ORBEX

The Orbit Exchange Format

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1. THE PHILOSOPHY AND HISTORY OF ORBEX

The International GNSS Service (IGS), formerly known as the International GPS Service, has been generating GPS precise orbits since its inception in 1994. The format used for these initial IGS orbits was the Standard Product 3 (SP3-a) format developed by Benjamin Remondi [Remondi 1989, Remondi 1991, Spofford and Remondi 1994]. In 1998, Werner Gurtner and Markus Rothacher defined an SP3-b format to allow for the combination of GPS and GLONASS orbits in a single file [IGEX Mail 0042, 27 Oct 1998]. At the 2000 IGS Analysis Center Workshop, it was suggested to further modify the SP3 format to include clock accuracy information, and to provide separate orbit accuracy information for both the observed and the predicted parts of the IGS ultra-rapid orbits. Rather than just create two sets of accuracy codes for the SP3 header, it was decided instead to put accuracy information at each epoch, for both the satellite position (X,Y,Z) and the satellite clock correction. The resultant SP3-c format also included new record types to store the correlation information between the satellite coordinates and satellite clock, and likewise between satellite velocity and satellite clock-rate. Single-character flags were added to denote epochs with predicted positions and/or predicted clock corrections, and epochs where clock events or satellite maneuvers might cause a discontinuity in the data [Hilla 2007]. Both SP3-b and SP3-c were designed to be as backwards-compatible as possible with the original SP3-a format, to minimize the amount of software changes for the receiver manufacturers and other users. In 2004, the IGS switched to SP3-c for its combined GPS orbits, beginning with week 1285 for the rapid and ultra-rapid orbits, and week 1283 for the final orbits [Gendt 2004].

The initial philosophy behind the SP3 format was to create an orbit file that would serve the needs of the geodetic surveying and scientific communities, and yet be compact in size. The header was designed to handle other types of satellites (up to 85 satellites in total) and future numerical constants, but had only a limited number of comment records (four). With the advent of additional Global Navigation Satellite Systems (GNSS), such as Galileo and COMPASS, the number of GNSS satellites in orbit will soon exceed 85 and the need for a wide variety of metadata for these constellations will require a more flexible header design. A recommended approach would be something similar to SINEX, where new sections can be defined for different purposes [SINEX 2006]. A software application can then be designed to skip over any "new" sections that it might not recognize, or any optional header sections or optional data records that it might view as uninteresting. It is anticipated that most users will mainly be concerned with the header sections and data records found in the precise GNSS orbit products distributed by the IGS. Other optional header sections, perhaps pertaining to specific geodetic satellite missions, will likely be of interest only to certain groups.

At the 2008 IGS Analysis Center Workshop in Miami Beach, it was suggested to create a new orbit format for the IGS called the ORBit EXchange format (ORBEX). This new format would also be usable for Low Earth Orbiting (LEO) satellites and would possess the following features:

- Unlimited number of satellites
- Unlimited number of comments
- Irregularly spaced data epochs
- Variable number of satellites at each epoch
- A more flexible, SINEX-like header
- 0.1 mm position precision (for GRACE, and other formation-flying satellites)
- Blank-space delimited fields (to allow for any size coordinate or precision)
- Attitude information.

All of these features have now been incorporated into this format document, along with many other useful ideas. But there are still additional SINEX-like blocks which will need to be added to ORBEX in the future, to accommodate metadata for new GNSS constellations, and other types of satellites. By necessity, the main philosophy behind ORBEX is flexibility. It is not the purpose of this document to try to predict all possible future record types or header blocks for ORBEX, but rather to describe the records that are needed now, and to set the ground rules that will allow users to create new header blocks and record types as new constellations and new kinds of orbital data become available.

In Section 2 below, the ORBEX format is introduced in general terms, using a very simple example. In Section 3, the lines in each mandatory and optional block are described in detail, including the column widths of each field and the various options/codes that can be used. In Section 4, the formats for the different record types used in the EPHEMERIS/DATA block are described, along with the optional flags used in columns 1 through 23 of each data record. Next come three example ORBEX files, which are presented in Section 5. The remaining sections, 6 through 8, contain acknowledgements, references, and the revision history for ORBEX. The Table of Contents on page 2 provides an easy way for readers to quickly find the format description for any type of block or data record.

2. GENERAL FORMAT DESCRIPTION

Figure 1 below shows a very simple ORBEX example with one satellite and three epochs. This example will serve as a starting point to describe the five mandatory parts of any ORBEX file: the two header lines, the FILE/DESCRIPTION block, the SATELLITE/ ID_AND_ DESCRIPTION block, the EPHEMERIS/DATA block, and %END_ORBEX record. Note that in ORBEX, any line that begins with an asterisk in column 1 is a comment.

2.1 Header Lines

Each ORBEX file starts with two header lines. The first header line always begins with the characters '%=ORBEX' followed by the ORBEX version number (e.g., 0.08) and the epoch-spacing flag (either 'EVENLY-SPACED ' or 'IRREGULARLY-SPACED'). The epoch-spacing flag is needed because the ORBEX format will be used to store "kinematic orbits", which often have irregularly-spaced epochs because of gaps, or because of the clock drift of the receiver onboard the satellite. If a file is expected to contain non-evenly-spaced epochs, then the epoch-spacing flag on line one should be set to 'IRREGULARLY-SPACED'. For these types of files, the EPOCH INTERVAL in the FILE/DECRIPTION block can be left blank. For files where the epochs are spaced at an exact interval (like the IGS combined orbits) the flag 'EVENLY-SPACED' should be used (see Examples 1 and 2 in Section 5). After the epoch spacing flag are three labels which explain: the units used for the satellite coordinates ('UNITS_XYZ=METERS'), the units used for the satellite clock corrections ('UNITS_SVCLK= MICROSECONDS'), and the reference point to which the satellite coordinates refer (either the satellite center-of-mass 'XYZ_REF_COM' or the satellite antenna phase center 'XYZ_REF_APC'). There is a group today that distributes two types of GPS orbit files, one where the satellite positions refer the manufacturer's satellite antenna phase center, and one where the satellite positions refer to the center-of-mass of the satellite. Additional comment lines in the FILE/DESCRIPTION block can be used to describe in detail how the satellite antenna phase center is defined. If a file has no clock correction information, the units label for the clock correction can be left blank.

The second header line begins with the characters '%% ', followed by two labels which explain the units for the velocities ('UNITS_VEL=METERS/SEC') and the units for the rate-of-change of the satellite clock correction ('UNITS_CLKRT=NANOSECS/SEC'). If the file contains no velocities or clock rates, then the unit labels for the velocities and clock rates can be left blank. See Section 3.1 for a detailed description of the two header lines.

```
%=ORBEX  0.08 IRREGULARLY-SPACED UNITS_XYZ=METERS                         XYZ_REF_COM
%%
+FILE/DESCRIPTION
 DESCRIPTION         EXAMPLE LEO ORBIT
 CREATED_BY          Dr. P. Caspian, Narnia AC
 CREATION_DATE       2003  1  8 12  0  0
 INPUT_DATA          p
 CONTACT             pc@igsac.narnia.gov
 TIME_SYSTEM         GPS
 START_TIME          2002 12 29  0  0  0.000000000000
 END_TIME            2002 12 29  0  0  2.000000000000
 EPOCH_INTERVAL
 COORD_SYSTEM        IGS00
 FRAME_TYPE          ECEF
 ORBIT_TYPE          FIT
 LIST_OF_REC_TYPES   POS
-FILE/DESCRIPTION
*-------------------------------------------------------------------------------
+SATELLITE/ID_AND_DESCRIPTION
*ID_  SATELLITE_DESCRIPTION_____________________________________________________
 L06  CHAMP
-SATELLITE/ID_AND_DESCRIPTION
*--------1---------2---------3---------4---------5---------6---------7----------
*234567890123456789012345678901234567890123456789012345678901234567890123456789 0
+EPHEMERIS/DATA
*
## 2002 12 29  0  0  0.000000000000   1
*REC ID_  FLAGS_ G/B_ N ________X_(m)___ ________Y_(m)___ ________Z_(m)___
 POS L06          1    3     1781848.9098     5968846.1797    -2704551.4098
## 2002 12 29  0  0  1.000000000001   1
 POS L06          1    3     1727998.7897     5780000.6581    -3119210.3412
## 2002 12 29  0  0  2.000000000003   1
 POS L06          1    3     1664504.1705     5565312.9920    -3519546.7577
-EPHEMERIS/DATA
%END_ORBEX
```

Figure 1. A very simple ORBEX example with one satellite and three epochs.

2.2 Header Blocks

In ORBEX, everything after the two header lines, and before the %END_ORBEX record, is a block (with the exception of comment lines, which can appear anywhere). There are two types of blocks: the blocks that come at the beginning of an ORBEX file (i.e., the header blocks), and the final block that stores the actual satellite positions and clock corrections (i.e., the EPHEMERIS/DATA block). In the future there may be other types of "data" blocks, but currently, the EPHEMERIS/DATA block is the only one. All of the various record types that are used to store satellite information (coordinates, velocities, clock corrections, clock rate-of-change, correlations, etc.) can be found in the EPHEMERIS/DATA block. It is always the last block in an ORBEX file.

Since ORBEX is usable for any satellite, in many instances the file will be very simple like the example given above (although probably not as short). Header blocks that contain detailed information are optional within ORBEX, since for many applications they are not required. There are three mandatory blocks that are required for any satellite (or group of satellites). The first is the FILE/DESCRIPTION block, which lists: a description of the file, the name of the person/agency which created the file, the creation date, and various lines which describe how the file was created and which types of data records were used. The second is the SATELLITE/ID_ AND_DESCRIPTION block, which defines the 3-character satellite ID(s) used throughout the file, and includes a description of each satellite. And finally, the EPHEMERIS/DATA block, which contains all of the actual ephemeris data. In the mandatory SATELLITE/ID_AND_ DESCRIPTION block, it is required that the satellites be listed in numerical order for each constellation. The order of the constellations is arbitrary (i.e., the GLONASS satellites can come before the GPS satellites, or vice-versa). All of the other optional SATELLITE blocks must use the same ordering for the satellite IDs as the SATELLITE/ID_AND_DESCRIPTION block. The FILE/DESCRIPTION block and the SATELLITE/ID_AND_DESCRIPTION block must always be the first and second blocks in an ORBEX file, respectively. The current list of ORBEX blocks is shown below.

The "mandatory" blocks are:

FILE/DESCRIPTION,
SATELLITE/ID_AND_DESCRIPTION,
EPHEMERIS/DATA

The "optional" header blocks are:

SATELLITE/LABELS_AND_STD_DEVS,
EPHEMERIS/MODELS,
SATELLITE/ORBIT_PLANES,
SATELLITE/MANEUVER_INFO,
SATELLITE/ECLIPSE_INFO,
SATELLITE/EVENT.

The first two optional header blocks, the SATELLITE/LABELS_AND_STD_DEVS block and the EPHEMERIS/MODELS block, merit some further discussion since they were designed to replicate the functionality currently found in the SP3-c format. Since GPS pseudorandom-noise (PRN) numbers and GLONASS slot numbers get re-used after a satellite is decommissioned, it is convenient to have other labels for GNSS satellites which can identify them uniquely. The optional SATELLITE/LABELS_AND_STD_DEVS block provides a way to cross-reference the 3-char IDs from the SATELLITE/ID_DESCRIPTION block with the satellite labels used in the IGS ANTEX file (e.g., the 20-character satellite antenna, the 4-character SVN or GLONASS number, and the 9-character COSPAR ID). Note that these last two labels can be found left-justified in the corresponding 10-character fields defined by the ANTEX format [Rothacher & Schmid 2006]. Similar to the SP3-c format, the SATELLITE/LABELS_AND_STD_DEVS block also contains the standard deviations for position for each satellite. And as a new feature, it now lists the standard deviations for the clock corrections as well. The quoted errors should represent one standard deviation for the specified time span for each respective satellite (i.e., there can now be separate standard deviations for both the observed and predicted parts of the IGS combined ultra-rapid orbits. See example 2 in Section 5).

The EPHEMERIS/MODELS block stores the same model information that is currently stored in the four comment records of the SP3-c format for the IGS combined orbits: the name of the satellite PCV model used (e.g., igs05_1580.atx), the names of the ocean and atmospheric tidal loading models used and whether a center-of-mass correction was included in these models, and the origin definitions for the orbits and clocks [Gendt 2006]. Further details can be found in Section 3.5.

2.3 The EPHEMERIS/DATA Block

Recall that in the SP3 format, each epoch is required to have the same number of satellites, which match exactly the number of satellites given in the header. If a satellite is missing at an epoch, it is required to fill those fields with zeros (which signifies that the positions at those epochs are unknown). This can happen, for example, if a satellite has a maneuver and the last portion of the day is missing. For ORBEX, one is now allowed to have a variable number of satellites at each epoch. Also, each satellite may have a different number of record types; for example, if a file has both GNSS satellites and LEO satellites, the LEOs may have attitude information (ATT records) but not the GNSS satellites. Similarly, the GNSS satellites may have clock information (CLK records) but not the LEO satellites.

In the EPHEMERIS/DATA block, the satellites at each epoch can come in any order. The various record types (see Figure 2 on page 23) can also come in any order and can even be separate from one another for the same satellite. There are two exceptions: a CPC record must always follow its corresponding PCS record, and a CVC record must always follow its corresponding VCS record. This is because both records together are required to build the 4-by-4 covariance matrix for the coordinates and clock correction (or the velocities and clock rate). Even though the satellites and record types are allowed to come in any order, for the sake of readability, it is "recommended" that the satellites follow the same order as the SATELLITE/ ID_AND_DESCRIPTION block, and that the record types for each satellite be kept together and follow the same general order shown in Figure 2.

The PCS record type, shown in Examples 1 and 2 in Section 5, stores the same information as the old P-record in the SP3-c format, namely: PRN/Slot number, X, Y, Z, satellite clock correction, and the standard deviations for these values. In the process of combining the orbits of several Analysis Centers (ACs) to make the IGS production orbits, standard deviations are inserted at each SP3-c epoch based on the agreement between the ACs [Gendt 2004b]. The new POS record type in ORBEX stores only the X,Y,Z coordinates for the satellites, and the stand-alone CLK record type stores only the satellite clock correction. These two new record types give users the flexibility of providing CLK records at a more frequent interval than the POS records, if necessary.

For the records which appear in the EPHEMERIS/DATA block, the data values on each line come after column 23 and are separated by blank spaces. In columns 2 through 23, the record type label, satellite ID, event flags, maneuver flags, predicted flags, good/bad flags, and the "number of data columns present" always follow a fixed-format. The actual number of values read in after column 23 will depend on the "number of data columns present" value stored in column 23. For example, there is a maximum of 8 data values for a PCS record, but if the user wishes to omit the standard deviations, then the number of data columns present will be 4 rather than 8. This saves time and space by not forcing users to pad missing data with 0.0 values. It is recommended that any software reading ORBEX files have a choice of several free-formatted read statements, each tailored to the actual number of data columns present (e.g., for the PCS record, the possible number of columns present that would make sense would be 3, 4, 7, or 8). Obviously, if an absent value is embedded between two data values that are being used, then that value must be represented by a 0.0 so that the total set of data values can still be read as a free-formatted set of numbers, each separated by one or more blank spaces. The good/bad flags in columns 19 through 21 can be used to flag data values that are missing or invalid. This feature gives those creating an ORBEX file a way to collect and store problematic data for later examination, while at the same time warning users that a particular data value is invalid and should be ignored. While some records (PCS,VCS) may use all four good/bad flags, other records (CPC,CVC) may use only the leftmost two flags in columns 18 and 19, or the single leftmost flag in column 18 (POS,VEL,CLK,CRT,ATT).

2.4 File Naming Convention

The recommended file naming convention for ORBEX files is similar to that used for SP3-c files; the file extension is simply changed from ".sp3" to ".obx". For example: igs16173.obx, igr16173.obx, and igu16173_06.obx , where 1617 is the GPS week, 3 is the day-of-week, and '_06' is the hour when the ephemeris begins. The numbering convention for the day-of-week is: Sunday = Day 0, Monday = Day 1, . . . , Saturday = Day 6.

2.5 Additional Formatting Tips

The remaining paragraphs in this section discuss general guidelines for formatting an ORBEX file. All fields in the header blocks are designed to have a FIXED-FORMAT. The records types in the EPHEMERIS/DATA block, which are used to store: position, velocity, satellite clock corrections, clock-rate, correlation information, attitude information, etc. are FREE-FORMATTED after column 23. This gives users the flexibility to use larger numbers, or a greater number of decimal places, if necessary. The record type formats discussed in Section 4 do include "recommended" field widths and formats, and these should work well for most satellites (up to geostationary altitudes). For the header blocks, and for these "recommended" field widths, the following rules apply. Unless otherwise specified, all character strings are left-justified in their defined fields, and all integers and floating-point numbers are right-justified. The width of each field, and the precision of the floating point numbers, are represented using Fortran syntax (e.g., A3, I17, F16.7, etc.). This is similar to other IGS formats like RINEX, SINEX, ANTEX, etc. Hopefully, with the examples given here, this syntax will be easily understood even by those who program in other computer languages. When data items are not needed for certain types of files, those fields can be left blank (such as the EPOCH INTERVAL field for files with irregularly-spaced epochs).

All year values are 4-digit integers. No need to pad the month, day, hour, minute, or second fields with leading zeroes; the only field that is padded with leading zeroes is the one used for the satellite names (e.g., G02 or R09).

Comment lines always begin with an "*" in column 1, and can be used to provide column headings and to show units. These column headings can also use underscore characters to show the width of each field. All ORBEX files must end with the %END_ORBEX record.

3. FORMATS FOR HEADER BLOCKS

There are currently nine different blocks defined for ORBEX. The following section begins with the format specifications for the two header lines, and then provides the specifications for each of the nine different types of blocks.

3.1 Header Lines (Mandatory)

Description:

Each ORBEX file must begin with the two header lines described below. The first header line begins with the characters %=ORBEX followed by: the ORBEX version number, the type of epoch spacing used ('EVENLY-SPACED ' or 'IRREGULARLY-SPACED'), the units label for the positions (UNITS_XYZ=METERS), the units label for the clock corrections (UNITS_SVCLK=MICROSECONDS), and the reference point to which the satellite coordinates refer (XYZ_REF_COM or XYZ_REF_APC).

The second line begins with the characters '%% ', followed by the units label for the satellite velocities (UNITS_VEL=METERS/SEC) and the units label for the satellite clock correction rate-of-change (UNITS_CLKRT=NANOSECS/SEC). The latter columns are reserved for future use.

Contents:

FIRST HEADER LINE			
Field	Description	Format	Cols
First Character	Single character '%' in column 1. No other character than '%' is allowed.	A1	1 to 1
Second Character	Single character '=' in column #2. No other character than '=' is allowed.	A1	2 to 2

Document Type	Five characters 'ORBEX' in cols 3 to 7. Indicates that this is an ORBit EXchange document.	A5	3 to 7
Format Version	Five digits indicating the version of ORBEX format used. ' 0.08' for this version.	1X,F5.2	8 to 13
Epoch-Spacing Flag	'EVENLY-SPACED ' means epochs in the final EPHEMERIS/DATA block are exactly evenly-spaced in time, as evidenced by the time tag lines 'IRREGULARLY-SPACED' means epochs may be un-evenly spaced in time. This will need to be taken into account when interpolating the data. Regardless of how the epochs are spaced, they must be in chronological order and be unique. There should be no time tag records with duplicate times.	1X,A18	14 to 32
Units label for X,Y,Z coords.	This character string is always the same: 'UNITS_XYZ=METERS'.	1X,A16	33 to 49
Units label for Clock Corr.	This character string is always the same: 'UNITS_SVCLK=MICROSECONDS'. If there are no satellite clock corrs., leave this field blank.	1X,A24	50 to 74
Reference point for the X,Y,Z coordinates.	There are two options: XYZ_REF_COM or XYZ_REF_APC COM = Center of Mass APC = Antenna Phase Center. How the APC is defined (e.g.,as the mean L1 and L2 phase center as given by the satellite manuf.) can be described by a comment in the FILE/DESCRIPTION block.	1X,A11	75 to 86
RESERVED COLUMNS	The remaining columns are reserved for future use.		87 to 120
		Total 120	

SECOND HEADER LINE

Field	Description	Format	Cols
First Character	Single character '%' in column #1. No other character than '%' is allowed.	A1	1 to 1
Second Character	Single character '%' in column #2. No other character than '%' is al-	A1	2 to 2

	lowed.		
Third Character	Single character ' ' in column #3. No other character than ' ' is allowed.	A1	3 to 3
Units label for X,Y,Z velocities.	This character string is always the same: 'UNITS_VEL=METERS/SEC'. If there are no velocities, leave this field blank.	1X,A20	4 to 24
Units label for Clock Corr. Rate-of-Change	This character string is always the same: 'UNITS_CLKRT=NANOSECS/SEC' If there are no satellite clock rates, leave this field blank.	1X,A24	25 to 49
RESERVED COLUMNS	The remaining columns are reserved for future use.		50 to 120
		Total 120	

3.2 FILE/DESCRIPTION Block (Mandatory)

Description:

This block provides information on the purpose of the file, the person/agency creating the file, the date the file was created, the type of data used in creating the file, etc. For each type of information, the formats used in cols 21 through 120 will differ. See the NOTES section below to see how to format the information associated with each particular label. This block must always be the first block in an ORBEX file.

Contents:

FILE/DESCRIPTION DATA LINE			
Field	Description	Format	Cols
Information Type Labels	Describes the type of information present in the next field. May take on the following values: 'DESCRIPTION' - Description of the file contents. 'CREATED_BY' - Name of agency which created the file. 'CREATION_DATE' - The YMDHMS when the file was created. 'INPUT_DATA' - Brief description of the input used to generate this ephemeris file. 'CONTACT' - E-mail address of the relevant contact person. 'TIME_SYSTEM' - 3-char code used to specify the time system used in file. 'START_TIME' - The first epoch in the file (as YMDHMS). The time may also be optionally given as: (MJD,fracOfDay) and (GPS week, secsOfWk). 'END_TIME' - The last epoch in the file (as YMDHMS). The time may also be optionally given as: (MJD,fracOfDay) and	1X,A19	1 to 20

	(GPS week, secsOfWk). 'EPOCH_INTERVAL' - Number of seconds between each epoch time tag. For files with irregularly spaced epochs this field will be left blank. 'COORD_SYSTEM'- 20-char label used to specify the reference frame used in file. (e.g. IGS05,ICRF,etc) 'FRAME_TYPE' - 20-char code denotes the frame type (e.g., ECEF, BCRS= Barycentric Ref.Sys., ECI,etc.) 'ORBIT_TYPE' - 3-char code denotes the orbit type (e.g., FIT=Fitted, EXT=Extrapol./Pred., BRD=Broadcast, HLM= Fitted after applying a Helmert transf.). 'LIST_OF_REC_TYPES' - List of 3-char record types used in file. All of the above labels must be present and in the above order. When comment records are added to this block, it is recommended that an asterisk be placed in column 1 and columns 2 through 21 be left blank.		
Information	Relevant information for each label (see the detailed notes below).	1X,A99	21 to 120
		Total 120	

NOTES:

'DESCRIPTION' – A description of the file contents (i.e., the type of orbit and the types of satellites, purpose of the orbit file, etc.). The format is: A99

'CREATED_BY' – The name of the person or agency which created the file. The format is: A99

'CREATION_DATE' – Date and Time of creation (given to the nearest second). Use cols 22 to 40. The YMDHMS format is: I4,5(1X,I2) The format for the entire line would be: format(1x,a19,1x,i4,5(1x,i2))

'INPUT_DATA' – A description of the data that was used to compute the orbit. The format is: A99. Since it is important to have this information easily read by computer, the following codes can be used alone, or joined together with the '+' sign, to represent the type(s) of data used for the orbit (and clock) determination:

```
u   -- undifferenced carrier phase
du  -- change in u with time
s   -- 2-receiver/1-satellite carrier phase
ds  -- change on s with time
d   -- 2-receiver/2-satellite carrier phase
dd  -- change in d with time

U   -- undifferenced code phase (range observations)
dU  -- change in U with time
S   -- 2-receiver/1-satellite code phase (range observations)
dS  -- change in S with time
D   -- 2-receiver/2-satellite code phase (range observations)
dD  -- change in D with time

a   -- angular measurements
p   -- position data (e.g, an orbit fitted to a GNSS kinematic navigation solution)
o   -- Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) data
L   -- Satellite Laser Ranging (SLR) observations
x   -- Other (explain in one or more comment records). This is a lowercase x.
```

+ -- type separator

For example, if a LEO satellite orbit was computed using GPS undifferenced phase and range, SLR, and DORIS measurements, it would have an input data code of “u+U+L+o". If there are measurements used that are not defined here, use “x” for “other” and describe the measurements using one or more comment records (recall that a comment record is any record that has an asterisk in column one). For files that are a combination of orbits from two or more sources, use the code ‘ORBIT’. This table is not final, suggestions are welcome.

'CONTACT' – The E-Mail address for the relevant contact person.
The format is: A99

‘TIME_SYSTEM’ – Examples: GPS, UTC(Universal Coordinated Time, BIPM), TAI(International Atomic Time), GAL(Galileo), GLO(GLONASS), ‘TT ‘(Terrestrial Time), etc. The format is: A20. For time systems like UTC and GLO that can be affected by leap seconds, the ORBEX file must be leap seconds free for its duration. For such files, the constant leap second offset used in the file (with respect to TAI) should listed after the TIME_SYSTEM code, for example:

```
UTC                 LEAP_SECOND_OFFSET_(UTC-TAI):  -34.0
```

The format is A20,A29,F7.1, with the A29 field being the ‘LEAP_SECOND_OFFSET_(UTC-TAI):’ label.

'START_TIME' - Time of first ephemeris epoch. For YMDHMS use cols 22 to 53 with the format: I4,4(1X,I2),1X,F15.12
- For Modified Julian Date and fraction of day (this is optional) use cols 56 to 80 with the format: I5,1X,F19.17
- For GPS week and seconds of week (this is optional) use cols 83 to 106 with the format is: i4,1X,F19.12

Note: The different date/time formats are for the user’s convenience. They must all agree and be in the same TIME SYSTEM as specified above. The GPS week is a continuous count starting in 1980 (no modulo 1024, no Galileo week count). If all three types of times are given, the format for the entire line would be: format(1x,a19,1x,i4,4(1x,i2),1x,f15.12,2x,i5,1x,f19.17,2x,i4,1x,f19.12)

'END_TIME' - Time of last ephemeris epoch. For YMDHMS use cols 22 to 53 with the format: I4,4(1X,I2),1X,F15.12
- For Modified Julian Date and fraction of day (this is optional) use cols 56 to 80 with the format: I5,1X,F19.17
- For GPS week and seconds of week (this is optional) use cols 83 to 106 with the format: i4,1X,F19.12

Note: The different date/time formats are for the user’s convenience. They must all agree and be in the same TIME SYSTEM as specified above. The GPS week is a continuous count starting in 1980 (no modulo 1024, no Galileo week count). If all three types of times are given, the format for the entire line would be: format(1x,a19,1x,i4,4(1x,i2),1x,f15.12,2x,i5,1x,f19.17,2x,i4,1x,f19.12)

'EPOCH_INTERVAL' - The spacing (in seconds) between each ephemeris epoch. Cols 22 to 30. The format is F9.3 . For files with irregularly-spaced epochs, this field can be left blank.

‘COORD_SYSTEM’ and ‘FRAME_TYPE’ – To make these fields machine-readable, please use the codes listed in the table below. This table is not considered final, suggestions are welcome and new coordinate systems will be added as they are created or requested. For the ECEF coordinate systems listed below for the original IGS orbits, the reference Epoch time scale is GPS Time. For The quasi-inertial ECI frames, the time scale is usually Terrestrial Time (TT) where TT = TAI + 32.184 seconds and TAI is International Atomic Time. The format for both codes is A20.

COORD_SYSTEM	(Epoch)	(time span when this system was used by the IGS orbits)		FRAME_TYPE
ITRF92	1994.0	0000 January 9, 1994	until 2400 December 31, 1994.	ECEF
ITRF93	1995.0	0000 January 1, 1995	until 2400 June 29, 1996.	ECEF
ITRF94	1996.0	0000 June 30, 1996	until 2400 February 28, 1998.	ECEF
ITRF96	1997.0	0000 March 1, 1998	until 2400 July 31, 1999.	ECEF
ITRF97	1997.0	0000 August 1, 1999	until 2400 June 3, 2000.	ECEF
IGS97	1997.0	0000 June 4, 2000	until 2400 December 1, 2001.	ECEF
ITRF2000	1997.0			ECEF
IGS00	1998.0	0000 December 2, 2001	until 2400 January 10, 2004.	ECEF
IGb00	1998.0	0000 January 11, 2004	until 2400 November 4, 2006.	ECEF
ITRF2005	2000.0			ECEF
IGS05	2000.0	0000 November 5, 2006	until the present.	ECEF

COORD_SYSTEM	Reference Epoch	FRAME_TYPE
J2000 (EME2000)	1 January 2000 at 12:00:00.00 TT (JD 2451545.0)	ECI
B1950	31 December 1949 at 22:09:07.2 TT (JD 2433282.423)	ECI
M50	1 January 1950 at 12:00:00.00 TT (JD 2433283.0)	ECI
ICRF	J2000.0 = 1 January 2000 at 12:00:00.00 TT (JD 2451545.0)	BCRS

SPECIAL (describe any “SPECIAL” COORD SYSTEM using a comment record)
(describe “OTHER” FRAME TYPE using a comment record) OTHER

Note: For the combined IGS orbits, the FRAME TYPE will likely be an Earth-Centered, Earth-Fixed frame (ECEF). For cases where the user may want to use the ORBEX format to store satellite positions in an inertial frame, this label may be ‘BCRS’ (for the quasi-inertial Barycentric reference system) or ‘ECI’ for a quasi-inertial, Earth-Centered reference frame. Note that there are many ECI frames (GCRF, MOD, TOD, J2000 or EME2000, TEME, M50, etc.). Use “OTHER” for any frame type not listed here, and explain using one or more comment records. This table is not final, suggestions are welcome.

'ORBIT_TYPE' – The “type of orbit” is described using a three character label. The four orbit types currently defined are listed below. This list is not final, other labels may be added in the future. The format is A3.
FIT (fitted)
EXT (extrapolated or predicted)
BRD (broadcast)
HLM (fitted after applying a Helmert Transformation).

'LIST_OF_REC_TYPES' - A list of the record types one can expect to find in this ORBEX file. For example, a file with positions, clocks, and attitude information might use three types of records:
POS CLK ATT
These three digit codes are each separated by a blank space. Cols 22 to 117. The format is 24(A3,1X).

3.3 SATELLITE/ID_AND_DESCRIPTION Block (Mandatory)

Description:

This block provides the definitions for the 3-character satellite identification labels (IDs) that will be used throughout the file, in the various header blocks and in the main EPHEMERIS/DATA block. This block must always follow the FILE/DESCRIPTION block as the second header block in an ORBEX file. Each 3-character ID is followed by a 100-character description field. In addition to satellite names, this description field can also be used to store certain types of satellite-specific information. This can be especially useful for applications which might not have special header blocks already defined. For the 3-character IDs, it is recommended that the IGS-defined IDs be used (especially for GNSS and LEO applications). These follow the conventions set by associated formats like RINEX and ANTEX (see the NOTES section below). If no previous IGS-defined code(s) exist, then user-defined satellite IDs can be used and described via this SATELLITE/ID_AND_DESCRIPTION block. The order of the satellite IDs in this block must match that used in the SATELLITE/ID_AND_DESCRIPTION block.

Contents:

SATELLITE/ID_AND_DESCRIPTION DATA LINE			
Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R09 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html . Note: SV IDs like "G 2" or "R 9" or “ 31” are not allowed. This is the unique satellite identifier for the entire file.	A1,I2.2	2 to 4
RESERVED COLUMN	This fifth column is reserved for later use (in case longer SV IDs become necessary).	1X	5 to 5
Satellite	The type of satellite within the	1X,A100	6 to 106

Description	constellation (e.g., BLOCK IIR-B for GPS, or GLONASS-M for GLONASS) For LEOs, this can be the SV name (e.g., for L06 use "CHAMP").		
		Total 106	

NOTES:

As described previously in the Sp3-c format, and in RINEX, the IGS-defined satellite IDs are comprised of a one-character satellite system identifier followed by two-digit integer number (e.g., G02, G31, R03, R15, E02, C01, S22, L06, etc.). The satellite system identifier codes are:

G : GPS
R : GLONASS
E : Galileo
C : COMPASS
L : Low Earth Orbiting satellite (LEO), see http://cddis.nasa.gov/sp3c_satlist.html
S : Satellite-Based Augmentation System (SBAS)

The 2-digit integer numbers represent the following for each different type of constellation:

PRN	(for GPS, Galileo, and COMPASS)
Slot number	(for GLONASS)
PRN-100	(for SBAS Geostationary)

If the integer number is less than 10, it should be padded with a leading zero (i.e., 'G01' not 'G 1'). All numbers must be >= 1 and <= 99; zero is not a valid satellite number.

There are codes for 58 different LEO satellites given at the CDDIS web page referenced above. If no IGS-defined code is available for a satellite (or group of satellites) the user can define new codes. It is recommended that the new codes not use any of the six letters listed above, to avoid any possible confusion regarding a satellite's identity.

For each constellation type, the satellite IDs must be listed in numerical order. The constellation types themselves can come in any order (e.g., in a file containing GPS and GLONASS satellites, the GLONASS satellites can come first in numerical order, followed by the GPS satellites in numerical order -- or vice-versa).

3.4 SATELLITE/LABELS_AND_STD_DEVS Block (Optional)

Description:

This block is designed to provide a way to cross-reference the 3-character satellite IDs (e.g. R21) with the 20-character satellite antenna label (e.g. 'GLONASS-M'), the 4-character satellite code/SVN or GLONASS number (e.g., 'R725'), and 9-character COSPAR ID (e.g., '2008-046B') used in the ANTEX file. Note that each of these labels appears in their respective 20-character, or 10-character fields in the ANTEX format (Rothacher and Schmid, 2006). As with ANTEX, the IGS-maintained rcvr_ant.tab file is the official source for the 20-character satellite antenna labels (rcvr_ant.tab, 2010). Similar to the older SP3-c format, this block also lists: the standard deviation of the satellite positions for a given time period (in mm), and now the standard deviation of the satellite clock corrections (in picosecs). Also listed are the GLONASS channel numbers, the observed/predicted flags, and the Start/End Times. For any satellite that is not GLONASS, the channel number in cols 72 to 74 can be left blank. Since each line has its own start and stop time, additional lines can be added to give different position and/or clock standard deviations for specific time spans (e.g., for the predicted part of the IGS ultra-rapid orbit, or for periods when a satellite is known to have experienced a problem). If a position standard deviation is unknown leave the file blank; if it is greater than 100 meters, use the value 99999.99 mm in columns 50 to 57. If a clock correction standard deviation is unknown leave the field blank; if it is greater than 100 microseconds, use the value 99999999.999 psec in columns 59 to 70. The order of the satellite IDs in this block must match that used in the SATELLITE/ID_AND_DESCRIPTION block.

Contents:

SATELLITE/LABELS_AND_STD_DEVS DATA LINE			
Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02	A1,I2.2	2 to 4

	for GPS, or R09 for GLONASS). For LEOs see: http://cddis.nasa.gov/ sp3c_satlist.html . Note: SV IDs like "G 2" or "R 9" or " 31" are not allowed. This is the unique satellite identifier for the entire file.		
RESERVED COLUMN	This fifth column is reserved for later use (in case longer SV IDs become necessary).	1X	5 to 5
Satellite Type	The type of satellite within the constellation (e.g., BLOCK IIR-B for GPS, or GLONASS-M for GLONASS) For LEOs, this can be the SV name (e.g., for L06 use "CHAMP").	1X,A20	6 to 26
Satellite Code (SVN or GLONASS number)	4-digit integer which represents the SVN or GLONASS number (e.g., in 2009, GPS PRN G02 was SVN 61, and R24 was GLONASS number 713). So their satellite codes would be G061 and R713, respectively.	1X,I4	27 to 37
COSPAR ID	9-char COSPAR number assigned by NORAD,NASA using YYYY-XXXA, where YYYY = launch year, XXX = sequential launch number for that year, and A = sequence number within a launch.	1X,A9	38 to 48
Standard Dev. for Positions	Standard Deviation for satellite positions, for the time period specified (one sigma, units = mm).	1X,F8.2	49 to 57
Standard Dev. for Satellite Clock Corrections	Standard Deviation for satellite clock corrections, for time period specified (one sigma, units = picoseconds).	1X,F12.1	58 to 70
Channel Number	Channel number used to compute the frequencies for a particular GLONASS satellite. For satellites that are not GLONASS, leave blank. Valid GLONASS channel numbers are between -7 and +13 See (GLONASS ICD, 2008).	1X,I3	71 to 74
Orbit Prediction Flag	A two-char Observed/Predctd. flag OB = orbit has been observed PR = orbit is predicted (for the time period specified).	1X,A2	75 to 77
Clock Corr. Prediction Flag	A two-char Observed/Predctd. flag OB = clock has been observed PR = clock is predicted (for the time period specified).	1X,A2	78 to 80
Start Time (YMDHMS)	First epoch for the time period specified for the standard devs, # epochs, and obs/predicted flag (time is to the nearest second).	1X,I4 1X,I2 1X,I2 1X,I2 1X,I2 1X,I2	81 to 100
End Time (YMDHMS)	Last epoch for the time period specified for the standard devs, # epochs, and obs/predicted flag (time is to the nearest second).	1X,I4 1X,I2 1X,I2 1X,I2	101 to 120

		1X,I2 1X,I2	
		Total 120	

3.5 EPHEMERIS/MODELS Block (Optional)

Description:

This block provides information on the various models used to calculate the satellite positions and satellite clock corrections in an ORBEX file. For the IGS combined orbit files, this might include the name of the satellite antenna Phase Center Variation (PCV) model, the name of the Ocean Tide Loading (OTL) model, the name of the Atmospheric Tide Loading (ATL) model, and whether or not the Earth Center-of-Mass Correction (CMC) was applied to the OTL and ATL models. IGS combined orbit files may also have model names and codes that describe the origin definition for the orbits and satellite clock corrections.

Contents:

EPHEMERIS/MODELS DATA LINES

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Model Type	Type of model being described.	A40	2 to 41
Model Description	Describe the file(s) used to implement each model, the options or parameters used to implement each model, or a particular name which describes the exact model that was used. See the 'Notes:' section below for examples.	1X, A60	42 to 102
		Total 102	

NOTES:

The following is an example of what an EPHEMERIS/MODELS block might look like for an IGS combined orbit file:

```
+EPHEMERIS/MODELS
*MODEL_TYPE_____________________________   DESCRIPTION_____________________________________________
 SATELLITE_ANTENNA_PCV_MODEL               igs05_1575.atx
 OCEAN_TIDE_LOADING_MODEL                  FES2004 EARTH_CMC_APPLIED
 ATMOSPHERIC_TIDE_LOADING_MODEL            NONE NO_EARTH_CMC_APPLIED
 ECEF_ORIGIN_DEFINITION_ORBITS             CENTER_OF_NETWORK
 ECEF_ORIGIN_DEFINITION_CLOCKS             CENTER_OF_NETWORK
-EPHEMERIS/MODELS
```

SATELLITE_ANTENNA_PCV_MODEL:
The history of which satellite antenna offsets and PCVs were used to create a GNSS orbit (or an IGS combined orbit) is tracked by noting the week number in the name of the ANTEX file (e.g., igs05_wwww.atx, where wwww is the GPS week when the file was released). For current GPS and GLONASS satellites the DESCRIPTION field should be filled using the complete, lowercase ANTEX filename (e.g. igs05_1575.atx). If no satellite PCV model was used, use the label NONE.

OCEAN_TIDE_LOADING_MODEL:
For orbit determination, the site-dependent amplitude and phase values for the 11 main tides can be generated upon request by the Bos-Scherneck Ocean Tide Loading (OTL) service at the Onsala Space Observatory: http://www.oso.chalmers.se/~loading/ . As an option, these 66 coefficients can

be corrected for the center-of-mass motion of the earth, for various OTL models such as FES2004:
http://www.oso.chalmers.se/~loading/cmc.html
The model name for the Ocean Tide Loading model must be given at the beginning of the DESCRIPTION field. If no OTL model was used, use the label NONE. Then, separated by one blank space, the label 'EARTH_CMC_APPLIED' or the label 'NO_EARTH_CMC_APPLIED' is given to indicate whether or not the center-of-mass correction (CMC) was included in the model.

ATMOSPHERIC_TIDE_LOADING_MODEL:
In a similar fashion, the name of the Atmospheric Tide Loading (ATL) model should be given at the beginning of the DESCRIPTION field. If no ATL model was used, use the label NONE. Then, separated by one blank space, the label 'EARTH_CMC_APPLIED' or the label 'NO_EARTH_CMC_APPLIED' is given to indicate whether or not the center-of-mass correction (CMC) was included in the model.

ECEF_ORIGIN_DEFINITION_ORBITS:
The orbits generated by the Analysis Centers (ACs) of the IGS are usually given in an Earth-Centered, Earth-Fixed frame (ECEF). Usually this frame is the latest International Terrestrial Reference Frame (ITRF) or a realization of the ITRF. The origin definition for the orbit(s) is CENTER_OF_NETWORK (CoN) if the center-of-mass corrections (CMC) are applied to the tide loading models during generation of the orbits. If these corrections are NOT applied, then the origin for the orbits is CENTER_OF_MASS (CoM).

ECEF_ORIGIN_DEFINITION_CLOCKS:
The origin definition for the clock(s) is CENTER_OF_NETWORK (CoN) if the station coordinates are fixed to the ITRF during clock adjustment. If the ORBEX file is created using Analysis Center data where not all of the clock data was referenced to the same origin, then the label used should be COMBINATION (Gendt, 2006). If no clocks are provided for the satellite(s), use the label NOT_APPLICABLE. Thus the choices for the origin definition of the clocks (as used together with an ECEF orbit) are:
CENTER_OF_NETWORK
COMBINATION
NOT_APPLICABLE

This EPHEMERIS/MODELS block may also be used to store information about other types of models. It is recommended that software reading this block be designed to skip over any model types it might not recognize. Below is a generic example that includes some additional model types.

```
+EPHEMERIS/MODELS
*MODEL_TYPE______________________________ DESCRIPTION_______________________________________
 SATELLITE_ANTENNA_PCV_MODEL              igs05_1575.atx
 OCEAN_TIDE_LOADING_MODEL                 FES2004  EARTH_CMC_APPLIED
 ATMOSPHERIC_TIDE_LOADING_MODEL           NONE  NO_EARTH_CMC_APPLIED
 ECEF_ORIGIN_DEFINITION_ORBITS            CENTER_OF_NETWORK
 NUTATION                                 IAU1980
 PRECESSION                               IAU1976
 SOLAR_SYSTEM_EPHEMERIS                   DE403
 RELATIVITY                               POST_NEWTONIAN
 ATMOSPHERE_MODEL                         MSIS77
 SOLAR_RADIATION_PRESSURE                 CODE_9PARAM
-EPHEMERIS/MODELS
```

3.6 SATELLITE/ORBIT_PLANES Block (Optional)

Description:

This block provides information on the orbital planes and slot numbers in each plane, for each of the GNSS satellites. For files with only non-GNSS satellites that are not part of a constellation, this block would be omitted. For files that contain both GNSS and single, non-constellation satellites, the data for the non-constellation satellites may be left blank (as in Example 3 in Section 5). The order of the satellite IDs in this block must match that used in the SATELLITE/ID_AND_DESCRIPTION block.

Contents:

SATELLITE/ORBIT_PLANES DATA LINE

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For	A1,I2.2	2 to 4

	LEOs see: http://cddis.nasa.gov/ sp3c_satlist.html .		
RESERVED COLUMN	This fifth column is reserved for later use (in case longer SV IDs become necessary).	1X	5 to 5
Orbit Plane Designation	The letter/number representing the orbital plane of the satellite (for GPS, planes A through F) (for GLONASS, planes 1 through 3).	1X,A5	6 to 11
Slot number within each plane	The number representing the position of the satellite within its orbital plane. (for GPS, slots 1 through 6) (for GLONASS, slots 1 through 24: 1st plane has slot numbers 1...8, 2nd plane has slot numbers 9...16, 3rd has slot numbers 17...24).	1X,A4	12 to 16
		Total 16	

3.7 SATELLITE/MANEUVER_INFO Block (Optional)

Description:

This block provides information on the start time and end time of a satellite maneuver, and the total resultant change in velocity after the maneuver, in the radial, along-track, and cross-track directions (as referenced to the inertial orbital plane). The Delta-V fields in columns 72 through 104 are optional; in some cases the actual velocity change will be unknown, but the start and stop times will still be important for avoiding bad data. If the end time (i.e., the duration) is unknown, columns 40 to 71 may be left blank. For those satellites that have had maneuvers, the order of the satellite IDs in this block must match that used in the SATELLITE/ID_AND_DESCRIPTION block.

Contents:

SATELLITE/MANEUVER_INFO DATA LINE

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/ sp3c_satlist.html .	A1,I2.2	2 to 4
RESERVED COLUMN	This fifth column is reserved for later use (in case longer SV IDs become necessary).	1X	5 to 5
Start Time (YMDHMS)	Date/Time when the maneuver was known to begin.	1X,I4 4(1X,I2) 1X,F15.12	6 to 38
End Time (YMDHMS)	Date/Time when the maneuver ended. If the end time (duration) is not known, these fields may be left blank.	1X,I4 4(1X,I2) 1X,F15.12	39 to 71
Radial	The resultant change in velocity	1X,F10.4	72 to 82

Delta-V	in the radial direction (m/sec).		
Along-Track Delta-V	Resultant change in velocity in the along-track direction (m/sec).	1X,F10.4	83 to 93
Cross-Track Delta-V	Resultant change in velocity in the cross-track direction (m/sec).	1X,F10.4	94 to 104
		Total 104	

3.8 SATELLITE/ECLIPSE_INFO Block (Optional)

Description:

This block provides information on the start and stop time of an eclipse period for a particular satellite. For those satellites that are in eclipse, the order of the satellite IDs in this block must match that used in the SATELLITE/ID_AND_DESCRIPTION block.

Contents:

SATELLITE/ECLIPSE_INFO DATA LINE			
Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	2 to 4
RESERVED COLUMN	This fifth column is reserved for later use (in case longer SV IDs become necessary).	1X	5 to 5
Start Time (YMDHMS)	Date/Time when the eclipse was known to begin.	1X,I4 4(1X,I2) 1X,F15.12	6 to 38
End Time (YMDHMS)	Date/Time when the eclipse was known to end.	1X,I4 4(1X,I2) 1X,F15.12	39 to 71
TYPE OF ECLIPSE	‘EARTH’ = the satellite is in the earth’s shadow, ‘MOON ’ = the satellite is in the moon’s shadow.	1X,A5	72 to 77
		Total 77	

3.9 SATELLITE/EVENT Block (Optional)

Description:

This block provides information on the start and stop times of any generic “event” for a particular satellite. These events might be related to the satellite “clock”, “phase”, “power”, etc. A clock event is any event which causes a discontinuity in the satellite clock corrections (such as when a clock fails and the satellite must switch to using a different onboard clock). An example of a phase event might be when the phase of the signal for a satellite suddenly shifts, and then shifts back again (the actual phase shift may vary, if the details are known they can be included in the description field). An example of a power event might be something like boosting the signal power on one or more satellites. For those satellites that are in eclipse, the order of the satellite IDs in this block must match that used in the SATELLITE/ID_AND_DESCRIPTION block. The list of event types given below is not final, suggestions are welcome.

Contents:

SATELLITE/EVENT DATA LINE			
Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	2 to 4
RESERVED COLUMN	This fifth column is reserved for later use (in case longer SV IDs become necessary).	1X	5 to 5
Event Type	The type of event being described: CLOCK PHASE POWER	1X,A10	6 to 16
Start Time (YMDHMS)	Date/Time when the satellite event was known to begin.	1X,I4 4(1X,I2) 1X,F15.12	17 to 49
End Time (YMDHMS)	Date/Time when the event ended. If the end time (i.e., duration) is unknown, columns 50 to 82 may be left blank.	1X,I4 4(1X,I2) 1X,F15.12	50 to 82
DESCRIPTION	67-char comment describing what caused the satellite event (e.g., “clock failure: switched from cesium to rubidium”).	1X,A67	83 to 150
		Total 150	

3.10 EPHEMERIS/DATA Block (Mandatory)

Description:

This block is always the last, and usually the largest, block since it contains all of the ephemeris data for the ORBEX file. The data for each epoch begins with a Time Tag Line which gives the Year, Month, Day, Hour, Minute, and Seconds for the epoch, plus the number of satellites which appear at that epoch. Each Time Tag Line starts with the characters "##" in columns one and two. The Time Tag Line is then followed by a series of data records, each of which begins with a blank character, followed by a 3-character record type, then another blank character, then a 3-character Satellite ID. The discussion in Section 3 below describes the format of the Time Tag Line and also the different record types which are used to store orbital data. It is not required that all satellites have the exact same number of record types. For example, a file that has GPS, GLONASS, and a LEO satellite might have attitude information for the LEO (ATT records) but not for the GNSS satellites. The satellites at each epoch can come in any order, and the record types can come in any order. However, for the sake of readability, it is recommended that the satellites be written in the same order as the mandatory SATELLITE/ID_AND_DESCRIPTION block, and that the record types for each satellite be kept together and follow the general order outlined in Figure 2 below. While the order of most record types can be arbitrary, there are two exceptions: a CPC record must always follow its corresponding PCS record, and a CVC record must always follow its corresponding VCS record. This is because both records are needed to build the 4-by-4 covariance matrix for the coordinates and clock correction (or for the velocities and clock rate-of-change).

Similar to all other blocks, this block must start with a +EPHEMERIS/DATA line and end with a -EPHEMERIS/DATA line. Recall that the last line in any ORBEX file must always be the %END_ORBEX line.

4. FORMATS FOR RECORD TYPES

Figure 2, on the following page, shows an example for the time tag record that defines the start of each epoch, and an example for each of the different record types used in the EPHEMERIS/DATA block.

Figure 2. Examples of possible record types used in the EPHEMERIS/DATA block.

Example TIME TAG record:

```
## 2009  4  7  0  0  0.000000000000  51
```

Example PCS record:

```
*REC ID_   FLAGS_ G/B_ N _________X_(m)____ _________Y_(m)____ _________Z_(m)____ __SVCLK_(usec)__ __STD_X __STD_Y __STD_Z _____STD_CLK
*                                                                                                      (mm)    (mm)    (mm)       (psec)
 PCS G02   NP  MP 1111 8     1718903.5130     17055266.0040     20273390.0550      153.7291220     3.8     4.8     6.0       19.358
```

Example CPC record:

```
*REC ID_   FLAGS_ G/B_ N _______xy_corr_____ _______xz_corr_____ _______xc_corr_____ _______yz_corr_____ _______yc_corr_____ _______zc_corr_____
 CPC G02          11   6   -23467890123456     43567892345123    -56723416544276     23456785432412    -76543567234234    -87452341567655
```

Example VCS record:

```
*REC ID_   FLAGS_ G/B_ N _______VX_(m/s)___ _______VY_(m/s)___ _______VZ_(m/s)___ _CLKRATE_(ns/s)_ _STD_VX _STD_VY _STD_VZ _____STD_CLK
*                                                                                                    (um/s)  (um/s)  (um/s)        (fs/s)
 VCS G02          1111 8    -2393.7383154     -1007.7310408      1004.8616286       -0.0002584     1.1     2.2     3.3   45.678901
```

Example CVC record:

```
*REC ID_   FLAGS_ G/B_ N _____vxvy_corr_____ _____vxvz_corr_____ _____vxvc_corr_____ _____vyvz_corr_____ _____vyvc_corr_____ _____vzvc_corr_____
 CVC G02          11   6   -23467890123456     43567892345123    -56723416544276     23456785432412    -76543567234234    -87452341567655
```

Example POS record:

```
*REC ID_   FLAGS_ G/B_ N _________X_(m)____ _________Y_(m)____ _________Z_(m)____
 POS G02    P   MP 1    3     1718903.5130     17055266.0040     20273390.0550
```

Example VEL record:

```
*REC ID_   FLAGS_ G/B_ N _______VX_(m/s)___ _______VY_(m/s)___ _______VZ_(m/s)___
 VEL G02          1    3    -2393.7383154     -1007.7310408      1004.8616286
```

Example CLK record:

```
*REC ID_   FLAGS_ G/B_ N __SVCLK_(usec)__
 CLK G02   N      1    1      153.7291220
```

Example CRT record:

```
*REC ID_   FLAGS_ G/B_ N __SVCLKR(ns/s)__
 CRT G02          1    1       -0.0002584
```

Example ATT record:

```
*REC ID_   FLAGS_ G/B_ N ___q0_(scalar)______ _____q1__x___________ _____q2__y___________ _____q3__z___________
 ATT L06          1    4  0.9164178227001020  0.3553674926002010  0.1624720204001450 -0.0865746035002370
```

4.1 Time Tag Line

TIME TAG LINE			
Field	Description	Format	Cols
First two characters	The '##' characters in columns one and two are meant to provide an easy to see marker that sets the time tags lines apart from all other record types.	A2	1 to 2
Epoch Date/Time (YMDHMS)	The Date/Time to which the data at this epoch pertains. Note that the seconds field has 12 decimal places to allow for future picosec precision (which is well beyond the 1 nanosec per day drift of the current hydrogen-maser clocks). All times are in the TIME SYSTEM specified in the FILE/DESCRIPTION block. All time tags must be in chronological order. No duplicate time tags are allowed.	1X,I4, 4(1X,I2), 1X,F15.12	3 to 35
Number of Satellites	The number of unique satellite IDs that appear at this epoch. (between 1 and 999). The integer zero is not allowed; if there are no data, then omit the time tag (integers are right-justified).	1X,I3	36 to 39
		Total 39	

4.2 PCS Record

PCS RECORD TYPE (POSITION, CLOCK, & STANDARD DEVIATIONS)			
Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: PCS).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
Satellite Event Flag	‘N’ = a satellite event has occurred (a CLOCK,PHASE,or POWER event) Blank means either no event has occurred, or it is unknown whether any event has occurred. See the NOTES section below.	1X,A1	10 to 11

Predicted Clock Flag	'P' = the satellite clock corr at this epoch is predicted. A blank means the clock corr is observed.	A1	12 to 12
RESERVED	Columns 13 and 14 are reserved for later use.	2X	13 to 14
Maneuver Flag	'M' = a maneuver has occurred. A blank means either no maneuver occurred, or it is unknown whether any maneuver occurred. See the NOTES section below.	A1	15 to 15
Predicted Orbit Flag	'P' = the satellite position at this epoch is predicted. A blank means the position is observed.	A1	16 to 16
Good/Bad Flag For Position	'1' = the X,Y,Z coordinates on this line are valid. '0' = the X,Y,Z coordinates on this line are invalid (they may be all 0.0, or have large errors). See the NOTES section below.	1X,I1	17 to 18
Good/Bad Flag For Satellite Clock Correction	'1' = the clock correction on this line is valid. '0' = the clock correction on this line is invalid (it may be 0.0, have a large error, or only the first 3 data cols are present) See the NOTES section below.	I1	19 to 19
Good/Bad Flag For Position Standard Deviations	'1' = the X,Y,Z std. deviations on this line are valid. '0' = the X,Y,Z std. deviations on this line are invalid (they may be 0.0, have large errors, or only the first 4 data cols are present) See the NOTES section below.	I1	20 to 20
Good/Bad Flag For Clock Correction Standard Deviation	'1' = the clk corr std. deviation on this line is valid. '0' = the clk corr std. deviation on this line is invalid (it is 0.0, has a large error, or only the first 7 data cols are present) See the NOTES section below.	I1	21 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. Choices are 3, 4, 7, or 8.	1x,I1	22 to 23
X-coordinate	The X-coordinate for the position of the satellite (in the coordinate system specified in the FILE/DESCRIPTION block). Units = meters.	1X,F16.4	24 to 40
Y-coordinate	The Y-coordinate for the position of the satellite. Units = meters.	1X,F16.4	41 to 57
Z-coordinate	The Z-coordinate for the position of the satellite. Units = meters.	1X,F16.4	58 to 74
Satellite Clock Correction	The satellite clock correction in units of microseconds. Bad/absent	1X,F16.7	75 to 91

	clock values are set equal to 9999999.9999999. Units = microseconds.		
Standard Dev. for X-coord.	The one-sigma standard deviation for the X-coordinate at this epoch (for the IGS combined orbits, see IGSMAIL-5008, 7 Sep 2004). If the sigma = 99999.9, it means the uncertainty for this coordinate is greater than 100 meters, or the orbit for this SV is unreliable. Units = millimeters.	1X,F7.1	92 to 99
Standard Dev. for Y-coord.	The one-sigma standard deviation for the Y-coordinate at this epoch If sigma = 99999.9, it means the uncertainty for this coordinate is greater than 100 meters, or the orbit for this SV is unreliable. Units = millimeters.	1X,F7.1	100 to 107
Standard Dev. for Z-coord.	The one-sigma standard deviation for the Z-coordinate at this epoch If sigma = 99999.9, it means the uncertainty for this coordinate is greater than 100 meters, or the orbit for this SV is unreliable. Units = millimeters.	1X,F7.1	108 to 115
Standard Dev. for Satellite Clock Correction	The one-sigma standard deviation for the satellite clock correction at this epoch (for the IGS combined orbits, see IGSMAIL-5008, 7 Sep 2004). If sigma = 9999999.999, then the uncertainty for this clock corr is greater than 10 microsec, or this SV clock corr should not be used. Units = picoseconds.	1X,F11.3	116 to 127
		Total 127	

NOTES: For each PCS record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., each data value is separated by one or more blank spaces). However, the 3-character record type code, the 3-character satellite ID, the satellite event flag, the predicted/observed flags, the maneuver flag, the good/bad flags, and the Number of Data Columns Present (i.e., all of the fields in columns 2 to 23) must be read according to the fixed formats given above.

The **Satellite Event Flag** in column 11 can be ‘N’ or blank. ‘N’ indicates that sometime between the previous epoch and the current epoch, or at the current epoch, a satellite event occurred. A blank means either no event occurred, or it is unknown whether any event occurred. The three types of satellite events currently defined are:
CLOCK event (e.g., a clock swap on a satellite),
PHASE event (e.g., a signal phase shift on a satellite),
POWER event (e.g., a power boost to one or more signals from a satellite).

This list is not final, suggestions are welcome. Additional details regarding a particular problem or event for a satellite can be placed into a SATELLITE/EVENT block, which must be positioned somewhere prior to the EPHEMERIS/DATA block.

The **Maneuver Flag** in column 15 can be ‘M’ or blank. ‘M’ indicates that sometime between the previous epoch and the current epoch, or at the current epoch, an orbit maneuver took place for this satellite. A maneuver is loosely defined as any planned or humanly-detectable thruster firing that changes the orbit of a satellite. A blank means either no maneuver occurred, or it is unknown whether any maneuver occurred. Additional details regarding start time, stop time (if known), and the delta V’s for a satellite can be placed in a SATELLITE/MANEUVER block, prior to the EPHEMERIS/DATA block.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The PCS record uses all four of these.

* The first flag, in column 18, applies to the X,Y,Z coordinates. A ‘1’ means that the three coordinate values are valid. A ‘0’ means that the three coordinate values are invalid. This could be because they have large errors and thus should be ignored by the user.

* The second flag, in column 19, applies to the satellite clock correction. A ‘1’ means that the clock correction value is valid. A ‘0’ means that the clock correction value is invalid. This could be because it is unknown or missing and thus set to 0.0, or because the value has a large error and hence it should be ignored by the user. This flag may also be set to ‘0’ when the record ends after the X,Y,Z coordinates (i.e., the last five data columns are missing; there is no clock correction, no position standard deviations, and no clock correction standard deviation given for this satellite).

* The third flag, in column 20, applies to the standard deviations for the X,Y,Z coordinates. A ‘1’ means that the three X,Y,Z standard deviation values are valid. A ‘0’ means that the three standard deviation values are invalid. This could be because they are missing and set to 0.0, or because the values have large errors and thus should be ignored by the user. This flag may also be set to ‘0’ when the record ends after the X, Y, Z, clock correction (i.e., the last four data columns are missing; there are no position standard deviations, and no clock correction standard deviation given for this satellite).

* The fourth flag, in column 21, applies to the standard deviation for the satellite clock correction. A ‘1’ means that the clock correction standard deviation value is valid. A ‘0’ means that the clock correction standard deviation value is invalid. This could be because it is missing and set to 0.0, or because the value has a large error and thus should be ignored by the user. This flag may also be set to ‘0’ when the record ends after the X, Y, Z, clock correction, and position standard deviations (i.e., the last data column is missing; there is no clock correction standard deviation given for this satellite).

The **Number of Data Columns Present** value in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values will depend on the record type: 8 for (PCS,VCS), 6 for (CPC,CVC), 4 for (ATT), 3 for (POS,VEL), and 1 for (CLK,CRT). Since the data values are read in free-formatted, it is recommended that reading programs first initialize all values to zero, then read the line into a buffer first (so that data items are never accidentally read from the next line), and then use a choice of read statements to read the actual number of data values present (otherwise, a read error may occur). For the above PCS record, the possible choices for the number of data columns are: 3, 4, 7, or 8. When a data value is invalid but is embedded in between two valid data values, then because of the free-formatting, it must be represented as a 0.0 - which acts as a place holder (e.g., if a PCS record has no clock information, but does have the position standard deviations, then the clock correction field must have a 0.0000000 as a place holder).

4.3 VCS Record

VCS RECORD TYPE (VELOCITY, CLOCK RATE, & STANDARD DEVIATIONS)

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: VCS).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
RESERVED	Columns 10 to 17 are not utilized for the VCS record.	7X	10 to 16
Good/Bad Flag For Velocity	‘1’ = the X,Y,Z velocities on this line are valid. ‘0’ = the X,Y,Z velocities on	1X,I1	17 to 18

	this line are invalid (they may be all 0.0, or have large errors). See the NOTES section below.		
Good/Bad Flag For Satellite Clock Correction Rate-of-Change	‘1’ = the clock corr rate on this line is valid. ‘0’ = the clock corr rate on this line is invalid (it may be 0.0, have a large error, or only the first 3 data cols are present) See the NOTES section below.	I1	19 to 19
Good/Bad Flag For Velocity Standard Deviations	‘1’ = the velocity std. deviations on this line are valid. ‘0’ = the velocity std. deviations on this line are invalid (they are 0.0, have large errors, or only the first 4 data cols are present) See the NOTES section below.	I1	20 to 20
Good/Bad Flag For Clock Correction Rate-of-Change Standard Deviation	‘1’ = the clk rate std. deviation on this line is valid. ‘0’ = the clk rate std. deviation on this line is invalid (it is 0.0, has a large error, or only the first 7 data cols are present) See the NOTES section below.	I1	21 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. Choices are 3, 4, 7, or 8.	1x,I1	22 to 23
X-component of the satellite velocity	The X-component of the satellite velocity (in the coordinate system specified in the FILE/DESCRIPTION block). Units = meters/second.	1X,F16.7	24 to 40
Y-component of velocity	The Y-component of velocity. Units = meters/second.	1X,F16.7	41 to 57
Z-component of velocity	The Z-component of velocity. Units = meters/second.	1X,F16.7	58 to 74
Rate-of-Change of satellite	The rate-of-change of the satellite clock correction. Bad/absent clock rate-of-change values are set equal to 9999999.9999999. Units = nanoseconds/second.	1X,F16.7	75 to 91
Standard Dev. for X-velocity	The one-sigma standard deviation for the X-velocity at this epoch. If sigma = 99999.9, it means the uncertainty for this velocity is greater than 1 decimeter/sec, or this SV’s orbit is unreliable. Units = micrometers/second.	1X,F7.1	92 to 99
Standard Dev. for Y-velocity	The one-sigma standard deviation for the Y-velocity at this epoch. If sigma = 99999.9, it means the uncertainty for this velocity is greater than 1 decimeter/sec, or this SV’s orbit is unreliable. Units = micrometers/second.	1X,F7.1	100 to 107
Standard Dev. for Z-velocity	The one-sigma standard deviation for the Z-velocity at this epoch. If sigma = 99999.9, it means the uncertainty for this velocity is greater than 1 decimeter/sec, or this SV’s orbit is unreliable. Units = micrometers/second.	1X,F7.1	108 to 115

Field	Description	Format	Cols
Standard Dev. Rate-of-Change of SV Clk corr.	The one-sigma standard deviation for the Rate-of_Change of the SV clock correction at this epoch. If sigma = 9999999.999, then the uncertainty for this clock rate is > than 10 nanosec/sec, or this clock rate should not be used. Units = femtoseconds/second.	1X,F11.3	116 to 127
		Total 127	

NOTES: For each VCS record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., each data value is separated by one or more blank spaces). However, the 3-character record type code, the 3-character satellite ID, the good/bad flags, and the Number of Data Columns Present (i.e., all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above. To avoid redundancy, the satellite event flag, the predicted/observed flags, and the maneuver flag, are not used for the VCS record.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The VCS record uses all four of these.
* The first flag, in column 18, applies to the X,Y,Z velocities. A ‘1’ means that the three velocity values are valid. A ‘0’ means that the three velocity values are invalid. This could be because they are missing and set to 0.0, or because the values have large errors and thus should be ignored by the user.

* The second flag, in column 19, applies to the clock correction rate-of-change. A ‘1’ means that the clock corr rate value is valid. A ‘0’ means that the clock corr rate value is invalid. This could be because it is unknown or missing and thus set to 0.0, or because the value has a large error and hence it should be ignored by the user. This flag may also be set to ‘0’ when the record ends after the X,Y,Z velocities (i.e., the last five data columns are missing; there is no clock corr rate, no velocity standard deviations, and no clock correction rate-of-change standard deviation given for this satellite).

* The third flag, in column 20, applies to the standard deviations for the X,Y,Z velocities. A ‘1’ means that the three velocity standard deviation values are valid. A ‘0’ means that the three standard deviation values are invalid. This could be because they are missing and set to 0.0, or because the values have large errors and thus should be ignored by the user. This flag may also be set to ‘0’ when the record ends after the X-dot, Y-dot, Z-dot, clock rate (i.e., the last four data columns are missing; there are no velocity standard deviations, and no clock correction rate-of-change standard deviation given for this satellite).

* The fourth flag, in column 21, applies to the standard deviation for the satellite clock correction rate-of-change. A ‘1’ means that the clock corr rate standard deviation value is valid. A ‘0’ means that the clock corr rate standard deviation value is invalid. This could be because it is missing and set to 0.0, or because the value has a large error and thus should be ignored by the user. This flag may also be set to ‘0’ when the record ends after the velocities, clock correction rate-of-change, and velocity standard deviations (i.e., the last data column is missing; there is no clock correction rate standard deviation given for this satellite).

The **Number of Data Columns Present** integer in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values for the above VCS record is 8. The possible choices are: 3, 4, 7, or 8.

4.4 CPC Record

CPC RECORD TYPE (CORRELATION COEFFICIENTS FOR POSITION & CLOCK)

(this record can be used together with a PCS record to compute covariances)

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: CPC).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5

Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
RESERVED	Columns 10 to 17 are not utilized for the CPC record.	7X	10 to 16
Good/Bad Flag For Position Coefficients	'1' = the xy,xz,yz coefficients on this line are valid. '0' = the xy,xz,yz coefficients on this line are invalid (they may be all 0.0, or have large errors). See the NOTES section below.	1X,I1	17 to 18
Good/Bad Flag For Satellite Clock Correction Coefficients	'1' = the xc,yc,zc coefficients on this line are valid. '0' = the xc,yc,zc coefficients on this line are invalid (they are 0.0, have large errors, or only the first 4 data cols are present) See the NOTES section below.	I1	19 to 19
RESERVED	Columns 20-21 are blank for a CPC record.	2X	20 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. Possible choices are 4 or 6.	1x,I1	22 to 23
XY CORRELATION Coefficient	The correlation coefficient between the X-coordinate and the Y-coordinate. The elements are in the order of the upper triangular part of the 4 x 4 correlation matrix. The covariance can be computed using this coeff and the std. devs. in the PCS record. Divide each 17-digit integer by 10**16 to obtain a correlation coeff between -0.9999999999999999 and +0.9999999999999999.	1X,I17	10 to 27
XZ CORRELATION Coefficient	The correlation coefficient between the X-coordinate and the Z-coordinate (divide by 10*16).	1X,I17	28 to 45
XC CORRELATION Coefficient	The correlation coefficient between the X-coordinate and the SV clock corr (divide by 10**16).	1X,I17	46 to 63
YZ CORRELATION Coefficient	The correlation coefficient between the Y-coordinate and the Z-coordinate (divide by 10**16).	1X,I17	64 to 81
YC CORRELATION Coefficient	The correlation coefficient between the Y-coordinate and the SV clock corr (divide by 10**16).	1X,I17	82 to 99
ZC CORRELATION Coefficient	The correlation coefficient between the Z-coordinate and the SV clock corr (divide by 10**16).	1X,I17	100 to 117

		Total 117	

NOTES: For each CPC record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., each data value is separated by one or more blank spaces). However, the 3-character record type code, the 3-character satellite ID, the good/bad flags, and the Number of Data Columns Present (all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above. To avoid redundancy, the satellite event flag, the predicted/observed flags, and the maneuver flag are not used for the CPC record.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The CPC record uses only the leftmost two flags in columns 18 and 19.

* The first flag, in column 18, applies to the correlation coefficients for the X,Y,Z coordinates (i.e., xy,xz,yz). A ‘1’ means that these three coefficients are valid. A ‘0’ means that these three coefficents are invalid. This could be because they have large errors and thus should be ignored by the user.

* The second flag, in column 19, applies to the correlation coefficients for the clock correction with respect to the X,Y,Z coordinates (i.e., xc,yc,zc). A ‘1’ means that these coefficients are valid. A ‘0’ means that these coefficients are invalid. This could be because they are unknown or missing and thus set to 0.0, or because the values have large errors and hence should be ignored by the user. This flag may also be set to ‘0’ when the record ends after the yz correlation coefficient (i.e., the last two data columns are missing because there are no correlation coefficients related to the satellite clock correction; in such a case, xc = 0 would be used as a place holder).

The **Number of Data Columns Present** value in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values for the above CPC record is 6. The possible choices are 4 or 6, as explained above.

4.5 CVC Record

CVC RECORD TYPE (CORRELATION COEFFICIENTS FOR VELOCITY & CLOCK-RATE)

(this record can be used together with a VCS record to compute covariances)

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: CVC).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
RESERVED	Columns 10 to 16 are not utilized for the CVC record.	7X	10 to 16
Good/Bad Flag For Position	‘1’ = the vxvy,vxvz,vyvz coeffs on this line are valid. ‘0’ = the vxvy,vxvz,vyvz coeffs on this line are invalid (they may be all 0.0, or have large errors).	1X,I1	17 to 18

	See the NOTES section below.		
Good/Bad Flag For Satellite Clock Correction	‘1’ = the vxvc,vyvc,vzvc coeffs on this line are valid. ‘0’ = the vxvc,vyvc,vzvc coeffs on this line are invalid (they are 0.0, have a large error, or only the first 4 data cols are present) See the NOTES section below.	I1	19 to 19
RESERVED	Columns 20-21 are blank for a CVC record.	2X	20 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. Choices are 4 or 6.	1x,I1	22 to 23
.. XY CORRELATION Coefficient correlation between the X-component of velocity & the Y-component of velocity	The correlation coefficient between X-dot and Y-dot (X & Y velocity components). Elements are in the order of the upper triangular part of the 4 x 4 correlation matrix. The covariance can be computed using this coeff and the std. devs. in the VCS record. Divide each 17-digit integer by 10**16 to obtain a correlation coeff between -0.9999999999999999 and +0.9999999999999999.	1X,I17	10 to 27
.. XZ CORRELATION Coefficient	The correlation coefficient between X-dot and Z-dot (divide by 10*16).	1X,I17	28 to 45
.. XC CORRELATION Coefficient	The correlation coefficient between the X-dot and the SV clock Rate-of-Change (divide by 10**16).	1X,I17	46 to 63
.. YZ CORRELATION Coefficient	The correlation coefficient between Y-dot and Z-dot (divide by 10**16).	1X,I17	64 to 81
.. YC CORRELATION Coefficient	The correlation coefficient between the Y-dot and the SV clock Rate-of-Change (divide by 10**16).	1X,I17	82 to 99
.. ZC CORRELATION Coefficient	The correlation coefficient between the Z-dot and the SV clock Rate-of-Change (divide by 10**16).	1X,I17	100 to 117
		Total 117	

NOTES: For each CVC record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., each data value is separated by one or more blank spaces). However, the 3-character record type code, the 3-character satellite ID, the good/bad flags, and the Number of Data Columns Present (all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above. To avoid redundancy, the satellite event flag, the predicted/observed flags, and the maneuver flag, are not used for the CVC record.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The CVC record uses only the leftmost two flags in columns 18 and 19.

* The first flag, in column 18, applies to the correlation coefficients for the X,Y,Z velocities (i.e., vxvy,vxvz,vyvz). A ‘1’ means that these three coefficients are valid. A ‘0’ means that these three coefficents are invalid. This could be because they have large errors and thus should be ignored by the user.

* The second flag, in column 19, applies to the correlation coefficients for the clock correction rate-of-change with respect to the X,Y,Z velocities (i.e., vxvc,vyvc,vzvc). A ‘1’ means that

these coefficients are valid. A '0' means that these coefficients are invalid. This could be because they are unknown or missing and thus set to 0.0, or because the values have large errors and hence should be ignored by the user. This flag may also be set to '0' when the record ends after the vyvz correlation coefficient (i.e., the last two data columns are missing because there are no correlation coefficients related to the satellite clock correction rate-of-change; in such a case, vxvc = 0 would be used as a place holder).

The **Number of Data Columns Present** integer in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values for the above CVC record is 6. The possible choices are 4 or 6, as explained above.

4.6 POS Record

POS RECORD TYPE (X,Y,Z COORDINATES OF THE SATELLITE)

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: POS).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
Satellite Event Flag	'N' = a satellite event has occurred (e.g.,CLOCK,PHASE,POWER). Blank means either no event has occurred, or it is unknown whether any event has occurred. See the NOTES section below.	1X,A1	10 to 11
RESERVED	Columns 12 to 14 are not utilized for the POS record.	3X	12 to 14
Maneuver Flag	'M' = a maneuver has occurred. A blank means either no maneuver occurred, or it is unknown whether any maneuver occurred. See the NOTES section below.	A1	15 to 15
Predicted Orbit Flag	'P' = the satellite position at this epoch is predicted. A blank means the position is observed.	A1	16 to 16
Good/Bad Flag For Position	'1' = the X,Y,Z coordinates on this line are valid. '0' = the X,Y,Z coordinates on this line are invalid (they may have large errors). See the NOTES section below.	1X,I1	17 to 18
RESERVED	Columns 19 to 21 are blank for a POS record.	3X	19 to 21
Number Of	Gives the number of data columns	1x,I1	22 to 23

Data Columns Present	present on this line after column 23. Only a choice of 3 make sense.		
X-coordinate	The X-coordinate for the Center of Mass of the satellite (in the coordinate system specified in the FILE/DESCRIPTION block). Units = meters.	1X,F16.4	24 to 40
Y-coordinate	The Y-coordinate for the Center of Mass of the satellite. Units = meters.	1X,F16.4	41 to 57
Z-coordinate	The Z-coordinate for the Center of Mass of the satellite. Units = meters.	1X,F16.4	58 to 74
		Total 74	

NOTES: For each POS record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., each data value is separated by one or more blank spaces). However, the 3-character record type code, the 3-character satellite ID, the satellite event flag, the predicted/observed flag, the maneuver flag, the good/bad flag, and the Number of Data Columns Present (i.e., all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above.

The **Satellite Event Flag** in column 11 can be 'N' or blank. 'N' indicates that sometime between the previous epoch and the current epoch, or at the current epoch, a satellite event occurred. A blank means either no event occurred, or it is unknown whether any event occurred. The three types of satellite events currently defined are:
CLOCK event (e.g., a clock swap on a satellite),
PHASE event (e.g., a signal phase shift on a satellite),
POWER event (e.g., a power boost to one or more signals from a satellite).

This list is not final, suggestions are welcome. Additional details regarding a particular problem or event for a satellite can be placed in a SATELLITE/EVENT block, prior to the EPHEMERIS/DATA block.

The **Maneuver Flag** in column 15 can be 'M' or blank. 'M' indicates that sometime between the previous epoch and the current epoch, or at the current epoch, an orbit maneuver took place for this satellite. A maneuver is loosely defined as any planned or humanly-detectable thruster firing that changes the orbit of a satellite. A blank means either no maneuver occurred, or it is unknown whether any maneuver occurred. Additional details regarding start time, stop time (if known), and the delta V's for a satellite can be placed in a SATELLITE/MANEUVER block, prior to the EPHEMERIS/DATA block.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The PCS record uses only the leftmost flag in column 18.

* The first flag, in column 18, applies to the X,Y,Z coordinates. A '1' means that the three coordinate values are valid. A '0' means that the three coordinate values are invalid. This could be because they are missing and set to 0.0, or because the values have large errors and thus should be ignored by the user.

The **Number of Data Columns Present** value in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values will depend on the record type: 8 for (PCS,VCS), 6 for (CPC,CVC), 4 for (ATT), 3 for (POS,VEL), and 1 for (CLK,CRT). Since the data values are read in free-formatted, it is recommended that reading programs first initialize all values to zero, then read the line into a buffer (so that data items are never accidentally read from the next line), and then use a choice of read statements to read the actual number of data values present (otherwise, a read error may occur). For the above POS record, the only possible choice is 3, since one would expect all three coordinates will always be valid or invalid together. If none of the coordinates are present, then obviously there would be no POS record included for this satellite.

4.7 VEL Record

VEL RECORD TYPE (X,Y,Z COMPONENTS FOR THE VELOCITY OF THE SATELLITE)			
Field	Description	Format	Cols
First Character	Single blank character in col one.	1X	1 to 1

	No other character than ' ' is allowed.		
Record Type	The 3-character Record Type code (for this record type: VEL).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
RESERVED	Columns 10 to 17 are not utilized for the VEL record.	7X	10 to 16
Good/Bad Flag For Velocity	‘1’ = the X,Y,Z velocities on this line are valid. ‘0’ = the X,Y,Z velocities on this line are invalid (they may have large errors). See the NOTES section below.	1X,I1	17 to 18
RESERVED	Columns 19 to 21 are blank for a VEL record.	3X	19 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. The only choice is 3.	1x,I1	22 to 23
X-component of the satellite velocity	The X-component of the satellite velocity (in the coordinate system specified in the FILE/DESCRIPTION block, for the SV Center-of-Mass) Units = meters/second.	1X,F16.7	24 to 40
Y-component of velocity	The Y-component of velocity. Units = meters/second.	1X,F16.7	41 to 57
Z-component of velocity	The Z-component of velocity. Units = meters/second.	1X,F16.7	58 to 74
		Total 74	

NOTES: For each VEL record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., each data value is separated by one or more blank spaces). However, the 3-character record type code, the 3-character satellite ID, the good/bad flags, and the Number of Data Columns Present (i.e., all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above. To avoid redundancy, the satellite event flag, the predicted/observed flags, and the maneuver flag, are not used for the VEL record.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The VCS record uses only the leftmost flag in column 18.

* The first flag, in column 18, applies to the X,Y,Z velocities. A ‘1’ means that the three velocity values are valid. A ‘0’ means that the three velocity values are invalid. This could be because they have large errors and thus should be ignored by the user.

The **Number of Data Columns Present** value in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values for the above VEL record is 3. The only possible choice is 3.

4.8 CLK Record

CLK RECORD TYPE (SATELLITE CLOCK CORRECTION)			
Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: CLK).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
Satellite Event Flag	‘N’ = a satellite event has occurred (e.g.,CLOCK,PHASE,POWER). Blank means either no event has occurred, or it is unknown whether any event has occurred. See the NOTES section below.	1X,A1	10 to 11
Predicted Clock Flag	‘P’ = the satellite clock corr at this epoch is predicted. A blank means the clock corr is observed.	A1	12 to 12
RESERVED	Columns 13 to 16 are not utilized for a CLK record.	4X	13 to 16
Good/Bad Flag For Satellite Clock Correction	‘1’ = the clock correction on this line is valid. ‘0’ = the clock correction on this line is invalid (it may have a large error).	1X,I1	17 to 18
RESERVED	Columns 19 to 21 are blank for a CLK record.	3X	19 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. The only choice is 3.	1x,I1	22 to 23
Satellite Clock Correction	The satellite clock correction. Units = microseconds.	1X,F16.7	24 to 40
		Total 40	

NOTES: For each CLK record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., the data value is separated by one or more blank spaces from col 23). However, the 3-character record type code, the 3-character satellite ID, the satellite event flag, the predicted-clock flag, the good/bad flag, and the number of data columns listed (i.e., all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above. To avoid redundancy, the predicted-orbit flag, and the maneuver flag, are not used for the CLK record.

The **Satellite Event Flag** in column 11 can be 'N' or blank. 'N' indicates that sometime between the previous epoch and the current epoch, or at the current epoch, a satellite event occurred. A blank means either no event occurred, or it is unknown whether any event occurred. The three types of satellite events currently defined are:
CLOCK event (e.g., a clock swap on a satellite),
PHASE event (e.g., a signal phase shift on a satellite),
POWER event (e.g., a power boost to one or more signals from a satellite).
This flag should only be used for a CLK record if a CLOCK event occurs. Additional details regarding a particular clock event for a satellite can be placed in a SATELLITE/EVENT block, prior to the EPHEMERIS/DATA block.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The CLK record uses only the leftmost flag in column 18.

* The first flag, in column 18, applies to the satellite clock correction. A '1' means that the clock correction value is valid. A '0' means that the clock correction value is invalid. This could be because it has a large error and hence it should be ignored by the user.

The **Number of Data Columns Present** value in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values for the above CLK record is 1. The only possible choice is 1.

4.9 CRT Record

CRT RECORD TYPE (RATE-OF-CHANGE OF THE SATELLITE CLOCK CORRECTION)

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: CRT).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
RESERVED	Columns 10 to 17 are not utilized for the CRT record.	7X	10 to 16
Good/Bad Flag For Clock Correction Rate-of-Change	'1' = the clock rate-of-change on this line is valid. '0' = the clock rate-of-change on this line is invalid (it has a large error). See the NOTES section below.	1X,I1	17 to 18
RESERVED	Columns 19 to 21 are blank for a CRT record.	3X	19 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. Only possible choice is 1.	1x,I1	22 to 23
Rate-of-Change of satellite clock corr.	The rate-of-change of the satellite clock correction. Units = nanoseconds/second.	1X,F16.7	24 to 40

Total 40	

NOTES: For each CRT record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., the data value is separated by one or more blank spaces from col 23). However, the 3-character record type code, the 3-character satellite ID, the good/bad flag, and the Number of Data Columns Present (i.e., all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above. To avoid redundancy, the satellite event flag, the predicted/observed flags, and the maneuver flag are not used for the CRT record.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The CRT record uses only the leftmost flag in column 18.

* The first flag, in column 18, applies to the clock correction rate-of-change. A ‘1’ means that the clock corr rate value is valid. A ‘0’ means that the clock corr rate value is invalid. This could be because it has a large error and hence it should be ignored by the user.

The **Number of Data Columns Present** value in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values for the above CRT record is 1. The only possible choice is 1.

4.10 ATT Record

ATT RECORD TYPE (SATELLITE ATTITUDE INFORMATION USING A QUATERNION)

Field	Description	Format	Cols
First Character	Single blank character in col one. No other character than ' ' is allowed.	1X	1 to 1
Record Type	The 3-character Record Type code (for this record type: ATT).	A3	2 to 4
RESERVED	The fifth column is left blank.	1X	5 to 5
Satellite ID	First character represents a constellation type. The last two are the PRN or slot number (e.g., G02 for GPS, or R02 for GLONASS). For LEOs see: http://cddis.nasa.gov/sp3c_satlist.html .	A1,I2.2	6 to 8
RESERVED	The ninth column is reserved for later use (in case longer SV IDs become necessary).	1X	9 to 9
RESERVED	Columns 10 to 17 are not utilized for the ATT record.	7X	10 to 16
Good/Bad Flag for the Quaternion Elements	‘1’ = the quaternion elements on this line are valid. ‘0’ = the quaternion elements on this line are invalid (they have large errors). See the NOTES section below.	1X,I1	17 to 18
RESERVED	Columns 19 to 21 are blank for a ATT record.	3X	19 to 21
Number Of Data Columns Present	Gives the number of data columns present on this line after column 23. Only possible choice is 4.	1x,I1	22 to 23
q0 part of the quaternion	The q0 or scalar part of the quaternion. The four parts of the quaternion will provide the trans-	1X,F19.16	10 to 29

	formation from the inertial frame to the spacecraft body frame. ORBEX will follow the quaternion notation (q0,q1,q2,q3) outlined in [Kuipers 1999] and [Montenbruck 2000].		
q1 part of the quaternion	The q1 or x-component part of the quaternion.	1X,F19.16	30 to 49
q2 part of the quaternion	The q2 or y-component part of the quaternion.	1X,F19.16	50 to 69
q3 part of the quaternion	The q3 or z-component part of the quaternion.	1X,F19.16	70 to 89
		Total 89	

NOTES: For each ATT record used in the EPHEMERIS/DATA block, the data after column 23 must be read free-formatted (i.e., each data value is separated by one or more blank spaces). However, the 3-character record type code, the 3-character satellite ID, the good/bad flag, and the Number of Data Columns Present (i.e., all of the pertinent fields in columns 2 to 23) must be read according to the fixed formats given above. To avoid redundancy, the satellite event flag, the predicted/observed flags, and the maneuver flag are not used for the ATT record.

There is a set of four possible **Good/Bad Flags** in columns 18 through 21. The ATT record uses only the leftmost flag in column 18.

* The first flag, in column 18, applies to the four elements of the quaternion. A ‘1’ means that the four values are valid. A ‘0’ means that the four values are invalid. This could be because they have large errors and thus should be ignored by the user.

The **Number of Data Columns Present** value in column 23 gives the number of data values that are actually listed for this satellite and this particular record type. The maximum number of data values for the above ATT record is 4. The only possible choice is 4.

5. EXAMPLES

The following pages show some example ORBEX files.

Example 1. An example of an IGS final orbit with both GPS and GLONASS satellites. The three mandatory blocks are present: FILE/DESCRIPTION, SATELLITE/ID_AND_DESCRIPTION, and EPHEMERIS/DATA. The SATELLITE/LABELS_AND_STD_DEVS block and EPHEMERIS/MODELS block are also shown.

```
%=ORBEX  0.08 EVENLY-SPACED      UNITS_XYZ=METERS UNITS_SVCLK=MICROSECONDS XYZ_REF_COM
%%
*------------------------------------------------------------------------------------------------------------------------
+FILE/DESCRIPTION
 DESCRIPTION         IGS FINAL GNSS ORBIT COMBINATION
 CREATED_BY          IGS Analysis Center Coordinator
 CREATION_DATE       2009  4 21 12  0  0
 INPUT_DATA          ORBIT
*                    Weighted Average of: cod emr esa gfz grz jpl mit ngs sio
 CONTACT             Jim.Ray@noaa.gov
 TIME_SYSTEM         GPS
 START_TIME          2009  4  7  0  0  0.000000000000  54928 0.00000000000000000  1526 172800.000000000000
 END_TIME            2009  4  7 23 45  0.000000000000  54928 0.98958333333333340  1526 258300.000000000000
 EPOCH_INTERVAL        900.000
 COORD_SYSTEM        IGS05
 FRAME_TYPE          ECEF
 ORBIT_TYPE          HLM
 LIST_OF_REC_TYPES   PCS
-FILE/DESCRIPTION
*------------------------------------------------------------------------------------------------------------------------
+SATELLITE/ID_AND_DESCRIPTION
*ID_  SATELLITE_DESCRIPTION______________________________________________________________________________
 G01  GPS BLOCK IIR-M
 G02  GPS BLOCK IIR-B
 G03  GPS BLOCK IIA
 G04  GPS BLOCK IIA
 .
 .
 .
 R21  GLONASS-M
 R22  GLONASS-M
 R23  GLONASS-M
 R24  GLONASS-M
-SATELLITE/ID_AND_DESCRIPTION
*------------------------------------------------------------------------------------------------------------------------
+SATELLITE/LABELS_AND_STD_DEVS
*ID_  SATELLITE_ANT_TYPE__ SVN_______ COSPAR#___ STDP(mm) STDCLK(psec) CH# PS CL START_TIME_________ END_TIME___________
 G01  BLOCK IIR-M          G049       2009-014A  99999.99 99999999.999     OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
 G02  BLOCK IIR-B          G061       2004-045A      8.48       17.304     OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
 G03  BLOCK IIA            G033       1996-019A      6.06       18.410     OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
 G04  BLOCK IIA            G034       1993-068A      8.17       20.087     OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
 .
 .
 .
 R21  GLONASS-M            R725       2008-046B     19.28 99999999.999  -1 OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
 R22  GLONASS-M            R726       2008-046C     21.41 99999999.999  -3 OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
 R23  GLONASS-M            R714       2005-050A     37.47 99999999.999   3 OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
 R24  GLONASS-M            R713       2005-050B  99999.99 99999999.999   2 OB OB 2009  4  7  0  0  0 2009  4  7 23 45  0
-SATELLITE/LABELS_AND_STD_DEVS
*------------------------------------------------------------------------------------------------------------------------
 .
 .
 .
```

```
*------ Example 1. (Continued) --------
 .
 .
 .
+EPHEMERIS/MODELS
*MODEL_TYPE________________________________ DESCRIPTION__________________________________________________
SATELLITE_ANTENNA_PCV_MODEL                 igs05_1567.atx
OCEAN_TIDE_LOADING_MODEL                    FES2004 EARTH_CMC_APPLIED
ATMOSPHERIC_TIDE_LOADING_MODEL              NONE NO_EARTH_CMC_APPLIED
ECEF_ORIGIN_DEFINITION_ORBITS               CENTER_OF_NETWORK
ECEF_ORIGIN_DEFINITION_CLOCKS               CENTER_OF_NETWORK
-EPHEMERIS/MODELS
*------------------------------------------------------------------------------------------------------------------------
+EPHEMERIS/DATA
## 2009  4  7  0  0  0.000000000000  51
*REC ID_  FLAGS_ G/B_ N ________X_(m)___ ________Y_(m)___ ________Z_(m)___ __SVCLK_(usec)__ __STD_X __STD_Y __STD_Z ____STD_CLK
*                                                                                             (mm)    (mm)    (mm)      (psec)
 PCS G01         0000 8    15241224.1750     5058063.4240    21090756.8720   999999.9999990 99999.9 99999.9 99999.9 9999999.999
 PCS G02         1111 8     1718903.5130    17055266.0040    20273390.0550      153.7291220     3.8     4.8     6.0      19.358
 PCS G03         1111 8     2025829.2720   -19586169.2480   -17970607.2600      375.9727660     4.8     4.8     3.8      15.123
 PCS G04         1111 8   -12801678.7490    10532088.7120    20686320.3260      -41.6910930     6.0     6.0     4.8      14.043
 .
 .
 .
 PCS R21         1010 8    20532966.7170    -3759472.4100    14731291.7220     -143.9677080     9.3     7.5    14.6 9999999.999
 PCS R22         1010 8    21498008.2120   -13433960.4000    -2117154.7760     -202.8994030    11.6    11.6    35.5 9999999.999
 PCS R23         1010 8     9576520.8680   -15103940.2070   -18166054.9630     -197.7920690    44.4    22.7    28.4 9999999.999
 PCS R24         0000 8    -8718012.6430    -7367533.1740   -22801114.6790   999999.9999990 99999.9 99999.9 99999.9 9999999.999
## 2009  4  7  0 15  0.000000000000  51
 .
 .
 .
## 2009  4  7 23 45  0.000000000000  51
 PCS G01         0000 8    15082111.7680     4678373.3290    21287877.5780   999999.9999990 99999.9 99999.9 99999.9 9999999.999
 PCS G02         1111 8     3240161.6440    17727180.8520    19527535.8950      153.7020930     4.8     7.5     4.8      36.786
 PCS G03         1111 8      758191.5350   -18726043.1800   -18997681.4990      376.4280980     6.0     2.4     7.5      32.514
 PCS G04         1111 8   -11249295.1630    11376440.6380    21110255.5670      -42.9485550     3.1     6.0     6.0      31.721
 .
 .
 .
 PCS R21         1010 8     9302951.0330     7209196.0140    22641779.4470     -144.0841100    18.2     9.3     7.5 9999999.999
 PCS R22         1010 8    21557124.6850    -4174991.1710    12912343.1810     -203.1429720     9.3    14.6     6.0 9999999.999
 PCS R23         1010 8    21207051.6440   -13199848.5210    -5066697.5310     -197.3316280    11.6     7.5    35.5 9999999.999
 PCS R24         0000 8     7307727.2270   -14059899.3810   -19941556.8550   999999.9999990 99999.9 99999.9 99999.9 9999999.999
-EPHEMERIS/DATA
%END_ORBEX
```

Example 2. An example of an IGS ultra-rapid orbit with only GPS satellites. The mandatory blocks are present: FILE/DESCRIPTION, SATELLITE/ID_AND_DESCRIPTION, and EPHEMERIS/DATA. The SATELLITE/LABELS_AND_STD_DEVS and EPHEMERIS/MODELS blocks are also shown. Note the separate standard deviations given for both the observed and the predicted parts of the ultra-rapid orbit.

```
%=ORBEX  0.08 EVENLY-SPACED      UNITS_XYZ=METERS UNITS_SVCLK=MICROSECONDS XYZ_REF_COM
%%
*------------------------------------------------------------------------------------------------------------------------
+FILE/DESCRIPTION
 DESCRIPTION         IGS ULTRA-RAPID ORBIT COMBINATION 15262_06
 CREATED_BY          IGS Analysis Center Coordinator
 CREATION_DATE       2009  4  7  9  0  0
 INPUT_DATA          ORBIT
*                    Weighted Average of: cou emu esu gfu gou siu usu
 CONTACT             Jim.Ray@noaa.gov
 TIME_SYSTEM         GPS
 START_TIME          2009  4  6  6  0  0.000000000000  54927 0.25000000000000000  1526 108000.000000000000
 END_TIME            2009  4  8  5 45  0.000000000000  54929 0.23958333333333320  1526 279900.000000000000
 EPOCH_INTERVAL        900.000
 COORD_SYSTEM        IGS05
 FRAME_TYPE          ECEF
 ORBIT_TYPE          HLM
 LIST_OF_REC_TYPES   PCS
-FILE/DESCRIPTION
*------------------------------------------------------------------------------------------------------------------------
+SATELLITE/ID_AND_DESCRIPTION
*ID_  SATELLITE_DESCRIPTION_______________________________________________________________________________
 G02  BLOCK IIR-B
 G03  BLOCK IIA
 G04  BLOCK IIA
  .
  .
  .
 G29  BLOCK IIR-M
 G30  BLOCK IIA
 G31  BLOCK IIR-M
 G32  BLOCK IIA
-SATELLITE/ID_AND_DESCRIPTION
*------------------------------------------------------------------------------------------------------------------------
+SATELLITE/LABELS_AND_STD_DEVS
*ID_  SATELLITE_ANT_TYPE__ SVN_______ COSPAR#___ STDP(mm) STDCLK(psec) CH# PS CL START_TIME_________ END_TIME___________
 G02  BLOCK IIR-B          G061       2004-045A     13.79       52.972     OB OB 2009  4  6  6  0  0 2009  4  7  5 45  0
 G02  BLOCK IIR-B          G061       2004-045A     34.32      468.380     PR PR 2009  4  7  6  0  0 2009  4  8  5 45  0
 G03  BLOCK IIA            G033       1996-019A     11.73       64.290     OB OB 2009  4  6  6  0  0 2009  4  7  5 45  0
 G03  BLOCK IIA            G033       1996-019A     38.70     2039.349     PR PR 2009  4  7  6  0  0 2009  4  8  5 45  0
 G04  BLOCK IIA            G034       1993-068A     14.67       89.069     OB OB 2009  4  6  6  0  0 2009  4  7  5 45  0
 G04  BLOCK IIA            G034       1993-068A     42.07      780.508     PR PR 2009  4  7  6  0  0 2009  4  8  5 45  0
  .
  .
  .
 G29  BLOCK IIR-M          G057       2007-062A     15.16       71.813     OB OB 2009  4  6  6  0  0 2009  4  7  5 45  0
 G29  BLOCK IIR-M          G057       2007-062A     35.50      787.943     PR PR 2009  4  7  6  0  0 2009  4  8  5 45  0
 G30  BLOCK IIA            G030       1996-056A     13.84       62.461     OB OB 2009  4  6  6  0  0 2009  4  7  5 45  0
 G30  BLOCK IIA            G030       1996-056A     32.70     1495.816     PR PR 2009  4  7  6  0  0 2009  4  8  5 45  0
 G31  BLOCK IIR-M          G052       2006-042A     17.92       62.865     OB OB 2009  4  6  6  0  0 2009  4  7  5 45  0
 G31  BLOCK IIR-M          G052       2006-042A     61.38      418.036     PR PR 2009  4  7  6  0  0 2009  4  8  5 45  0
 G32  BLOCK IIA            G023       1990-103A     12.66       99.257     OB OB 2009  4  6  6  0  0 2009  4  7  5 45  0
 G32  BLOCK IIA            G023       1990-103A     40.31     1625.077     PR PR 2009  4  7  6  0  0 2009  4  8  5 45  0
-SATELLITE/LABELS_AND_STD_DEVS
*------------------------------------------------------------------------------------------------------------------------
  .
  .
  .
```

```
*-------- Example 2. (Continued) -------
 .
 .
 .

+EPHEMERIS/MODELS
*MODEL_TYPE________________________________ DESCRIPTION__________________________________________________
SATELLITE_ANTENNA_PCV_MODEL                 igs05_1567.atx
OCEAN_TIDE_LOADING_MODEL                    FES2004 EARTH_CMC_APPLIED
ATMOSPHERIC_TIDE_LOADING_MODEL              NONE NO_EARTH_CMC_APPLIED
ECEF_ORIGIN_DEFINITION_ORBITS               CENTER_OF_NETWORK
ECEF_ORIGIN_DEFINITION_CLOCKS               CENTER_OF_NETWORK
-EPHEMERIS/MODELS
*-----------------------------------------------------------------------------------------------------------------------
+EPHEMERIS/DATA
## 2009  4  6  6  0  0.000000000000  31
*REC ID_  FLAGS_ G/B_ N ________X_(m)___ ________Y_(m)___ ________Z_(m)___ __SVCLK_(usec)__ __STD_X __STD_Y __STD_Z ____STD_CLK
*                                                                                              (mm)    (mm)    (mm)      (psec)
 PCS G02         1111 8   -17033320.1300     1266609.1830   -20350817.7220      153.7494320     7.5    18.2     7.5      96.364
 PCS G03         1111 8    19552874.2880     2683655.1740    17628511.1600      375.6269200     7.5    14.6     7.5     109.027
 PCS G04         1111 8   -11296681.1130   -11706843.3750   -21072263.3550      -40.7402520    11.6    14.6     7.5     126.438
 .
 .
 .
 PCS G29         1111 8     2378442.8870    22326932.6460   -14111601.6370        6.5393150    18.2     9.3     7.5     126.438
 PCS G30         1111 8    -4952232.8610    15715395.1680   -21178818.5590      137.2970520    14.6     7.5     3.8     120.346
 PCS G31         1111 8    11911757.1450     9229593.4540   -21650125.8680      -56.9138710     7.5    22.7     7.5      66.536
 PCS G32         1111 8    22260699.0830    -7605906.2310   -11685545.2670      278.2352010     7.5    18.2     6.0      79.090
## 2009  4  6  6 15  0.000000000000  31
 .
 .
 .
## 2009  4  8  5 45  0.000000000000  31
 PCS G02   P   P 1111 8   -17443243.7680     2212519.8080   -19898950.0300      153.6890110    22.7    44.4    14.6    1031.350
 PCS G03   P   P 1111 8    19001074.7190     1865420.8380    18297835.3330      376.5320820    18.2    55.5    22.7    3724.322
 PCS G04   P   P 1111 8   -11837973.7340   -10738247.1510   -21306552.4870      -43.2675070    35.5    44.4    18.2     825.831
 .
 .
 .
 PCS G29   P   P 1111 8     2838117.4700    22894707.0100   -13088797.8310        7.2501730    55.5    22.7    28.4    1608.554
 PCS G30   P   P 1111 8    -3904181.8360    15646108.4270   -21455788.1490      137.7760220    35.5    14.6    18.2    3724.322
 PCS G31   P   P 1111 8    12445254.0340     8209420.4170   -21765377.7610      -57.0971120    55.5    86.7    22.7     529.495
 PCS G32   P   P 1111 8    21618317.6930    -7720097.7270   -12742679.7990      277.4017030    28.4    44.4    28.4    2701.699
-EPHEMERIS/DATA
%END_ORBEX
```

Example 3. An example of an orbit with two GPS satellites and one LEO satellite. Several of the optional header blocks are present. Note also the record types being used: POS, VEL, CLK, and ATT.

```
%=ORBEX  0.08 IRREGULARLY-SPACED UNITS_XYZ=METERS UNITS_SVCLK=MICROSECONDS XYZ_REF_COM
%% UNITS_VEL=METERS/SEC
+FILE/DESCRIPTION
 DESCRIPTION         EXAMPLE GPS + LEO ORBIT
 CREATED_BY          Dr. P. Caspian
 CREATION_DATE       2009  4 21 12  0  0
 INPUT_DATA          d+p
*                    Global tracking data for G01 and G02, and data from the receiver on-board CHAMP
 CONTACT             pc@igsac.narnia.gov
 TIME_SYSTEM         GPS
 START_TIME          2002 12 29  0  0  0.000000000000  52637 0.00000000000000000  1199      0.000000000000
 END_TIME            2002 12 29 23 45  0.000000000000  52637 0.98958333333333340  1199  85500.000000000000
 EPOCH_INTERVAL
 COORD_SYSTEM        IGS05
 FRAME_TYPE          ECEF
 ORBIT_TYPE          FIT
 LIST_OF_REC_TYPES   POS VEL CLK ATT
-FILE/DESCRIPTION
*-----------------------------------------------------------------------------------------------------------------------
+SATELLITE/ID_AND_DESCRIPTION
*ID_  SATELLITE_DESCRIPTION___________________________________________________________
 G02  GPS BLOCK IIR-B
 G03  GPS BLOCK IIA
 L06  CHAMP
-SATELLITE/ID_AND_DESCRIPTION
*-----------------------------------------------------------------------------------------------------------------------
+SATELLITE/LABELS_AND_STD_DEVS
*ID_  SATELLITE_ANT_TYPE__ SVN_______ COSPAR#___ STDP(mm) STDCLK(psec) CH# PF CL START_TIME_________ END_TIME___________
 G02  BLOCK II             G013       1989-044A      5.00       19.000     OB OB 2002 12 29  0  0  0 2002 12 29 23 45  0
 G03  BLOCK IIA            G033       1996-019A      4.00       15.000     OB OB 2002 12 29  0  0  0 2002 12 29 23 45  0
 L06  CHAMP (LEO)                     2000-039B     24.00                  OB OB 2002 12 29  0  0  0 2002 12 29 23 45  0
-SATELLITE/LABELS_AND_STD_DEVS
*-----------------------------------------------------------------------------------------------------------------------
+EPHEMERIS/MODELS
*MODEL_TYPE______________________________ DESCRIPTION________________________________________________
 SATELLITE_ANTENNA_PCV_MODEL              igs05_1567.atx
 OCEAN_TIDE_LOADING_MODEL                 FES2004 EARTH_CMC_APPLIED
 ATMOSPHERIC_TIDE_LOADING_MODEL           NONE NO_EARTH_CMC_APPLIED
 ECEF_ORIGIN_DEFINITION_ORBITS            CENTER_OF_NETWORK
 ECEF_ORIGIN_DEFINITION_CLOCKS            CENTER_OF_NETWORK
-EPHEMERIS/MODELS
*-----------------------------------------------------------------------------------------------------------------------
+SATELLITE/ORBIT_PLANES
*ID_  PLANE SLOT
 G02  B     2
 G03  C     3
 L06
-SATELLITE/ORBIT_PLANES
*-----------------------------------------------------------------------------------------------------------------------
+SATELLITE/MANEUVER_INFO
*ID_  MANEUVER_START_TIME_____________ MANEUVER_END_TIME_______________   DV_RADIA   DV_ALONG   DV_CROSS
 G03  2002 12 29 12 36 07.123456789012 2002 12 29 12 36 29.123456789012     1.2300   324.5000   -10.2340
-SATELLITE/MANEUVER_INFO
*-----------------------------------------------------------------------------------------------------------------------
 .
 .
 .
```

```
*-----Example 3. (Continued) -------
 .
 .
 .

+SATELLITE/ECLIPSE_INFO
*ID_  ECLIPSE_START_TIME______________ ECLIPSE_END_TIME________________ TYPE_
 G02  2002 12 29 01 48 30.123456789012 2002 12 29 02 42 30.123456789012 EARTH
-SATELLITE/ECLIPSE_INFO
*-----------------------------------------------------------------------------------------------------------------------
+EPHEMERIS/DATA
*
## 2002 12 29  0  0  0.000000000000   3
*REC ID_  FLAGS_ G/B_ N ________X_(m)___ ________Y_(m)___ ________Z_(m)___
 POS G02         1    3     4049646.6140    25594715.4960    -5815946.7980
*REC ID_  FLAGS_ G/B_ N ______VX_(m/s)__ ______VY_(m/s)__ ______VZ_(m/s)__
 VEL G02         1    3        -353.5783         821.0842        2972.7179
*REC ID_  FLAGS_ G/B_ N __SVCLK_(usec)__
 CLK G02         1    1      -39.2268190
 POS G03         1    3      992811.0780    16781981.6600   -20596776.8060
 VEL G03         1    3       -2362.6884        1126.0735         823.5752
 CLK G03         1    1       92.5224210
 POS L06         1    3     1781848.9098     5968846.1797    -2704551.4098
 VEL L06         1    3        -816.9472       -2926.5637       -7019.8869
*REC ID_  FLAGS_ G/B_ N ___q0_(scalar)_____ ____q1__x__________ ____q2__y__________ ____q3__z__________
 ATT L06         1    4  0.9164178227001020  0.3553674926002010  0.1624720204001450 -0.0865746035002370
## 2002 12 29  0  0  1.000000000000   1
 POS L06         1    3     1727998.7897     5780000.6581    -3119210.3412
 VEL L06         1    3        -978.0014       -3365.6139       -6796.8063
 ATT L06         1    4  0.9264178234567890  0.3653674934567890  0.1724720345678901 -0.0965746045678901
## 2002 12 29  0  0  2.000000000000   1
 POS L06         1    3     1664504.1705     5565312.9920    -3519546.7577
 VEL L06         1    3       -1138.2837       -3787.6430       -6542.6599
 ATT L06         1    4  0.9364178245678901  0.3753674945678901  0.1824720456789012 -0.1165746056789012
 .
 .
 .
## 2002 12 29 23 45  0.000000000000   3
 POS G02         1    3     4304136.5610    24976241.1960    -7742704.1010
 VEL G02         1    3        -399.3729        1052.1896        2877.2689
 CLK G02         1    1      -39.7468990
 POS G03         1    3     2577521.6400    16060438.0370   -21042936.0520
 VEL G03         1    3       -2449.0774        1067.0806         533.4498
 CLK G03         1    1       92.7929170
 POS L06         1    3    -1761142.2643    -5848719.9669    -2970621.8193
 VEL L06         1    3        -998.0043       -3184.4734        6880.3132
 ATT L06         1    4 -0.5066930256001020 -0.2289786888002010  0.7772033941001450 -0.2945943349002370
-EPHEMERIS/DATA
%END_ORBEX
```

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7. REFERENCES

Gendt, G., 2004: [IGSMAIL-5000] Switch-over to sp3-c format for IGS orbits. http://igscb.jpl.nasa.gov/mail/igsmail/2004/msg00224.html

Gendt, G., 2004b: [IGSMAIL-5008] Some information on the error codes given in the sp3-c. http://igscb.jpl.nasa.gov/mail/igsmail/2004/msg00231.html

Gendt, G., 2006: [IGSMAIL-5490] Change in SP3 header comment line / Clock RINEX. http://igscb.jpl.nasa.gov/mail/igsmail/2006/msg00213.html

GLONASS ICD, 2008: Edition 5.1, Retrieved April 27, 2010 from http://www.GLONASS-ianc.rsa.ru

Gurtner, W., 2000: RINEX: The Receiver-Independent Exchange Format, GPS World, Volume 5, Number 7, 48-52. Also available from: ftp://igscb.jpl.nasa.gov/igscb/data/format/rinex210.txt

Hilla, S., 2007: The Extended Standard Product 3 Orbit Format (SP3-c), (12 February 2007). Available from: ftp://igscb.jpl.nasa.gov/igscb/data/format/sp3c.txt or from: http://www.ngs.noaa.gov/orbits/sp3c.txt

IGEX98 SP3-b format [IGEX Mail-0042, SP3 Modifications (corrigenda)] can be viewed at http://igscb.jpl.nasa.gov/mail/igexmail/1998/msg00041.html

Kuipers, J. B. 1999: Quaternions and Rotation Sequences: A primer with Applications to Orbits, Aerospace and Virtual Reality, Princeton University Press, Princeton, New Jersey.

Montenbruck, O., 2000: Quaternion Representation of BIRD Orientation and Reference System Transformations, DLR-GSOC TN 00-03, http://www.weblab.dlr.de/rbrt/pdf/TN_0003.pdf

rcvr_ant.tab file, 2010:(the source for the satellite antenna type names; e.g. BLOCK IIR-B, GLONASS-M, etc.). Available from: http://igscb.jpl.nasa.gov/igscb/station/general/rcvr_ant.tab

Remondi, B. W. 1989: Extending the National Geodetic Survey Geodetic Orbit Formats, NOAA Technical Report 133 NGS 46, 85 pp.

Remondi, B. W., 1991: NGS Second Generation ASCII and Binary Orbit Formats and Associated Interpolated Studies, Proceedings of the Twentieth General Assembly, International Union of Geodesy and Geophysics, Vienna, Austria, August 11-24, 1991, 28 pp.

Rothacher, M. and Schmid, R., 2006: ANTEX: The Antenna Exchange Format Version 1.3 (20 September 2006). Forschungseinrichtung Satellitengeodäsie, TU München. Available from: http://igscb.jpl.nasa.gov/igscb/station/general/antex13.txt

SINEX – Solution Independent Exchange Format, Version 2.10 (September 15, 2006). Available from: http://igscb.jpl.nasa.gov/igscb/data/format/sinex_v210_proposal.pdf

Spofford, P. R. and Remondi, B. W., 1994: The National Geodetic Survey Standard GPS Format SP3. (SP3-a format) available from the IGS website: http://igscb.jpl.nasa.gov/igscb/data/format/sp3_docu.txt

A list of identifiers for Low-Earth Orbiting satellites can be viewed at http://cddis.gsfc.nasa.gov/sp3c_satlist.html

8. REVISION HISTORY

12 May 2009:	Initial version written (0.01).
12 June 2009:	Additional text added (0.02).
10 July 2009:	Clarifications added for certain header blocks (0.03).
11 August 2009:	Modifications to ATT record type (0.04).
24 September 2009:	Shorten FILE/DESCRIPTION block, add flags (0.05).
27 November 2009:	Combine Origin/Def. and Center-of-Mass/Info blocks (0.06).
22 January 2010:	Moved examples to back. ":" marks where PCS flags begin (0.07).
7 May 2010:	Added good/bad flags, modified Sec. 1 & 2, added Fig 1. (0.08).