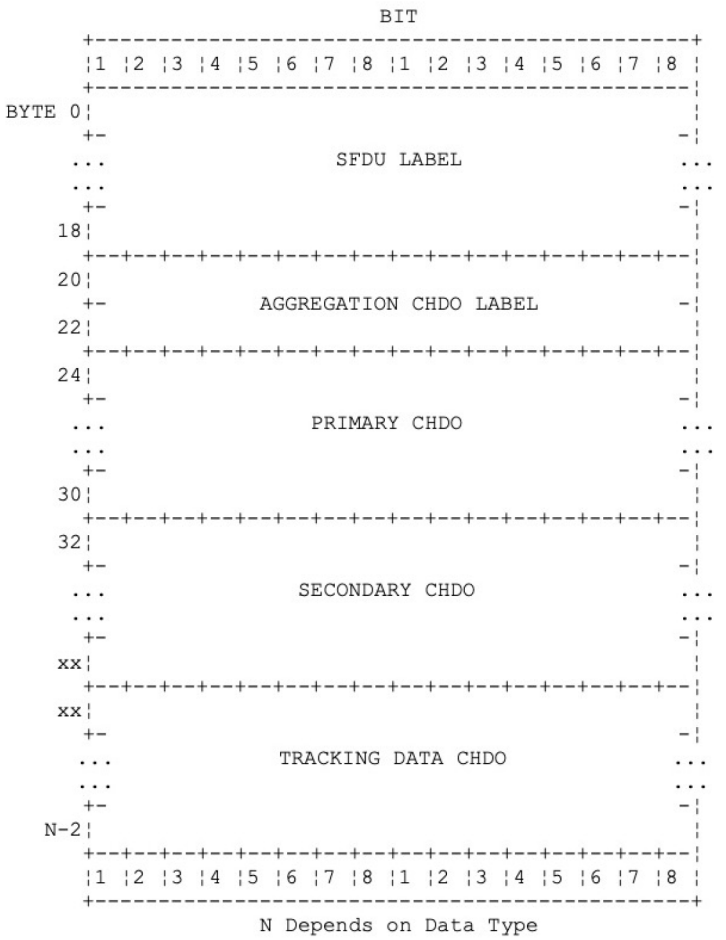

Figure 1. Structure of a single record in a TRK-2-34 binary file (adapted from Figure 3-2 in [5]).

The SFDU Label, Aggregation Compressed Header Data Object (CHDO) Label, and Primary CHDO have fixed structure. The length and contents of the Secondary CHDO depend on which of five broad classes of data the record contains (Table 1).

Table 1 – TRK-2-34 Data Classes and Types

Data Class	Secondary CHDO Type	Data Types	Secondary CHDO Length (bytes)
Uplink	132	0, 2, 4, 9	70
Downlink	133	1, 3, 5	114
Derived	134	6, 7, 8, 11, 14, 15, 16, 17	128
Interferometric	135	10	92
Filtered	136	12, 13	102

The Tracking Data CHDO structure and content is unique to each of the 18 data types. Table 2 provides a summary, including references to the tables in [5] where detailed information can be found about the components of a record for each data type. For example, the complete structure of a record with data type 9 in its Tracking Data CHDO is given by Tables 3-1, 3-2, 3-3, 3-5, and 3-12.

Table 2 – TRK-2-34 Record Structure by Data Type

		Tables in [5] Specifying Structure and Content				
Data Type	**Description**	**SFDU Label**	**Aggregation CHDO Label**	**Primary CHDO**	**Secondary CHDO**	**Tracking Data CHDO**
0	Uplink Carrier Phase	3-1	3-2	3-3	3-5	3-9
1	Downlink Carrier Phase				3-6	3-13
2	Uplink Sequential Ranging Phase				3-5	3-10
3	Downlink Sequential Ranging Phase				3-6	3-14
4	Uplink PN Ranging Phase				3-5	3-11
5	Downlink PN Ranging Phase				3-6	3-15
6	Doppler Count				3-4	3-16
7	Sequential Range				3-4	3-17
8	Angle				3-4	3-18
9	Ramp				3-5	3-12
10	VLBI				3-7	3-24
11	DRVID				3-4	3-19
12	Smoother Noise				3-8	3-25
12	Allan Deviation				3-8	3-26
14	PN Range				3-4	3-20
15	Tone Range				3-4	3-21
16	Carrier Frequency				3-4	3-22
17	Total Count Phase				3-4	3-23

Lengths of the components and the total length of binary data records of each type are listed in Table 3. The example file (*tnfp.dat*) has the content summarized in Table 4. Total volume of the five CSV files is approximately two times the volume of the binary file.

Table 5 shows a hexadecimal dump of the first three records of the binary data file *tnfp.dat*. Each record begins with an SFDU Label, within which the first four bytes are the character string 'NJPL'. The data description identifier (bytes 9-12) 'C123' identifies this as a record with uplink data; the SFDU length attribute (bytes 13-20) further specifies this as an uplink record with type 0 data. The complete translation of the first record is given in Table 6, all of the type

0 records are included in CSV file *tnfp00.csv*, and all of the binary file records in the set of *tnfp??.csv* files.

Table 3 – TRK-2-34 Component and Record Lengths (in bytes) by Data Type

Data Type	Description	SFDU Label	Aggregation CHDO Label	Primary CHDO	Secondary CHDO	Tracking Data CHDO	Total
0	Uplink Carrier Phase	20	4	8	70	80	182
1	Downlink Carrier Phase				114	232	378
2	Uplink Sequential Ranging Phase				70	112	214
3	Downlink Sequential Ranging Phase				114	178	324
4	Uplink PN Ranging Phase				70	194	296
5	Downlink PN Ranging Phase				114	262	408
6	Doppler Count				128	60	220
7	Sequential Range				128	190	350
8	Angle				128	38	198
9	Ramp				70	42	144
10	VLBI				92	100	224
11	DRVID				128	42	202
12	Smoother Noise				102	50	184
12	Allan Deviation				102	46	180
14	PN Range				128	208	368
15	Tone Range				128	54	214
16	Carrier Frequency				128	60	220
17	Total Count Phase				128	76	236

Table 4 – Contents of Example File *tnfp.dat*

Data Type	Description	Record Length	Number of Records	Block Size (bytes)	CSV Files	Spreadsheet Size (bytes)
0	Uplink Carrier Phase	182	14687	2673034	*tnfp00.csv*	5073928
1	Downlink Carrier Phase	378	8903	3365334	*tnfp01.csv*	7205005
9	Ramp	144	88	12672	*tnfp09.csv*	24806
16	Carrier Frequency	220	8898	1957560	*tnfp16.csv*	4407766
17	Total Count Phase	236	8898	2099928	*tnfp17.csv*	4716336
	Total			10108528		21427841

```
0000000    4e  4a  50  4c  32  49  30  30  43  31  32  33  00  00  00  00
0000020    00  00  00  a2  00  01  00  4e  00  02  00  04  06  0e  18  00
0000040    00  84  00  42  30  31  00  ca  00  00  6e  e1  00  00  00  00
0000060    07  e3  00  cd  40  e4  38  e0  00  00  00  00  57  d4  03  c6
0000100    27  5f  41  02  01  02  00  00  00  00  01  02  00  00  00  00
0000120    00  00  00  00  33  53  1a  19  00  00  00  00  00  00  01  06
0000140    00  00  00  00  00  00  00  0a  00  4c  00  1a  5b  fb  85  72
0000160    49  44  bb  a4  80  00  41  fa  c7  95  17  00  00  00  00  00
0000200    00  00  00  00  00  00  02  03  00  00  00  00  54  4e  00  00
0000220    00  00  00  00  41  00  00  00  00  00  00  00  00  00  00  00
0000240    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0000260    00  00  00  00  00  00
                                  4e  4a  50  4c  32  49  30  30  43  31
0000300    32  33  00  00  00  00  00  00  00  a2  00  01  00  4e  00  02
0000320    00  04  06  0e  18  00  00  84  00  42  30  31  00  ca  00  00
0000340    6e  e2  00  00  00  01  07  e3  00  cd  40  e4  39  00  00  00
0000360    00  00  57  d4  03  c6  27  5f  41  02  01  02  00  00  00  00
0000400    01  02  00  00  00  00  00  00  00  00  33  53  1a  19  00  00
0000420    00  00  00  00  01  06  00  00  00  00  00  00  00  0a  00  4c
0000440    00  1a  5b  fd  31  eb  9a  b4  fd  d0  00  00  41  fa  c7  95
0000460    17  00  00  00  00  00  00  00  00  00  00  00  02  00  00  00
0000500    00  00  54  4e  00  00  00  00  00  00  41  00  00  00  00  00
0000520    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0000540    00  00  00  00  00  00  00  00  00  00  00  00
                                                      4e  4a  50  4c
0000560    32  49  30  30  43  31  32  33  00  00  00  00  00  00  00  a2
0000600    00  01  00  4e  00  02  00  04  06  0e  18  00  00  84  00  42
0000620    30  31  00  ca  00  00  6e  e3  00  00  00  02  07  e3  00  cd
0000640    40  e4  39  20  00  00  00  00  57  d4  03  c6  27  5f  41  02
0000660    01  02  00  00  00  00  01  02  00  00  00  00  00  00  00  00
0000700    33  53  1a  19  00  00  00  00  00  00  01  06  00  00  00  00
0000720    00  00  00  0a  00  4c  00  1a  5b  fe  de  64  ec  24  fd  d0
0000740    00  00  41  fa  c7  95  17  00  00  00  00  00  00  00  00  00
0000760    00  00  02  03  00  00  00  00  54  4e  00  00  00  00  00  00
0001000    41  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0001020    00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
0001040    00  00
```

Table 5. Hexadecimal dump of records 1-3 from data file *tnfp.dat* (unix command *od -t x1 tnfp.dat*). Record boundaries are indicated by line breaks. The left column gives byte addresses in octal; remaining columns give content of sequential bytes.

Table 6a. SFDU Label Translation from Record 1 of Example File *tnfp.dat* Using Table 3-1 [5]					
Bytes	**Identifier**	**Description**	**Hexadecimal**	**Translation**	**Interpretation**
1-4	control_auth_id	control authority ID	4e 4a 50 4c	NJPL	a product of NASA JPL
5	sfdu_version_id	SFDU version ID	32	2	bytes 13-20 are binary
6	sfdu_class_id	SFDU class ID	49	I	data to be used by an application
7-8	Reserve	reserved for future use	00 00	N/A	two bytes
9-12	data_description_id	registration ID with control authority	43 31 32 33	C123	uplink data type
13-20	sfdu_length	bytes in remainder of record	00 00 00 00 00 00 00 a2	162	162 bytes follow this SFDU Label

Table 6b. Aggregation Header Translation from Record 1 of Example File *tnfp.dat* Using Table 3-2 [5]					
Bytes	**Identifier**	**Description**	**Hexadecimal**	**Translation**	**Interpretation**
21-22	chdo_type	type of this CHDO	00 01	1	this is an aggregation of CHDOs
23-24	chdo_length	length of this CHDO	00 4e	78	78 bytes follow in this CHDO

Table 6c. Primary CHDO Translation from Record 1 of Example File *tnfp.dat* Using Table 3-3 [5]					
Bytes	**Identifier**	**Description**	**Hexadecimal**	**Translation**	**Interpretation**
25-26	chdo_type	type of this CHDO	00 02	2	this is a primary CHDO
27-28	chdo_length	length of this CHDO	00 04	4	4 bytes follow in this CHDO
29	mjr_data_class	major data class	06	6	ground station monitor data*
30	mnr_data_class	minor data class	0e	14	processed tracking data*
31	mission_id	mission identifier	18	24	per DSN 820-013, OPS-6-21
32	format_code	data type (0-17)	00	0	uplink carrier phase CHDO

- per DSN 820-013, 0172-Telecomm-CHDO

Table 6d. Secondary CHDO Translation from Record 1 of Example File *tnfp.dat* Using Table 3-5 [5]					
Bytes	**Identifier**	**Description**	**Hexadecimal**	**Translation**	**Interpretation**
33-34	chdo_type	type of this CHDO	00 84	132	CHDO contains uplink data
35-36	chdo_length	length of this CHDO	00 42	66	66 bytes follow in this CHDO
37	orig_id	where record contents originated	30	48	DSN*
38	last_modifier_id	where record contents were last modified	31	49	Tracking Data Delivery Service*
39	Reserve	reserved for future use	00	0	one byte
40	scft_id	spacecraft number	ca	234	MAVEN#
41-44	upl_rec_seq_num	uplink record sequence number	00 00 6e e1	28385	reported by uplink sequencing equipment
45-48	rec_seq_num	record sequence number	00 00 00 00	0	counts from 0 for each operation
49-50	Year	time tag year	07 e3	2019	year of data collection
51-52	Doy	time tag day of year	00 cd	066	day of year (7 March)
53-60	Secs	time tag seconds of day	40 e4 38 e0 00 00 00 00	4.1415e+04	time 11:30:15
61-62	rct_day	record creation time (day)	57 d4	22484	days since 1/1/58 when record was created
63-66	rct_msec	record creation time (ms since start of day)	03 c6 27 5f	63317855	RCT milliseconds since midnight
67	ul_dss_id	uplink DSN antenna	41	65	Madrid 34-m antenna%
68	ul_band	uplink frequency band	02	2	X-band
69	ul_assembly_num	uplink assembly number	01	1	S/X-band uplink
70	transmit_num	transmitter number	02	2	
71	transmit_stat	transmit status	00	0	not transmitting out the horn

72	transmit_mode	transmitter mode	00	0	low power
73	cmd_modul_stat	command modulation status	00	0	command modulation OFF
74	rng_modul_stat	ranging modulation status	00	0	ranging modulation OFF
75	fts_vld_flag	frequency and timing validity	01	1	equipment is synchronized with the Frequency and Timing Subsystem (FTS)
76	ul_software_version	uplink software version	02	2	
77-84	transmit_time_tag_delay	Uplink time delay offset	00 00 00 00 00 00 00 00	0.0e+00	no uplink time offset
85-88	ul_zheight_corr	uplink path length correction	33 53 1a 19	4.9151e-08	seconds
89-90	mod_day	modification time (days)	00 00	0	no modification in days
91-94	mod_msec	modification time (ms)	00 00 00 00	0	No modification in milliseconds
95	version_num	version of assembly creating data	01	1	
96	sub_version_num	assembly subversion number	06	6	
97	sub_sub_version_num	assembly subsubversion number	00	0	
98	Reserve	reserved for future use	00	0	one byte
99-102	Reserve	reserved for future use	00 00 00 00	0	four bytes

* per DSN 820-013 0172-Telecomm-CHDO

\# per DSN 820-013, OPS-6-21

% per DSN 810-047

Table 6e. Tracking Data CHDO Translation from Record 1 of Example File *tnfp.dat* Using Table 3-9 [5]					
Bytes	**Identifier**	**Description**	**Hexadecimal**	**Translation**	**Interpretation**
103-104	chdo_type	type of this CHDO	00 0a	10	CHDO contains binary data
105-106	chdo_length	length of this CHDO	00 4c	76	76 bytes follow in this CHDO
107-110	ul_hi_phs_cycles	total integer phase cycles divided by 2^{32}	00 1a 5b fb	1727483	high part of total integer phase
111-114	ul_lo_phs_cycles	total integer phase cycles modulo 2^{32}	85 72 49 44	2238859588	low part of total integer phase
115-118	ul_frac_phs_cycles	fractional part of phase (cycles)	bb a4 80 00	-5.0201416e-03	total phase modulo 1.
119-126	ramp_freq	ramp frequency at time tag	41 fa c7 95 17 00 00 00	7.188599152e+09	
127-134	ramp_rate	rate at which the uplink frequency changes	00 00 00 00 00 00 00 00	0.0e+00	
135	transmit_switch_stat	state of the transmit switch	02	2	invalid or unknown
136	ramp_type	ramp_type	03	3	periodic report
137-140	transmit_op_pwr	transmitter output power	00 00 00 00	0.0e+00	
141-148	sup_data_id	support data id	54 4e 00 00 00 00 00 00	TN	ID of the frequency predicts used
149-156	sup_data_rev	support data revision	41 00 00 00 00 00 00 00	A	revision of the frequency predicts used
157-164	prdx_time_offset	predicts time offset	00 00 00 00 00 00 00 00	0.0e+00	seconds added to current time
165-172	prdx_freq_offset	predicts frequency offset	00 00 00 00 00 00 00 00	0.0e+00	Hz added to predicted value

173	time_tag_corr_flag	time tag correction flag	00	0	no validation attempted
174	type_time_corr_flag	the type of time tag correction made	00	0	no correction
175	fabricated_sfdu_flag	flag if data were fabricated for testing	00	0	not fabricated; data generated by Uplink Tracking and Command System and validated by Telemetry, Tracking and Command System software
176	reserved1	reserved for future use	00	N/A	one byte
177-182	reserved6	reserved for future use	00 00 00 00 00 00		six bytes

Users may wish to read the CSV files into a spreadsheet program for ease of display and manipulation. The first row in each CSV file gives the Identifier (or a close approximation) from the specification tables in [5] (see Table 2 above). An exception is the SFDU Label which is completely translated and stored as a 20-character string in the first field of each CSV record. The second and third fields in each CSV record contains the aggregation CHDO type and length *agg_chdo_type* and *agg_chdo_length*, respectively, per Table 3-2 in [5].

In reading numeric values into a spreadsheet program, pay heed to the precisions listed in row 2 of each file. Many of the fields stored in scientific notation may not be fully displayed using default spreadsheet settings. For example, the first three values of *ramp_freq* (field 47) in *tnfp09.csv* are 7.188599152E+09 Hz; but Excel will show them only as 7.19E+09 without intervention.

Figure 2 is a plot of *ramp_freq.* versus *sec* (field 20) from *tnfp09.csv* with bias values removed, showing the value resolution available.

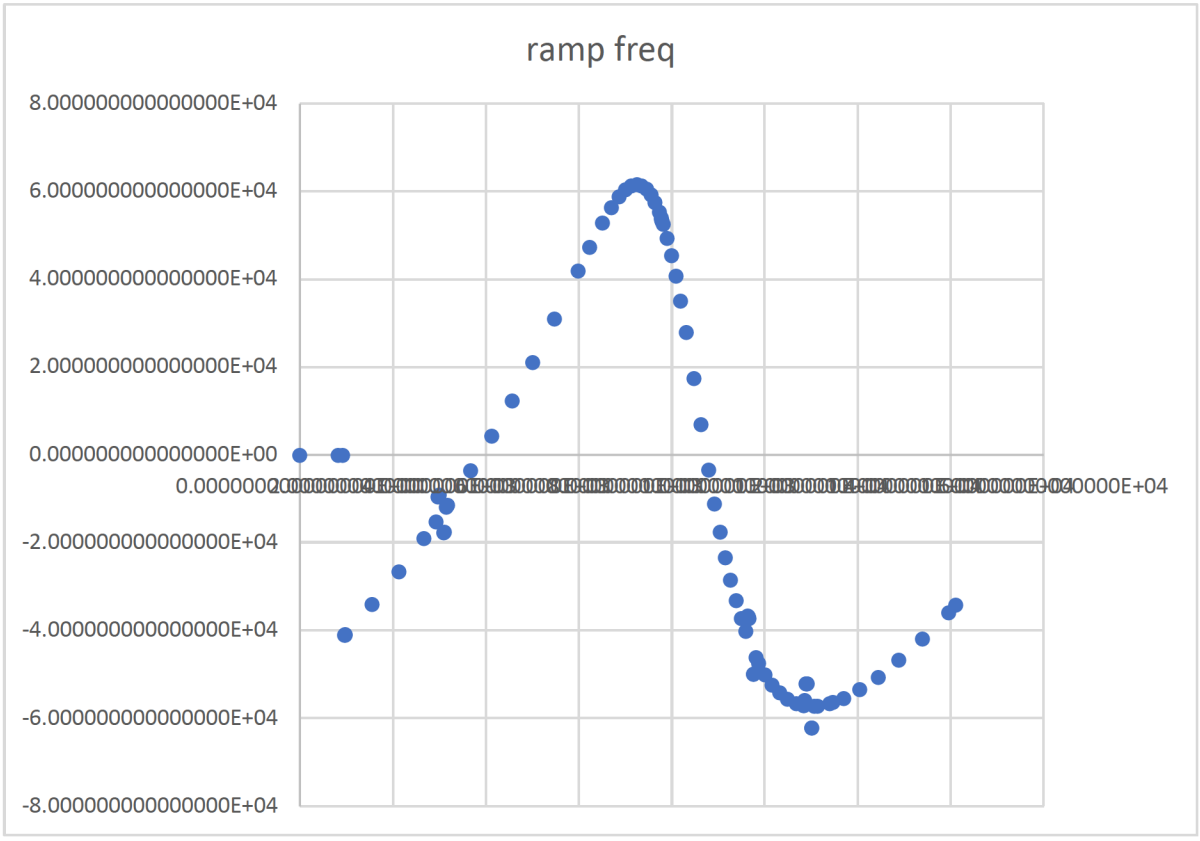

Figure 2. Ramp Frequency (Hz) vs Time (s) from the beginning of the tnfp09.csv file.

Also included with this document are two listings of warning messages returned during conversion of the binary blocks to ASCII. The warning messages (*tnfp00.txt* and *tnfp01.txt*) note values that exceeded limits set for data type 0 and 1 parameters, respectively, in [5]; there were no warning messages during conversion of data type 9, 16, and 17 records.

Appendix B in [5] documents a 'file' format that is not used in PDS. Users can identify such files by the 4-characters 'CCSD' at the beginning.