The Consultative Committee for Space Data Systems

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Consultative
Committee for
Space Data Systems

RECOMMENDATION FOR SPACE DATA SYSTEM STANDARDS

TIME CODE FORMATS

CCSDS 301.0-B-3

BLUE BOOK

January 2002

CCSDS HISTORICAL DOCUMENT

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CCSDS HISTORICAL DOCUMENT

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-- The **standard** itself.

-- The anticipated date of initial operational capability.

-- The anticipated duration of operational service.

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CCSDS HISTORICAL DOCUMENT

FOREWORD

This document is a technical Recommendation for time code formats and has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The set of time code formats described in this Recommendation is the baseline concept for time representation in data interchange applications that are cross-supported between Agencies of the CCSDS.

This Recommendation establishes a common framework and provides a common basis for the formats of time code data. It allows implementing organizations within each agency to proceed coherently with the development of compatible derived Standards for the flight and ground systems that are within their cognizance. Derived Agency Standards may implement only a subset of the optional features allowed by the Recommendation and may incorporate features not addressed by this Recommendation.

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CCSDS HISTORICAL DOCUMENT

DOCUMENT CONTROL

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CCSDS 301.0-B-1	Time Code Formats, Issue 1	January 1987	Original Issue (superseded).
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CCSDS 301.0-B-3	Time Code Formats, Issue 3	January 2002	Current issue (supersedes Issue 2)

CONTENTS

1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommendation is to establish a small number of standardized recommended time code formats for use in data interchange applications between Agencies of the CCSDS. This Recommendation does not address timing performance issues such as stability, precision, accuracy, etc.

1.2 SCOPE

Time codes are digital representations of time information. Four standard CCSDS-Recommended time codes are described (one "unsegmented" and three "segmented" codes) which use the international standard second as the fundamental unit of time.

An unsegmented time code is a pure binary count of time units and fractional time units from a starting time called the "epoch".

A segmented time code is one in which the count of time units and fractional time units is accumulated in two or more cascaded counters which count modulo of various bases and start from the epoch.

The four Recommended time code formats carry both the time data (in the TIME SPECIFICATION FIELD, or T-FIELD) and, where applicable, additional information (in the TIME CODE PREAMBLE FIELD or P-FIELD) that uniquely identifies a specific time code format. The P-FIELD may be either explicit or implicit (refer to paragraph 2.1.1).

1.3 CATEGORIZING OF CCSDS TIME CODE FORMATS

In this Recommendation, four Levels of time code formats can be defined based on the four degrees of interpretability of the code.

All time code Levels provide for recognizing the boundaries of the time code field and thus that field can be transferred, as a block, to another location.

Level 1: Complete Unambiguous Interpretation

Level 1 code formats are fully self-defined and allow absolute time interpretation for the events tagged with the code. Time comparison with other time sources utilizing Level 1 codes can thus be made. These codes are the CCSDS-Recommended codes and have the Recommended epochs.

Level 2: Partial Interpretation

Level 2 code formats have a fully self-defined structure, but support only partial interpretation because it is necessary to obtain the epoch from an external source. Relative time interpretation for the events tagged with Level 2 formats can be made. To make accurate time comparisons with other time sources which use other epochs (Level 1 or Level 2), additional information must be obtained from external sources.

Level 3: No Interpretation Except for Recognition of Increasing Time Value

Level 3 code formats are those for which only the code length is self-defined and a monotonically increasing (possibly non-uniformly increasing) value is guaranteed except for the recycling instant (i.e., counter rollover). For Level 3 codes, the epoch, the time units, and the T-field structure are not self-defined.

Level 4: No Interpretation

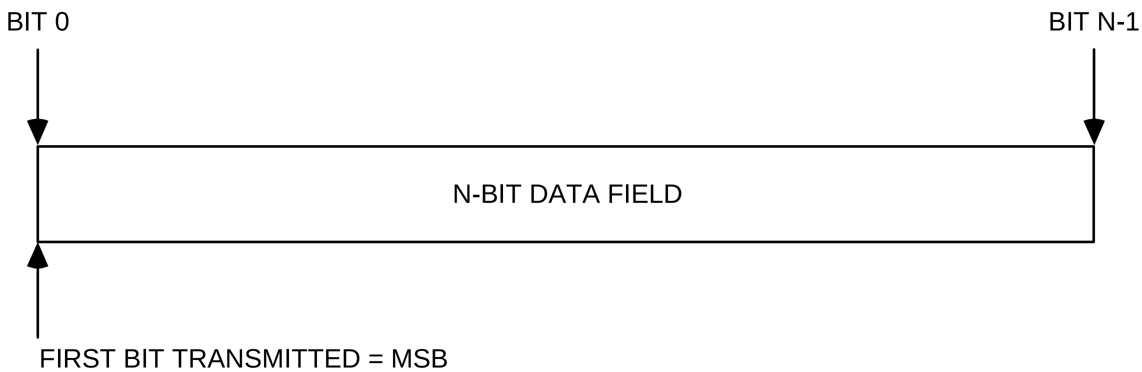
Level 4 code formats are those for which only the code length is self-defined. No other features of the code are identified.

1.4 APPLICABILITY

This Recommendation contains a number of time codes designed for applications involving data interchange in space data systems. It does not attempt to prescribe which code to use for any particular application. The rationale behind the design of each code is described in Annex B and may help the application engineer to select a suitable code. Definition of the timing accuracy underlying a particular time code is not a function of this Recommendation but is the responsibility of the authority cognizant of time performance for the applicable system.

1.5 BIT NUMBERING CONVENTION AND NOMENCLATURE

In this document, the following convention is used to identify each bit in an N-bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be "Bit 0"; the following bit is defined to be "Bit 1" and so on up to "Bit N-1". When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., "Bit 0".



In accordance with modern data communications practice, spacecraft data fields are often grouped into 8-bit "words" which conform to the above convention. Throughout this Recommendation, the following nomenclature is used to describe this grouping:

8-BIT WORD = "OCTET"

2 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.

2.1 TIME CODE FIELDS

2.1.1 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.

As presently defined, the explicit representation of the P-field is limited to one octet whose format is described 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 a second octet is included in the P-field for time code identification. Such an expansion may be required to accommodate new time codes or to provide more information (for example, on the clock used). Presently, the value of this bit is "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.

2.1.2 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.

2.2 CCSDS UNSEGMENTED TIME CODE (CUC)

2.2.1 T-FIELD

For the unsegmented binary time codes described herein, the T-field consists of a selected number of contiguous time elements, each element being one octet in length. An element 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 basic time unit is the second. The T-field consists of 1 to 4 octets of coarse time (seconds) and 0 to 3 octets of fine time (subseconds). The coarse time code elements are a count of the number of seconds elapsed from the epoch. Four octets of coarse time results in a maximum ambiguity period of approximately 136 years. This allows a time code representation of time through the year 2094 for those which are referenced to the TAI epoch of 1958 January 1.

Zero to three octets of fine code elements result in a resolution of, respectively: 1 second; 2^{-8} second (about 4 ms); 2^{-16} second (about 15 µs); or 2^{-24} second (about 60 ns).

The CCSDS-Recommended epoch is that of 1958 January 1 (TAI), but other Agency-defined epochs may be accommodated as a Level 2 code.

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

2.2.2 P-FIELD

Bit 1 - 3 = Time code identification

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

Bit 4 - 5 = (number of octets of coarse time) – minus one*

Bit 6 - 7 = (number of octets of fine time)

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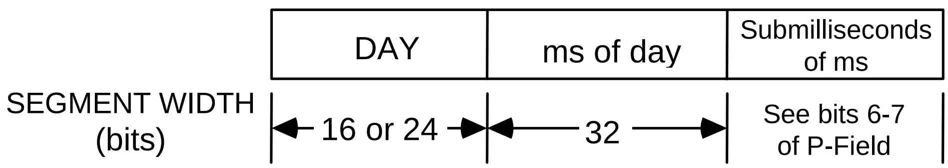
*For the 1958 epoch, bits 4-5 must be "11" to ensure a long enough ambiguity period. The value in this field may be variable and shall be in the range of 0 to 3, corresponding to 1 to 4 octets.

2.3 CCSDS DAY SEGMENTED TIME CODE (CDS)

2.3.1 T-FIELD

For the segmented binary time code described herein, the T-field consists of a selected number of contiguous time segments. Each segment represents the state of a binary counter, cascaded with the adjacent counters, which rolls over at a modulo specified for each counter.

The segmented binary day count code Recommendation, designated CDS (CCSDS Day Segmented), is as follows:



Each segment above is a right-adjusted binary counter. The CCSDS recommended day segment is a continuous counter of days from 1958 January 1 starting with 0, but other Agency-defined epochs may be accommodated as a level 2 code.

The submilliseconds segment is optional depending upon the resolution desired (see bits 6-7 of the P-Field). Since this code is UTC-based, the leap second correction must be made.

2.3.2 P-FIELD

Bits 1 - 3 = time code identification = '100'

Bit 4 = epoch identification:

'0' — 1958 January 1 epoch (Level 1)
'1' — Agency-defined epoch (Level 2)

Bit 5 = length of day segment:

'0' — 16-bit day segment
'1' — 24-bit day segments

Bits 6 - 7 = length of submillisecond segment (i.e., resolution):

'00' — submillisecond segment is absent (millisecond)
'01' — 16-bit (microsecond)
'10' — 32-bit (picosecond)
'11' — reserved for future use

2.4 CCSDS CALENDAR SEGMENTED TIME CODE (CCS)

2.4.1 T-FIELD

For the segmented Binary Coded Decimal (BCD) time code described herein, the T-field consists of a variable number of contiguous time segments. Each 8-bit segment represents two decimal digits.

Both CCS time code variations are UTC-based. The leap second correction must be made.

The calendar segmented code Recommendations, designated CCS (CCSDS Calendar Segmented time code), are Level 1 time code formats and are as follows:

2.4.1.1 Month of Year/Day of Month Calendar Variation

							OPTIONAL					
	YR	MO	DOM	h	m	s	10^{-2} s	10^{-4} s	10^{-6} s	10^{-8} s	10^{-10} s	10^{-12} s
SEGMENT WIDTH (bits)	16	8	8	8	8	8	8	8	8	8	8	8

The year A.D. segment (YR) requires 16 bits for proper representation of the decimal year. All other segments require 8 bits for proper representation. The month (MO) and day of month (DOM) segments are present when the calendar variation flag (bit 4 of the P-field) is set to zero.

2.4.1.2 Day of Year Calendar Variation

						OPTIONAL					
	YR	DOY	h	m	s	10^{-2} s	10^{-4} s	10^{-6} s	10^{-8} s	10^{-10} s	10^{-12} s
SEGMENT WIDTH (bits)	16	16	8	8	8	8	8	8	8	8	8

This variation of the CCS time code substitutes day of year (DOY) in place of the month (MO) and day of month (DOM) segments. The day of year segment must be 16 bits long (all segments must be multiples of 8 bits). The four most significant bits of this segment are not used and are set to zero. The day of year segment is present when the calendar variation flag (bit 4 of the P-field) is set to a value of one. The year A.D. segment is 16 bits in length.

2.4.2 P-FIELD

Bits 1 - 3 = time code identification = 101

Bit 4 = calendar variation flag:

0 — month of year/day of month variation
1 — day of year variation

Bits 5 - 7 = resolution (number of optional subsecond segments):

000 — 1 s
001 — 10^{-2} s
010 — 10^{-4} s
011 — 10^{-6} s
100 — 10^{-8} s
101 — 10^{-10} s
110 — 10^{-12} s
111 — not used

2.5 CCSDS ASCII CALENDAR SEGMENTED TIME CODE (ASCII)

2.5.1 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.

2.5.1.1 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)

Note that 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: 1988-01-18T17:20:43.123456Z

2.5.1.2 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)

Note that 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: 1988-018T17:20:43.123456Z

2.5.1.3 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" instead of "89") because of the need to accommodate the upcoming century rollover in only 11 years. Note, 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 recommendation.

2.5.2 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.

2.6 AGENCY-DEFINED CODES

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

2.6.1 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 Section 1.3.

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

2.6.2 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.

ANNEX A

RANGE OF SEGMENT COUNTERS

FOR SEGMENTED TIME CODES

(THIS ANNEX **IS** PART OF THE RECOMMENDATION)

Purpose:

This Annex specifies the range of the counters defined in the Recommended segmented codes.

RANGE OF TIME CODE SEGMENT COUNTERS

Segment Identification	Range of Counter
Microsecond-of-millisecond	0 to 999
Millisecond-of-day	0 to 86,399,999 (0 to 86,400,999 or 86,398,999 when leap second adjustments are introduced)
Second-of-minute	0 to 59 (0 to 60 or 58 when leap second adjustments are introduced)
Minute-of-hour	0 to 59
Hour-of-day	0 to 23
Day	0 to $(2^{16} - 1)$, or 0 to $(2^{24} - 1)$
Day-of-month	1 to 31 for month 1,3,5,7,8,10,12 1 to 30 for month 4,6,9,11 1 to 28 for month 2 (1 to 29 for leap years)*
Day-of-year	1 to 365 (366 for leap years)*
Month-of-year	1 to 12
Year	1 to 9999

* Leap year: every year divisible by 4, except for the years divisible by 100 and not divisible by 400.

ANNEX B

RATIONALE FOR TIME CODES

(THIS ANNEX **IS NOT** PART OF THE RECOMMENDATION)

Purpose:

This Annex presents the rationale behind the design of each code. It may help the application engineer to select a suitable code.

B1 GENERAL

Instrument data acquired from spacecraft have little value unless it is possible to recreate the significant environment of the instrument during the measurement collection phase. Such ancillary data parameters as time, position, velocity, attitude, instrument temperature, concurrent ground truth measurements and many other parameters may be essential for the proper interpretation of the instrument data. Of these ancillary data parameters, the time of the instrument measurements is certainly the most vital parameter. The reasons for this are the following:

(1) In many cases, the instrument analysis can be based, nearly exclusively, on the sampled sensor time series.

(2) Time provides the most efficient and often the only possible linkage between instrument data and externally generated ancillary parameters. Two independent measurement processes, each correlated with time, can then be correlated with each other.

However, the resulting proliferation of slightly different codes is not desirable. The selection of one particular code will depend on the chosen optimization criteria in the given application. For example, Table B-1 compares the four Recommended codes in terms of the three selection criteria identified by the CCSDS:

- UTC compatible : Permits unambiguous representation of leap seconds
- Computer efficient : Fewer segments improves data handling and processing
- Human readable : Easily readable code corresponding to widely used civil time representation

Table B-1: Applicability of the Criteria

Time Code	S (Segmented) U (Unsegmented)	UTC Compatible	Computer Efficient	Human Readable
CUC	U	No	Yes	No
CDS	S	Yes	Yes	No
CCS	S	Yes	No	Yes
ASCII	S	Yes	No	Yes

B2 SERVICE RELATED TO THE DIFFERENT LEVELS OF TIME CODE FORMATS

The different Levels of the time codes have been distinguished by the self-interpretability of the codes.

All time code Levels provide for recognizing the boundaries of the time code field and thus can transfer that field, as a block, to another location.

The different services which can be achieved without special arrangements between users of the CCSDS time codes are:

- Absolute time interpretation: time comparison and differencing for events based on separate time sources, with all sources having the same CCSDS-Recommended epoch.

- Relative time interpretation: time comparison and differencing for events based on the same time source, with the source having a known, Agency-defined epoch.

- Ordering of events time-tagged from a single source.

Table B-2 shows how these three services can be related to the time code Levels.

Table B-3 shows the different time code format identifications in the P-field, and the associated time code Levels.

Table B-2: Time Code Services

Level	Absolute Time Interpretation	Relative Time Interpretation	Ordering
CUC Level 1	Y	Y	Y
CUC Level 2	N	Y	Y
CDS Level 1	Y	Y	Y
CDS Level 2	N	Y	Y
CCS Level 1	Y	Y	Y
Level 3	N	N	Y
Level 4	N	N	N
ASCII	Y	Y	Y

Table B-3: Service Categories of Time Codes

Time Code Name	Format Identification P-field – (Bits 1-3)	Time Code Category
Reserved	0 0 0	–
C U C	0 0 1	Level 1
C U C	0 1 0	Level 2
Reserved	0 1 1	–
C D S	1 0 0	Level 1 or 2
C C S	1 0 1	Level 1
Agency-Defined	1 1 0	Level 3 or 4
Reserved	1 1 1	–
ASCII	None	Level 1 or 3

B3 DISCUSSION OF RECOMMENDED CODES

All the Recommended time code lengths are an integer number of octets. This helps to optimize the computer processing of these codes and allows the use of high level languages.

The range of all segment counters (especially for leap year and leap second) is shown in Annex A.

B3.1 CCSDS UNSEGMENTED (CUC)

The unsegmented binary time code is particularly suited to computer applications which involve arithmetic computation of time differences. Since the unsegmented format is a representation of the state of consecutive bits of a binary counter (i.e., a continuous function with no discontinuities), arithmetic operations can be carried out directly.

The code allows for both absolute time (TAI scale) and time measured relative to an Agency-defined epoch. Various allowed truncations of the code make it bit-efficient. The attributes of this code make it suitable for applications such as spacecraft clock measurement.

B3.2 CCSDS DAY SEGMENTED (CDS)

Most terrestrial time measurements are made using the UTC time scale. Usually, spacecraft instrument events are ultimately time-tagged with UTC because the events have to be correlated with other phenomena. This time code is based on UTC. Since UTC contains discontinuities at the instant of leap second correction, the unsegmented binary code cannot be used to represent UTC.

The CCSDS Day Segmented code (CDS) consists in its simplest form of two binary counters, one counting days from a defined epoch and the other counting milliseconds of day. The code retains attributes similar to the unsegmented binary code in being oriented toward arithmetic operations by computers. The choice of millisecond unit results in an optimum use of 4 octets (28 bits used) and also provides the resolution necessary for most time computations.

Extended microsecond precision is provided by allowing one optional additional segment. Provision has been made in the P-field to accommodate, in the future, greater resolution.

CCSDS recommends the epoch 1958 January 1 (Julian date 2436203.5), the epoch of the TAI time scale. An Agency-defined epoch is also allowed (such as 1950 January 1). Note that the difference between the epochs 1958 January 1 and 1950 January 1 is exactly 2922.0 days on the Julian date calendar.

The optional 24-bit length of the day segment is included for special applications such as Astronomy. CDS is the most "machine friendly" of the UTC codes and is therefore particularly suitable for use in computer-to-computer communication requiring very frequent, very fast automated time interpretation and processing.

B3.3 CCSDS CALENDAR SEGMENTED (CCS)

In human interactions, UTC is frequently expressed in a segmented form consisting of years, months, days, hours, minutes, seconds and decimal fractions of seconds. UTC is also expressed in a segmented form consisting of years, days of year, hours, minutes, seconds and decimal fractions of seconds. The CCSDS Calendar Segmented (CCS) codes (both variations) are oriented towards representing these segments directly in binary coded decimal (BCD) format for ease of human reading and interpretation.

CCS is useful for applications where all or part of the code is to be frequently interpreted by humans, for example, when frequently converting to character form for display purposes. However, CCS is not as efficient as CDS for arithmetic operations.

B3.4 CCSDS ASCII

While binary or BCD-based time code formats are computer efficient and minimize overhead on uplinked/downlinked data streams, there are many ground-segment applications for which an ASCII character-based time code is more appropriate. For example, when files or data objects are created using text editors or word processors, ASCII character-based time code format representations are necessary. They are also useful in transferring text files between heterogeneous computing systems, because the ASCII character set is nearly universally used and is interpretable by all popular systems. In addition, direct humanly readable dumps of text files or objects to displays or printers are possible without preprocessing. The penalty for this convenience is inefficiency.

The two ASCII time code variations (A, day of month, and B, day of year) include the most widely used human-readable presentations. Both variations are subsets of ISO 8601 ("Data Elements and Interchange Formats--Information Interchange--Representation of Dates and Times, 1986-06-05" [reference (6)]).

ANNEX C

GLOSSARY OF SELECTED TIME TERMS

(THIS ANNEX **IS NOT** PART OF THE RECOMMENDATION)

Purpose:

This Annex presents definitions of a number of time-related terms used in the Recommendation or useful in understanding the text of the Recommendation.

The definitions used in this CCSDS Recommendation are those approved by the CCIR and are found in various CCIR publications (Reference [4] - Report 730). Where appropriate, this Recommendation uses definitions supplied by BIH or CCIR (Study Group 7).

ACCURACY:

Generally equivalent to systematic uncertainty of a measured value (Reference [4] - Report 730).

AMBIGUITY PERIOD:

The interval between successive recurrences of the same time code.

ASCII:

A coded set of alphanumeric and control characters used for information interchange. The coded character set used to form the ASCII time codes defined in section 2.5 is described in detail in International Standard ISO 8859-1 (Reference [7]).

ATOMIC TIME SCALE:

A time scale based on the periodicities of atomic or molecular phenomena. (See definition of "Unit of Time" - "International Atomic Time Scale".)

COORDINATED UNIVERSAL TIME (UTC): (See Universal Time)

DATE:

Synonymous with "time-scale reading", but usually referred to as calendar.

Note: The date can be expressed in years, months, days, hours, minutes, seconds and fractions thereof.

EPOCH:

The origin (the beginning) of a time scale.

INTERNATIONAL ATOMIC TIME (TAI): (See Universal Time)

JULIAN DATE:

The Julian day number followed by the fraction of the day elapsed since the preceding noon (12 hours UT) (Reference [4] - Report 730).

Example: The date 1900 January 0.5 UT corresponds to JD = 2415020.0.

JULIAN DAY NUMBER:

A number of a specific day from a continuous day count having an initial origin of 12 hours UT on 1 January 4713 BC, Julian Calendar (start of Julian Day zero) (Reference [4] - Report 730).

Example: The day extending from 1900 January 0.5 d UT to 1900 January 1.5 d UT as the number 2 415 020.

MODIFIED JULIAN DATE (MJD):

Julian Date less 2 400 000.5 days (Reference [4] - Report 730).

Note: Other modifications of the Julian date can be created by using other constants; for example:

(1) The constant 2,436,203.5 days, which occurs on 1958 January 1, gives the origin of TAI, recognized as the epoch of both the CCSDS Unsegmented Code (CUC) and the CCSDS Day Segmented Code (CDS).

(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).

PRECISION:

Random uncertainty of a measured value, expressed by the standard deviation or by a multiple of the standard deviation (Reference [4] - Report 730).

TIME CODE FORMAT:

A format used to convey time information (Reference [4] - Report 730).

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.

TIME INTERVAL:

The duration between two instants read on the same time scale (Recommendations) (Reference [4] - Report 730).

TIME SCALE:

A quantitative reference system for specifying occurrences with respect to time.

TIME SCALE READING:

The value read on a time scale at a given instant (Reference [4] - Report 730).

TIME SCALE UNIT:

The basic time interval in a time scale (Reference [4] - Report 730).

TRUNCATED JULIAN DATE:

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

UNIVERSAL TIME (UT) (Reference [4] - Recommendation 460-3 - Annex 1):

In applications in which an imprecision of a few hundredths of a second cannot be tolerated, it is necessary to specify the form of UT which should be used:

UT0 is the mean solar time of the prime meridian obtained from direct astronomical observation.

UT1 is UT0 corrected for the effects of the Earth's polar motion; it corresponds directly with the angular position of the Earth around its axis of diurnal rotation.

UT2 is UT1 corrected empirically for the effects of a small seasonal fluctuation in the rate of rotation of the Earth.

TAI is the international reference scale of atomic time (TAI), based on the second of the International System of Units (SI), as realized at sea level, and is formed by the Bureau International de l'Heure (BIH) on the basis of clock data supplied by cooperating establishments. It is in the form of a continuous scale, e.g., in days, hours, minutes and seconds from the origin 1958 January 1 (adopted by the CGPM 1971).

UTC is the time scale maintained by the BIH which forms the basis of a coordinated dissemination of standard frequencies and time signals. It corresponds exactly in rate with TAI but differs from it by an integral number of seconds.

The UTC scale is adjusted by the insertion or deletion of seconds (positive or negative leap seconds) to ensure approximate agreement with UT1.

Concise definitions of the above terms and the concepts involved are available in the glossary of the annual publication: The Astronomical Almanac (U.S. Government Printing Office, Washington D.C. and H.M. Stationery Office - London).

ANNEX D

CONVERSION BETWEEN TAI AND UTC

(THIS ANNEX **IS NOT** PART OF THE RECOMMENDATION)

Purpose:

This Annex provides a conversion formula between TAI time and UTC time expressed in seconds.

In the TAI time scale, the CUC code represents a binary count of the elapsed seconds since the 1958 January 1 epoch. Thus it is ideally suited to computation of the true time difference between widely separated events.

In the UTC time scale, CCS time code is the code normally used for time presentation. Computation of the difference between two UTC times requires knowledge of any intervening leap seconds in order to achieve a true difference.

Since January 1, 1972, the relationship between TAI and UTC has been given by a simple accumulation of leap seconds occurring approximately once per year:

At any instant i: T_i = TAI time

U_i = UTC time expressed in seconds

$T_i = U_i + L_i$

where L_i is the accumulated leap second additions between the epoch and the instant i.

The following table contains a reference list of the accumulated leap second additions L_i between 1972 and 1990:

Time Period			L_i
1972 Jan. 1	-	1972 July 1	10.000 000 0 s
1972 July 1	-	1973 Jan. 1	11.000 000 0 s
1973 Jan. 1	-	1974 Jan. 1	12.000 000 0 s
1974 Jan. 1	-	1975 Jan. 1	13.000 000 0 s
1975 Jan. 1	-	1976 Jan. 1	14.000 000 0 s
1976 Jan. 1	-	1977 Jan. 1	15.000 000 0 s
1977 Jan. 1	-	1978 Jan. 1	16.000 000 0 s
1978 Jan. 1	-	1979 Jan. 1	17.000 000 0 s
1979 Jan. 1	-	1980 Jan. 1	18.000 000 0 s
1980 Jan. 1	-	1981 July 1	19.000 000 0 s
1981 July 1	-	1982 July 1	20.000 000 0 s
1982 July 1	-	1983 July 1	21.000 000 0 s
1983 July 1	-	1985 July 1	22.000 000 0 s
1985 July 1	-	1988 Jan. 1	23.000 000 0 s
1988 Jan. 1	-	1990 Jan. 1	24.000 000 0 s
1990 Jan. 1	-		25.000 000 0 s

NOTE: For other periods, see BIH Annual Report (Reference [2]).

ANNEX E

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

(THIS ANNEX **IS NOT** PART OF THE RECOMMENDATION)

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 PB-5J code is constructed as follows:

			OPTIONAL			
	TJD	s of day	ms of s	µs of s	ns of µs	PB-5J ID Code
SEGMENT WIDTH (bits)	16	24	16	16	16	8

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

CCSDS HISTORICAL DOCUMENT

ANNEX F

INFORMATIVE REFERENCES

This annex **is not** part of the Recommendation.

[1] *Procedures Manual for the Consultative Committee for Space Data Systems*. CCSDS A00.0-Y-7. Yellow Book. Issue 7. Washington, D.C.: CCSDS, November 1996.

[2] Annual Report of the Bureau International des Poids et Mesures (BIPM). Available online at www.bipm.org. Cedex, France.

[3] Monthly Report of the Bureau International des Poids et Mesures (BIPM). Available online at www.bipm.org. Cedex, France.

[4] Recommendations and Reports of the CCIR, XVth Plenary Assembly, Geneva 1982, Vol. VII: Standard Frequencies and Time, as modified in 1983 and 1985, or later issue. [This material has subsequently been incorporated into Recommendations and Reports of the International Telecommunication Union—Radiocommunication Sector (ITU-R), available online at www.itu.int.]

[5] *SI Units and Recommendations for the Use of Their Multiples and of Certain Other Units*. International Standard, ISO 1000:1992. 3rd ed. Geneva: ISO, 1992.

[6] *Data Elements and Interchange Formats—Information Interchange—Representation of Dates and Times*. International Standard, ISO 8601:2000. 2nd ed. Geneva: ISO, 2000.

[7] *Information Technology—8-Bit Single-Byte Coded Graphic Character Sets—Part 1: Latin Alphabet No. 1*. International Standard, ISO/IEC 8859-1:1998. Geneva: ISO, 1998.

The latest issue of CCSDS documents may be obtained from the CCSDS Secretariat at the address indicated on page i.