The Consultative Committee for Space Data Systems

Draft Recommendation for
Space Data System Standards

# TIME CODE FORMATS

## DRAFT RECOMMENDED STANDARD

## CCSDS 301.0-P-4.1

## PINK SHEETS

**August 2024**

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# PREFACE

This document is a draft CCSDS Recommended Standard. Its 'Pink Sheet' status indicates that the CCSDS believes the document to be technically mature and has released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process.

Implementers are cautioned **not** to fabricate any final equipment in accordance with this document's technical content.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

# DOCUMENT CONTROL

| Document | Title | Date | Status |
|---|---|---|---|
| CCSDS 301.0-B-1 | Time Code Formats, Issue 1 | January 1987 | Original issue, superseded |
| CCSDS 301.0-B-2 | Time Code Formats, Issue 2 | April 1990 | Issue 2, superseded |
| CCSDS 301.0-B-3 | Time Code Formats, Issue 3 | January 2002 | Issue 3, superseded |
| CCSDS 301.0-B-4 | Time Code Formats, Recommended Standard, Issue 4 | November 2010 | Current issue:<br>– defines a second P-Field octet for the CCSDS Unsegmented Time Code (CUC)<br>– adds a new section on security<br>– updates some editorial elements |
| CCSDS 301.0-B-4 EC 1 | Editorial Change 1 | February 2014 | Corrects erroneous information on page v. |
| CCSDS 301.0-P-4.1 | Time Code Formats, Draft Recommended Standard, Issue 4.1 | August 2024 | Current draft update:<br>– incorporates changes identified in the course of periodic reconfirmation review. |

NOTE – Only pages containing changes are included in this review document.

# 3 TIME CODE FORMATS

The time code formats can be represented as a combination of a preamble field (P) and a time specification field (T). The P-field uniquely defines the options, parameters, and encoding structure of the T-field and should be included whenever the recipient of the time code may be uncertain as to the selected code. The T-field and the P-field shall each be an integral number of octets in length.

## 3.1 TIME CODE FIELDS

### 3.1.1 PREAMBLE FIELD (P-FIELD)

The time code preamble field (P-field) may be either *explicitly* or *implicitly* conveyed. If it is implicitly conveyed (not present with T-field), the code is not self-identified, and identification must be obtained by other means.

When it is explicitly conveyed the explicit representation of the mandatory first octet is as follows:

| Bit | Interpretation |
|---|---|
| 0 | Extension flag |
| 1 - 3 | Time code identification |
| 4 - 7 | Detail bits for information on the code |

The first bit (Bit 0) of the P-field is the extension flag, used to indicate that an additional octet is included in the P-field for time code format definition. Such an expansion may be required to accommodate new time codes or to provide more information (for example, on the clock used). ~~Presently~~If no second octet of the P-field is present, the value of this bit ~~is~~shall be ‘0’~~, indicating that there is not a second octet present~~. If a second octet is present, its first bit shall be an extension flag with the same definition: ‘0’ implies it is the last octet of the P-field, ‘1’ implies another octet follows.

The detailed specifications of bits 1 to 7 are given in the following paragraphs with the description of each code. The time code identifications (bit 1 - 3) = 000, 011 and 111 are reserved for future application.

The preamble field does not apply in the case of the ASCII time code.

### 3.1.2 TIME FIELD (T-FIELD)

For each code the T-field has a basic structure and optional extensions which allow increases in resolution or ambiguity period.

## 3.2 CCSDS UNSEGMENTED TIME CODE (CUC)

### 3.2.1 T-FIELD DESCRIPTION

The T-field consists of a selected number of contiguous octets representing an integrated number of basic time units from a defined epoch along with an optional integer number of octets representing the elapsed binary fraction of the basic time unit. Each octet within the T-field represents the state of 8 consecutive bits of a binary counter, cascaded with the adjacent counters, which rolls over at a modulo of 256. The time code represented by the T-field shall increase monotonically without reversion.

The basic unit of time intended for correlation with Earth-based clocks is the second. The basic unit of time represented by the value of the T-Field is required to be defined in the metadata. The metadata also defines the epoch of the time and the number of octets of basic and fractional time units. This metadata can be provided by the P-field if self-identification is employed or by metadata external to the P-field.

~~The CCSDS Recommended epoch is that of 1958 January 1 (TAI) and the recommended time unit is the second, using TAI as reference time scale, for use as a level 1 time code. This time code is not UTC-based and leap-second corrections do not apply.~~

The epoch is a managed parameter.

NOTES

1 This time code is not UTC-based and leap-second corrections do not apply.

2 Many missions define the epoch to be 1958-01-01T00:00:00.000000 (TAI).

### 3.2.2 P-FIELD DESCRIPTION

**Octet 1** (mandatory if P-Field is used)

Bit 0 = P-Field Extension (‘zero’: no extension; ‘one’: field is extended)

Bit 1 - 3 = Time code identification

001 — 1958 January 1 epoch (Level 1 Time Code)
010 — Agency-defined epoch (Level 2 Time Code)

Bit 4 - 5 = Number of octets of the basic time unit minus one

Bit 6 - 7 = Number of octets of the fractional time unit

**Octet 2** (optional—presence is signaled in Octet 1)

Bit 0 = P-Field Extension (‘zero’: no extension; ‘one’: field is extended)

## 3.5 CCSDS ASCII CALENDAR SEGMENTED TIME CODE (ASCII)

### 3.5.1 T-FIELD

The CCSDS ASCII segmented time code is composed of a variable number of ASCII characters forming the T-field.

Both ASCII time code variations are UTC-based and leap second corrections must be made. The time represented is intended to match civil time usage. Therefore, the epoch is taken to be the usual Gregorian calendar epoch of 1 AD, and the time is that of the prime meridian.

The ASCII time code recommendations are Level 1 time code formats.

#### 3.5.1.1 ASCII TIME CODE A, Month/Day of Month Calendar Variation:

The format for ASCII Time Code A is as follows:

YYYY-MM-DDThh:mm:ss.d→dZ

where each character is an ASCII character using one octet with the following meanings:

| | | |
|---|---|---|
| YYYY | = | Year in four-character subfield with values 0001-9999 |
| MM | = | Month in two-character subfield with values 01-12 |
| DD | = | Day of month in two-character subfield with values 01-28, -29, -30, or -31 |
| T | = | Calendar-Time separator |
| hh | = | Hour in two-character subfield with values 00-23 |
| mm | = | Minute in two-character subfield with values 00-59 |
| ss | = | Second in two-character subfield with values 00-59 (-58 or -60 during leap seconds) |
| d→d | = | Decimal fraction of second in one- to n-character subfield where each d has values 0-9 |
| Z | = | time code terminator (optional) |

The hyphen (-), colon (:), letter ‘T’ and period (.) are used as specific subfield separators, and that all subfields must include leading zeros.

As many ‘d’ characters to the right of the period as required may be used to obtain the required precision.

An optional terminator consisting of the ASCII character ‘Z’ may be placed at the end of the time code.

EXAMPLE: ~~1988~~2023-01-18T17:20:43.123456Z

### 3.5.1.2 ASCII TIME CODE B, Year/Day of Year Calendar Variation:

The format for ASCII Time Code B is as follows:

YYYY-DDDThh:mm:ss.d→dZ

where each character is an ASCII character using one octet with the following meanings:

| | | |
|---|---|---|
| YYYY | = | Year in four-character subfield with values 0001-9999 |
| DDD | = | Day of year in three-character subfield with values 001-365 or -366 |
| T | = | Calendar-Time separator |
| hh | = | Hour in two-character subfield with values 00-23 |
| mm | = | Minute in two-character subfield with values 00-59 |
| ss | = | Second in two-character subfield with values 00-59 (-58 or -60 during leap seconds) |
| d→d | = | Decimal fraction of second in one- to n-character subfield where each d has values 0-9 |
| Z | = | time code terminator (optional) |

The hyphen (-), colon (:), letter ‘ T’ and period (.) are used as specific subfield separators, and that all subfields must include leading zeros.

As many ‘d’ characters to the right of the period as required may be used to obtain the required precision.

An optional terminator consisting of the ASCII character ‘Z’ may be placed at the end of the time code.

EXAMPLE: ~~1988~~2023-018T17:20:43.123456Z

### 3.5.1.3 SUBSETS OF THE COMPLETE TIME CODES:

When it is desired to use SUBSETS of each of the TWO ASCII time code format variations described above, the following rules must be observed:

a) The ‘calendar’ subset (all subfields to the left of the ‘T’) and the ‘time’ subset (all subfields to the right of the ‘T’) may be used independently as separate ‘calendar’ or ‘time’ formats, provided the context in which each subset is used makes its interpretation unambiguous.

b) When calendar or time subsets are used alone, the ‘T’ separator is omitted.

c) Calendar or time subsets may contain all the defined subfields, or may be abbreviated to the span of interest by deleting the unneeded subfields, either on the left or on the right. However, when subfields are deleted on the LEFT, all separators that had delimited the deleted subfields must be retained (except for the ‘T’ which, by rule b, is dropped if the subset is used alone.) When subfields are deleted on the RIGHT, the separators that had delimited the deleted subfields are dropped.

d) Subsets may NOT consist of partial subfields (e.g., must use ‘ss’, not ‘s’). In particular, consistent use of the complete four-character YYYY subfield is required (e.g., ‘~~1989~~2023’ instead of ‘~~89~~23’)~~ because of the need to accommodate the upcoming century rollover in only 11 years~~. It should be noted, however, that each fractional second (‘d’ character) is considered to be a complete subfield, and so any number of fractional seconds may be used.

e) If calendar and time SUBSETS are then brought together to form a single time code format (joined with the ‘T’ separator) the CALENDAR subset may NOT have been truncated from the RIGHT, and the TIME subset may NOT have been truncated from the LEFT. That is, the format must be integral around the ‘T’.

f) Standardization on the use of these time code formats for purposes OTHER than identifying an instant of calendar or time in UTC (e.g., unconventional use as a counter or tool for measuring arbitrary intervals) is not recommended. It is felt such a specialized application can best be viewed not as a time code format but rather as an engineering measurement format. Any such application of these time code formats is considered beyond the scope of this Recommended Standard.

### 3.5.2 P-FIELD

There is no P-field identifying the ASCII Time Code Formats. The P-field information is implicit in the parsing of the ASCII time code.

## 3.6 AGENCY-DEFINED CODES

~~These codes are not CCSDS-Recommended, but the presence of a P-field may allow a limited level of service.~~

Agency-defined codes are not CCSDS-Recommended, but they enable an Agency to state that its time code is 'CCSDS-conformant'. The P-Field signals that an Agency-defined code is in use. Both the Agency itself and the format for the Agency-specific T-Field must be treated as managed parameters.

### 3.6.1 T-FIELD

For the time codes described herein, the T-field consists of a variable number of octets. ~~These octets together can be considered a binary number. If that number increases monotonically with time (except at a recycle time), the code is a Level 3 code; if not, it is a Level 4 code.~~

~~The time code Levels are defined in 1.3.~~

The length of that T-field is indicated by the P-field.

### 3.6.2 P-FIELD

Bit 1 - 3 = time code identification

110 — ~~Level 3 or 4~~ Agency-defined code

Bit 4 - 7 = T-field length [(number of octets of time) minus one[1]]

[1] The value in this field may be variable and shall be in the range of 0 to 15, corresponding to 1 to 16 octets.

**DATE:**

The reading of a specified time scale, usually a calendar.

NOTE – The date can be conventionally expressed in years, months, days, hours, minutes, seconds and fractions thereof.

**DTAI:**

The value of the difference TAI – UTC, as disseminated with time signals is denoted DTAI. DTAI = TAI – UTC may be regarded as a correction to be added to UTC to obtain TAI.

**DUT1:**

The value of the predicted difference UT1 – UTC, as disseminated with the time signals. DUT1 may be regarded as a correction to be added to UTC to obtain a better approximation to UT1. The values of DUT1 are given by the International Earth Rotation Service and Reference Systems (IERS) in multiples of 0.1 s. (See ‘universal time’.)

**EPHEMERIS TIME**:

~~An astronomical time scale based on the orbital motion of the Earth around the sun. It was used to define the SI second between 1960 and 1967, and continued in use for astronomical applications until 1977 when it was replaced by Terrestrial Dynamical Time (TDT). TDT in turn was replaced by Terrestrial Time (TT) in 1991.~~

An astronomical time scale based on the orbital motion of the Earth around the sun. It was used to define the SI second between 1960 and 1967 and continued in use for astronomical applications until 1977 when it was replaced by Terrestrial Dynamical Time (TDT) and Barycentric Dynamical Time (TDB). TDT in turn was replaced by Terrestrial Time (TT) in 1991. TDB is generally used for applications beyond the Earth environment, while TT is generally used for Earth orbiting applications. In current usage, ‘Ephemeris time’ may refer to either TT or TDB.

**EPOCH:**

The beginning of an era (or event) or the reference date of a system of measurements.

**GREENWICH MEAN TIME (GMT)**:

Mean solar time as it was measured at the Royal Observatory, Greenwich. GMT was adopted as the world’s first global time scale in 1884. However, while the term remains in popular usage, GMT is no longer maintained and has been replaced by Universal Time (UT) and Coordinated Universal Time (UTC) for precise applications.

(2) The constant 2,440,000.5, which occurs on 1968 May 24.0 gives the origin of the Truncated Julian Date (TJD) time scale used in the NASA PB-5J time code (see annex E).

**NETWORK TIME PROTOCOL (NTP):**

The Network Time Protocol (NTP) is used to synchronize the time of a computer client or server to another server or reference time source, such as a terrestrial or satellite broadcast service or modem. NTP provides distributed time accuracies on the order of one millisecond on LANs and tens of milliseconds on WANs. NTP is widely used over the Internet to synchronize computer clocks to national time references.

**PRECISION:**

The degree of mutual agreement among a series of individual measurements; often, but not necessarily, expressed by the standard deviation. (See also 'uncertainty'.)

**SI SECOND:**

The basic unit of time or time interval in the International System of Units (SI) that is equal to the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of caesium-133 as defined at the 1967 CGPM meeting. In 1997 the CIPM affirmed that: "This definition refers to a caesium atom at rest at a temperature of 0 K." This was intended to make it clear that the definition of the SI second is based on a Cs atom unperturbed by black-body radiation, that is, in a 0 K environment, and therefore the frequencies of primary frequency standards should be corrected for the shift due to ambient radiation, as further stated at the CCTF meeting in 1999.

**BARYCENTRIC DYNAMICAL TIME (TDB):**

A relativistic coordinate time scale, intended for astronomical use as a time standard to take account of time dilation when calculating orbits and astronomical ephemerides of planets, asteroids, comets, and interplanetary spacecraft in the solar system.

**TIME CODE FORMAT:**

A system of digital or analogue symbols used in a specified format to convey time information (i.e. date, time of day or time interval).

NOTE – Any representation of time NOT based on the second as the fundamental unit of time is not considered a time code, but is considered to be an engineering parameter. However, it is not necessary for the second to appear explicitly in the time code; decimal multiples or submultiples (e.g., milliseconds of day) may be used.

**TERRESTRIAL DYNAMICAL TIME (TDT):**

An astronomical time scale, renamed to Terrestrial Time in 1991 by the International Astronomical Union. (See Terrestrial Time.)

**TIME INTERVAL:**

The duration between two instants read on the same time scale.

**TIME SCALE:**

A system of unambiguous ordering of events.

**TIME SCALE READING:**

The value read on a time scale at a given instant. To avoid ambiguity the reading of a time scale should be denoted by giving the time scale name. (e.g. UTC, TAI, etc.) followed, in parenthesis, by the clock name, transmitting station, astronomical observatory, institution, or standards laboratory such as UTC (k).

**TIME SCALE UNIT:**

The basic time interval in a time scale.

**TRUNCATED JULIAN DATE:**

A four-decimal-digit day count originating at midnight 1968-05-23,24 (see annex E).

**TERRESTRIAL TIME (TT):**

A modern astronomical time standard defined by the International Astronomical Union, primarily for time-measurements of astronomical observations made from the surface of Earth. This was formerly called Terrestrial Dynamical Time (TDT).

**UNCERTAINTY:**

Parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

Frequently it is possible to distinguish two components, the random component (also known as Type A error) and the component due to systematic (also known as Type B error) effects.

# ANNEX E

# EXAMPLE OF ACCOMMODATION OF AGENCY-DEFINED CODES (PB-5J)

# (INFORMATIVE)

**Purpose:**

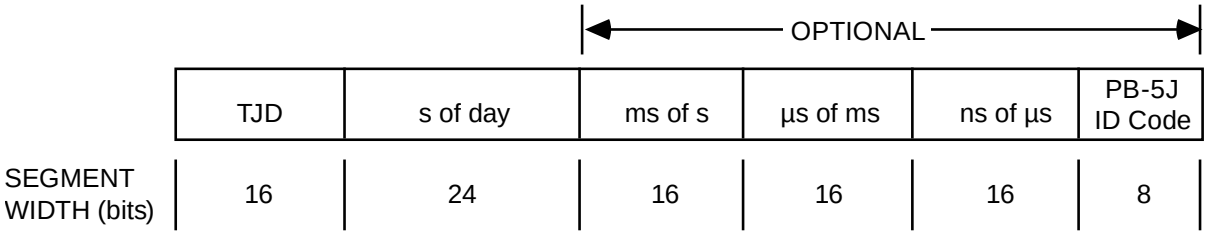
This annex shows how Agency-defined ~~(Level 3 and Level 4)~~ time codes may be accommodated. A typical example is the ~~new~~ PB-5J code ~~which is presently being~~ considered for use by NASA.

## E1 PB-5J

The NASA PB-5J time code is a segmented time code in which the segments represent, respectively, coarse time in truncated Julian day (TJD) and fine time in SI units with optional resolution to 1 nanosecond. The segment boundaries coincide with the octet boundaries. The length of the optional forms of PB-5J are all multiples of 8 bits.

The adoption of this specific code, which is signaled by the Time Code Identification 110, must be defined 'by management', that is, identified by some out-of-band signals. The format of the code itself must similarly be signaled by management.

The PB-5J code is constructed as follows:




Fill bits have been added in the most significant position of each segment to ensure that the segments end on octet boundaries.

For consistency with the CCSDS standard format, the P-field must be constructed as follows:

Bits 1 - 3 = Time Code Identification : 110

Bits 4 - 7 = Length PB-5JA (6 octets): 0101

PB-5JB (8 octets): 0111

PB-5JC (10 octets): 1001

PB-5JD (12 octets): 1011