Interface Control Document

for

TWINS Spacecraft Ephemeris Files
TWINS Instrument Pointing Files
TWINS PGS-Based Data Files

Prepared by

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1. INTRODUCTION

This ICD describes the content and structure of TWINS ephemeris files, TWINS pointing files containing sensor orientation, and TWINS daily data files derived from telemetry packaged by the Payload Ground Station (PGS). File naming conventions are indicated, but delivery mechanisms and distribution timing are specified elsewhere. Each file type is produced once per day and nominally covers a 24-hour period from midnight to midnight UT.

2. EPHEMERIS FILES

File names will conform to the following convention: **TW***xYYYYDDD***_R***z***.eph**, where bold characters are fixed literal items in the pattern, *x* is 1 or 2 to indicate flight number, *YYYY* is the calendar year in four-digit form, *DDD* is the day of year, and z is in the range 1 to 9 to specify a file release number.

2.1 Computational Basis

A TWINS Ephemeris File (TEF) contains computed ephemeris elements derived from *(i)* the spacecraft Raw Ephemeris File (REF), *(ii)* standard geomagnetic configuration models, and *(iii)* representative space environment indices. The internal geomagnetic field will be modeled initially using the International Geomagnetic Reference Field (IGRF) 2005.0 adjusted for the relevant date by means of the IGRF secular variation coefficients. The external component of the field will not be modeled. Nevertheless, both internal and external model identifiers will appear within the TEF so as not to restrict future flexibility. Altitude computations are based on an oblate spheroid Earth model (WGS84).

2.2 File Structure

The TEF consists of a sequence of ASCII-formatted records, each delimited by a <CR><LF> pair which acts as a record terminator. The initial two records in the file are *header* records. The first contains metadata describing the file and its contents. The second contains labels for the columns of ephemeris data. The third and following records in the file are *data* records each of which contain ephemeris elements for a particular time. Data records stand in one-to-one correspondence with time-based records in the REF and thus, although they will be ordered chronologically, their time-spacing will not be uniform. More data records will be generated for the perigee orbital phase than for the apogee phase, for example. Typically, the number of data records in a TEF will be about 240.

2.3 Header Record Format and Content

A TEF primary header record consists of a series of (*key, value*) pairs, where *key* specifies the information type and *value* the relevant setting. In the record, a (*key*, *value*) pair is formatted as the text string "*key = value*" (without quotes) where white space can appear before and after the equal symbol and within *value*. Multiple pairs in the record are separated by white space. Parsing code should not assume any particular order for pairs within the record. Moreover, such code should be tolerant of unanticipated pairs. Defined keys with sample values are as follows:

```
FileName = TW12005364_R1.eph
FileCreationUT = 2005-12-31 03:32:19
FileGeneratorVersion = 1.00
EphemlibVersion = 4.91
CoverageStartUT = 2005-12-30 00:03:14
CoverageEndUT = 2005-12-30 23:58:36
MaximumSpacingSeconds = 554
MinimumSpacingSeconds = 29
InternalFieldModel = IGRF 2005
ExternalFieldModel = none
```

A TEF secondary header record is a single line of column labels. This line can be parsed programmatically using a Fortran "A" format with field widths identical to those for the corresponding numerical items (see §2.4). Alternatively, the line can be parsed as a space-delimited set of strings.

2.4 Data Record Format and Content

A TEF data record consists of an ordered series of ASCII-formatted ephemeris data elements. Each element of the series is a text string conforming to a standardized Fortran scaled exponential format. Not all of the digits included are significant and therefore the text elements do not necessarily reflect the accuracy of the underlying ephemeris value. Table 2-1 specifies both semantic and formatting details for each element in the series and also indicates the ordering of elements. Note that a single item in the table can represent more than one element in the data record (e.g., an item having a type of *float[3]* is represented in the data record by three consecutive elements). The *Type* column indicates a generic classification, not a specific programming language storage declaration. Thus, items described as type *float* should be stored on input as double precision (i.e., 64-bit or higher). The *Name* column is for reference only; strings in the table do not appear in the TEF. The *Label* column specifies a prototype descriptive text string which appears in the TEF secondary header. The ***** character in the table is replaced by ***x***, ***y***, or ***z*** in the actual file header. In the *Valid Range* column, items which have no intrinsic range of well-defined values are listed with an entry of "Format-based", indicating that the range limitation arises from the format employed. Note that by design data items will be separated by white space and thus parsing code can assume fields are space delimited (as an alternative to using a Fortran-style formatted read). Coordinate system acronyms appearing in the table include ECI (Earth-Centered Inertial True-of-Date frame), GSM (Geocentric Solar Magnetospheric frame), and ECD (Eccentric Dipole frame based on geodipole tilt and displacement).

Item	Name	Label	Type[1]	Format	Valid Range	Units	Description
1	EphTime	ModJulianDate_day	float	E23.15	> 0	day	Modified Julian Date
2	EphSCECI	SatPosECI*_km	float[3]	E20.12	Format-based	km	S/C ECI Cartesian coordinates
3	EphSCGEO	SatPosGEO*_km	float[3]	E20.12	Format-based	km	S/C Geographic Cartesian coordinates
4	EphSCGSM	SatPosGSM*_km	float[3]	E20.12	Format-based	km	S/C GSM Cartesian coordinates
5	EphSCECD	SatPosECD*_km	float[3]	E20.12	Format-based	km	S/C ECD Cartesian coordinates
6	EphSClonGEO	SatPosGEOlon_deg	float	E20.12	[0, 360)	deg	S/C Geographic East longitude
7	EphSClatGEO	SatPosGEOlat_deg	float	E20.12	[-90, 90]	deg	S/C Geographic (geocentric) latitude
8	EphSCradial	SatPosGEOradial_km[2]	float[2]	E20.12	> 0	km	S/C geocentric radial distance & altitude
9	EphSunECI	SunPosECI*_km	float[3]	E20.12	Format-based	km	Sun ECI Cartesian coordinates
10	EphBECI	BvecSatECI*_nT	float[3]	E20.12	Format-based	nT	Magnetic field vector w.r.t. ECI basis
11	EphBmirror	BMirror_nT	float	E20.12	> 0	nT	Field magnitude at mirror point
12	EphBequatorial	BMagEqu_nT	float	E20.12	> 0	nT	Field magnitude at field-line minimum
13	EphBnorth100km	BNorth100km_nT	float	E20.12	> 0	nT	Field magnitude at north 100 km point
14	EphBsouth100km	BSouth100km_nT	float	E20.12	> 0	nT	Field magnitude at south 100 km point
15	EphMirrorGSM	MirrorPosGSM*_km	float[3]	E20.12	Format-based	km	Mirror point GSM Cartesian coordinates
16	EphEquatorialGSM	MagEquPosGSM*_km	float[3]	E20.12	Format-based	km	Equatorial point GSM Cartesian coordinates
17	EphNorth100kmGSM	North100PosGSM*_km	float[3]	E20.12	Format-based	km	North 100 km point GSM Cartesian
18	EphSouth100kmGSM	South100PosGSM*_km	float[3]	E20.12	Format-based	km	South 100 km point GSM Cartesian
19	EphLshell	Lshell	float	E20.12	> 0	none	Dimensionless McIlwain shell parameter
20	EphInvLat	InvLat_deg	float	E20.12	[0, 90]	deg	Invariant magnetic latitude
21	EphDipoleRadius	DipoleRadial_km	float	E20.12	> 0	km	Dipole magnetic radial distance
22	EphDipoleLat	DipoleLat_deg	float	E20.12	[-90, 90]	deg	Dipole magnetic latitude
23	EphSClatECD	SatPosECDlat_deg	float	E20.12	[-90, 90]	deg	S/C latitude in ECD frame
24	EphLTGEO	LocalTimeGEO_hr	float	E20.12	[0, 24)	hr	Local time in geographic frame
25	EphLTECD	LocalTimeECD_hr	float	E20.12	[0, 24)	hr	Magnetic local time (MLT) in ECD frame
26	EphLTequatorialECD	LocalTimeEquECD_hr	float	E20.12	[0, 24)	hr	Equatorial-mapped MLT in ECD frame
27	EphSolarZenithCos	SolZenithAngleCos	float	E20.12	[-1, 1]	none	Solar-zenith angle cosine
28	EphLossCone	LossConeAngle_deg	float	E20.12	[0, 90]	deg	Particle loss cone angle
29	EphDipoleTilt	TiltAngle_deg	float	E20.12	[0, 90]	deg	Magnetic dipole tilt angle
30	EphDipoleOffset	DipoleDispGEO*_km	float[3]	E20.12	Format-based	km	Magnetic dipole displacement

Table 2-1. Specification of TEF Data Record

[1] Programming language storage type for float values should be 64-bit or higher.
[2] Label for the altitude item is *SatPosGEOalt_km*.

3. POINTING FILES

File names will conform to the following convention: **TW***xYYYYDDD***_R***z***.att**, where bold characters are fixed literal items in the pattern, *x* is 1 or 2 to indicate flight number, *YYYY* is the calendar year in four-digit form, *DDD* is the day of year, and z is in the range 1 to 9 to specify a file release number.

3.1 Computational Basis

A TWINS Pointing File (TPF) contains polar ($\hat{p}$) and azimuthal ($\hat{a}$) instrument pointing vectors, each expressed with respect to an ECI Cartesian basis. The polar vector points along the TWINS actuator rotation axis. The azimuthal vector lies in the plane normal to the polar vector and points in the direction indicated in Figure 3-1. More precisely, the vectors are defined as follows (with right-handed basis unit vectors specified in Fig. 3-1):

$$\hat{p} = \hat{y}\cos\varphi + \hat{z}\sin\varphi \qquad \hat{a} = \hat{x} \qquad \varphi = 10^\circ$$

Pointing is derived from both the spacecraft attitude history file (SAH) and the sensor mounting orientation (see Fig. 3-1). The computation employed is designed to achieve a pointing accuracy of 0.5°. Any deviation from this accuracy level is indicated in the header record metadata. Appendix I contains an explanation of how pointing as described here is connected to previously provided sun-in-view tables.

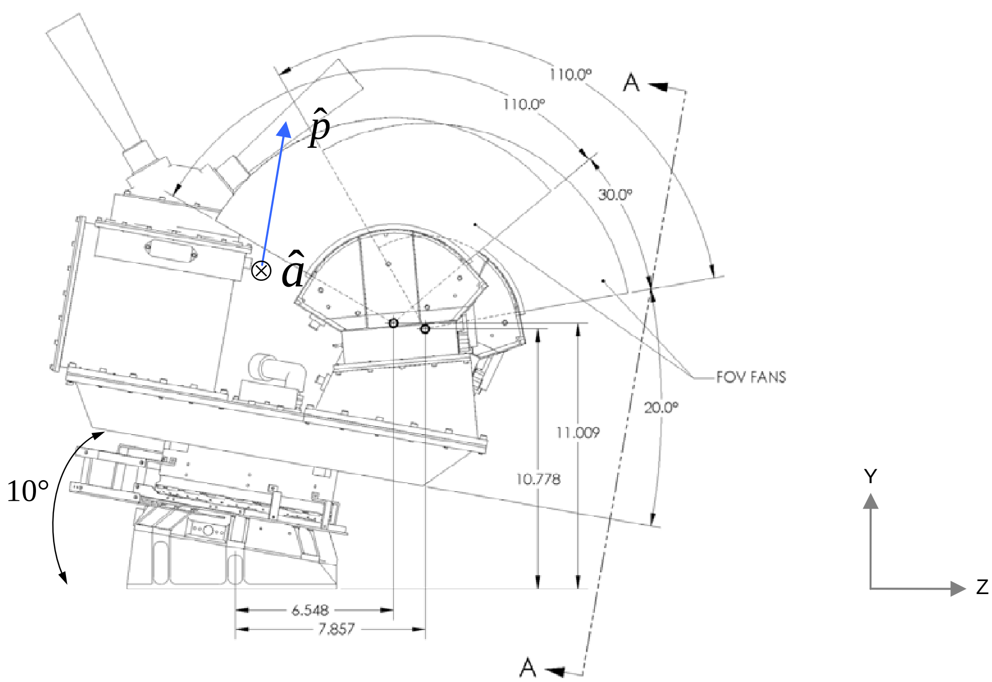

Figure 3-1. TWINS Pointing Geometry

3.2 File Structure

Similarly to the TEF, the TPF consists of a sequence of ASCII-formatted records delimited by <CR><LF> pairs. The first record in the file is a *header* record containing metadata describing the file and its contents. The second record is also a header record and contains labels for the columns of pointing data. The third and following records are *data* records which contain the two pointing unit vectors for a particular time. Data records stand in one-to-one correspondence with time-based records in the SAH and thus, although they will be ordered chronologically, their time-spacing will not be precisely uniform. Typically, data records are spaced at roughly one second intervals.

3.3 Header Record Format and Content

Primary and secondary TPF header records follow the same formatting conventions as the corresponding TEF header records. The content of the primary header varies slightly, as indicated in the following set of defined keys and sample values:

```
FileName = TW12005364_R1.att
FileCreationUT = 2005-12-31 03:32:19
FileGeneratorVersion = 1.00
CoverageStartUT = 2005-12-30 00:01:39
CoverageEndUT = 2005-12-30 23:59:09
MaximumSpacingSeconds = 83
MinimumSpacingSeconds = 49
PointingAccuracyDegrees = 0.5
```

3.4 Data Record Format and Content

A TPF data record consists of an ordered series of seven ASCII-formatted data elements separated by white space. Each element of the series is a text string conforming to a standardized Fortran scaled exponential format and, as with the TEF data record, not all of the digits included are significant. The seven elements represent time, three components of the polar unit pointing vector, and three components of the azimuthal pointing vector. Table 3-1 specifies both semantic and formatting details for the series and also indicates the ordering of elements. Interpretation of Table 3-1 is identical to that of Table 2-1.

Item	Name	Label	Type	Format	Valid Range	Units	Description
1	PointingTime	ModJulianDate_day	float	E23.15	> 0	day	Modified Julian Date
2	PolarUnitVectorECI	PolarVecECI*	float[3]	E20.12	[-1, 1]	none	Polar unit vector ECI components
3	AzimuthalUnitVectorECI	AzimuthalVecECI*	float[3]	E20.12	[-1, 1]	none	Azimuthal unit vector ECI components

Table 3-1. Specification of TPF Data Record

4. PGS-BASED DATA FILES

File names will conform to the following convention: **TW***xYYYYDDDHHMM***_R***z***.dat**, where bold characters are fixed literal items in the pattern, *x* is 1 or 2 to indicate flight number, *YYYY* is the calendar year in four-digit form, *DDD* is the day of year, *HH* is the hour of day (0-23), *MM* is the minute of hour, and *z* is in the range 1 to 9 to specify a file release number. The hour and minute filename elements identify the time associated with the first data packets stored in the file. Regardless of the time associated with the first packet, each file contains data from a single calendar day.

4.1 File Content

The TWINS daily data file contains raw, unprocessed data in the packet format produced by the PGS using only those packet types relevant to the TWINS instrument and repackaged from multiple one-hour files into a single one-day file. Other than removal of duplicate packets, no data correction, conversion to engineering units, or any other processing of the packet data (or change in packet ordering) has been performed. A 24-byte "wrapper" is pre-pended to each packet by the PGS to incorporate ground-receipt time and decoded packet identifiers.

4.2 File Structure

The daily data file is made up of a series of *segments*. Each segment is comprised of the PGS wrapper followed by a CCSDS packet (primary header + secondary header + data + checksum byte). The packet portion of the segment may be as much as 512 bytes in length. Packet *data* is described in document *TWINS-ES Telemetry Description (Draft)*.

4.3 Segment Wrapper

The 24-byte wrapper added to every CCSDS packet by the PGS has the format specified in Table 4-1. Note that the value in 'Start Byte' has been carried over from the original PGS one-hour file and is largely irrelevant in the context of the one-day file.

Item	Bits	Value (binary)	Description
Packet Time Tag	32	Variable [unsigned long]	Coarse timer; stamped at packet creation (seconds)
Ground receipt Time	32	Variable [unsigned long]	Ground receipt time (seconds) since 01/01/1970 00:00:00; stamped when packet is received by ground station (GMT)
Start Byte	32	Variable [unsigned long]	Byte index into .dat file of packet
Frame Size	32	Variable [unsigned long]	CCSDS packet length + CCSDS header size
Frame Type	32	Variable	4 byte ASCII representation of frame name
		THKP	TWINS housekeeping
		TDMP	TWINS dump data
		TTST	TWINS test data
		TIMG	TWINS image data
		EHKP	TDU housekeeping
		LOV2	LAD Out of view (FM2 only)
Ground receipt Time	32	Variable [unsigned long]	Milliseconds portion of ground receipt time (GMT)

Table 4-1. PGS Wrapper Format

4.4 GSE Data File Comparison

Files have previously been generated by the TWINS-ES Ground Support Equipment (GSE). Except for the format of the 24-byte pre-pended wrapper, these files share the same segment structure and ordering as those produced by the PGS. Table 4-2 gives the format of the GSE wrapper. Note the changes in wrapper items 1, 2 and 6 and in particular the PGS reference time 1/1/1970 00:00:00.

Item	Bits	Value (binary)	Description
Computer provided time#1	32	Variable [unsigned long]	Simulated S/C time (Mac time, stamped when packet is received by GSE; seconds since 01/01/1904 00:00:00)
Computer provided time#2	32	Variable [unsigned long]	Computer time (Mac time, stamped when packet saved to disk; seconds since 01/01/1904 00:00:00)
Start Byte	32	Variable [unsigned long]	Byte index into .dat file of packet
Frame Size	32	Variable [unsigned long]	CCSDS packet length + CCSDS header size
Frame Type	32	Variable	4 byte ASCII representation of frame name
		THKP	TWINS housekeeping
		TDMP	TWINS dump data
		TTST	TWINS test data
		TIMG	TWINS image data
		EHKP	TDU housekeeping
		EDMP	TDU dump data
		DHKP	DOSE housekeeping
		DDMP	DOSE dump data
		DDAT	DOSE data
		EOOV	TDU out of view data
		TDUM	TWINS dummy [for internal GSE use only]
		SADC	Slow ADC [for internal GSE use only, do not include CCSDS headers]
		SSTA	Sow status [for internal GSE use only, do not include CCSDS headers]
		TDE1	(TWINS direct events for head 1) [for internal GSE use only, do not include CCSDS headers]
		TDE2	(TWINS direct events for head 2) [for internal GSE use only, do not include CCSDS headers]
		NATM	Neutral atom
Spare	32		Spare bytes

Table 4-2. GSE Wrapper Format

4.5 TWINS Headers

Tables 4-3 and 4-4 define the contents of the primary and secondary headers for TWINS FM1 and FM2.

Item	# Bits	Value (binary)	Description
Version Number	3	000	Flight Model 1
		001	Engineering Model
		010	Flight Model 2
Type Indicator	1	0	Designates type of packet is telemetry
Secondary Header Flag	1	1	Secondary header is present always
Application ID	11	Inst (2)- Packet (4) - Subcom Counter (5)	
Instrument	2	00	TWINS
		01	TDU
Packet	4	0000	Housekeeping Packet
		0001	Memory Dump Packet
		0010	Test Packet
		0011	Image Packet
Subcom Counter	5	Variable	Subcom Counter counts for each packet
Grouping Flags	2	Indicates which packet in the group	
		01	First Packet in Group
		00	Intermediate Packet in Group
		10	Last Packet in Group
		11	Not Part of Group
Source Count	14		Modulo App. ID Counter
Packet Length	16	Variable	Packet Length = Data + Secondary Header+Checksum (506 bytes max.)

Table 4-3. TWINS Primary Header Format

Item	# Bits	Value (binary)	Description
Packet Time Tag	32	Variable	Coarse timer; stamped at packet creation (seconds)
Fine Timetag	12	Variable	Fine time tag; 1 ms resolution; counts 0 to 999; stamped at packet creation
Telemetry Mode	4	0001	Maintenance Mode
		0010	Engineering Mode
		0011	Static Test Mode
		0100	Dynamic Test Mode
		0101	Static Imaging Mode
		0110	Dynamic Imaging Mode
		0111	Sleep Mode

Table 4-4. TWINS Secondary Header Format

4.6 TDU Headers

Tables 4-5 and 4-6 define the contents of the primary and secondary headers for TDU.

Item	# Bits		Value (binary)	Description
Version Number	3		000	Flight Model 1
			001	Engineering Model
			010	Flight Model 2
Type Indicator	1		0	Designates type of packet is telemetry
Secondary Header Flag	1		1	Secondary header is present always
Application ID	11		Inst (2)- Packet (4) - Subcom Counter (5)	
Instrument		2	01	TDU
Packet		4	xxxx	See Tables 5-2 and 5-3
Subcom Counter		5	Variable	Subcom Counter counts for each packet
Grouping Flags	2		Indicates which packet in the group	
			01	First Packet in Group
			00	Intermediate Packet in Group
			10	Last Packet in Group
			11	Not Part of Group
Source Count	14			Modulo App. ID Counter
Packet Length	16		Variable	Packet Length = Data + Secondary Header+Checksum (506 bytes max.)

Table 4-5. TDU Primary Header

Item	Bits	Value (binary)	Description
Packet Time Tag	32	Variable	Course timer; stamped at packet creation (seconds)
Fine Timetag	12	Variable	Fine timetag; 1 ms resolution; counts 0 to 999; stamped at packet creation
Telemetry Mode	4	0001	Maintenance Mode
		0010	Engineering Mode

Table 4-6. TDU Secondary Header (FM1 and FM2)

Appendix I. REFERENCE SYSTEM FOR SUN-IN-VIEW TABLES

The clock and cone angles indicate the position of the sun relative to the ***p*** and ***a*** vectors. The *clock angle* is defined as the angle between the ***a*** vector and the projection of the line from the sensor to the sun into the plane normal to ***p***. The clock angle is measured from ***a*** and increases in the clockwise direction. The *cone angle* is the angle between the line from the sensor to the sun and the ***p*** vector. These measurements are made in the *field of regard*, which encompasses all that the sensor would see in one complete sweep of the turntable. It is defined as a fixed cone with its apex at the intersection of ***a*** and ***p***. It does not rotate with the turntable.

The crude drawing below may help. This is a view looking along the ***p*** vector (***p*** is into the page and normal to it). The line labeled "Direction to Sun" is the projection into the page of the line from the sensor to the sun. Instantaneous fields of view for the sensor heads rotate with the turntable. When the Sun in T1 FOV flag is "1", the sun is in the instantaneous field of view of the head labeled T1. A turntable angle is also calculated that is defined to be zero when the long side of the instantaneous field of view is normal to the ***a*** vector. Because of the way the turntable angle is calculated, it is unsigned (that is, always positive) and ranges from 90 to 0 to 90 degrees.

One thing to keep in mind is that the analysis employed simulated attitudes that probably do not match the actual vehicle attitude. They should be well within 90 degrees, however.