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Change Record

Issue	Date	Sheet	Description of Change
1	26.08.2010	all	first issue
2	11.10.2011	all	Update of document including: • Definition of LOBT "Time/Sync Quality" byte for LCT/OCP • Identification of Time Synchronisation requirements on the CSW (Section 3) • Update of the Time Synchronisation mode transitions
		Section 5.1	• Refinement of complete Section
		Section 3.3.2	• Reworded requirement OBTM-650 • Added requirement OBTM-1149
		Secction 1.5	• Added figure with CSW specification tree in section 1.5

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Issue	Date	Sheet	Description of Change
3	08.11.2012		• Figure 2.2-1 updated according to modified Figure 47 in the OBC User Manual (see Email RUAG 21.06.2012) • Section 3.1: update of descriptions of all three external synchronisation modes WAIT_FOR_GPS, SYNC_IN, and GPS_SYNC primarily to address the mechanism for deciding valid GPST input; • Figure 3.1-1: update in order to replace "GPSR Quality Index" by "GPST validity bit of the time correlation packet"; • OBTM-1133: corrected typo in the formula concerning the indices of the factors F_i. • OBTM-1143: note added (see explanation for OBTM-1134); • OBTM-1134: deleted. This requirement is covered in general by requirement OBTM-1143, to which a note has been added; • OBTM-1149: reworded. Master and Slave TTRM PPS and 10PPS output are requested to be enable for all groups now; • OBTM-1067: deleted. The calculation of various time differences is already implicitly required by the use of the smooth sync algorithm (OBTM-665). Therefore, there is no need to have an extra requirement on this level; • OBTM-1066: reworded. TC(9,128) shall be rejected (by means of service 1) instead of an event packet being sent; • OBTM-1060: deleted. The calculation of various time differences is already implicitly required by the use of the smooth sync algorithm (OBTM-665). Therefore, there is no need to have an extra requirement on this level; • OBTM-681: deleted; • OBTM-682: reworded. Replaced "GPSR Quality Index" by "GPST validity bit of the time correlation packet"; • OBTM-687: deleted. The calculation of various time differences is already implicitly required by the use of the smooth sync algorithm (OBTM-665). Therefore, there is no need to have an extra requirement on this level; • OBTM-1064: deleted (including note); • Figure 3,.4-1 deleted; •

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Issue	Date	Sheet	Description of Change
			• OBTM-1147: deleted. The calculation of various time differences is already implicitly required by the use of the smooth sync algorithm (OBTM-665). Therefore, there is no need to have an extra requirement on this level; • OBTM-1032: completely reworded in order to clarify the intended rationale for this requirement; • OBTM-696, OBTM-701: replaced "GPSR Quality Index" by "GPST validity bit of the time correlation packet". Modified "at least 4" to "at least four consecutive" in order to clarify the intended implementation. Reworded the two requirements such that they are complementary and do not overlap in the requested functionality; • Corrected statement on top paragraph of page 30 to state that the GPST Time Correlation Packet contains the time at the time of the occurrence of the last GPSR Sync Pulse and not at the next (GPSR Measurement Data Interface Specification, Section 5.4.1.3); • OBT-638: Deleted incorrect note to this requirement.

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Table of Contents

1 INTRODUCTION 8
1.1 Scope of the Document 8
1.2 References 8
1.2.1 Applicable Documents 8
1.2.2 Reference Documents 8
1.3 Definitions 9
1.3.1 General Terms 9
1.3.2 Time References 9
1.4 Abbreviations 11
1.5 Applicability 11

2 ON-BOARD TIME MANAGEMENT 13
2.1 System Overview 13
2.2 Unit Descriptions 14
2.2.1 On-Board Computer (OBC) 14
2.2.2 Global Positioning System Receiver (GPSR) 16
2.2.3 Inertial Measurement Unit (IMU) 17
2.2.4 Star Tracker Electronics (STRA-E) 17
2.2.5 Mass Memory & Formatting Unit (MMFU) 17
2.3 Time Format Definition 18
2.3.1 On-Board Time Format 18
2.3.2 On-Board Time Epoch Definition 19
2.3.3 On-board Time/Sync Quality Byte 19
2.4 On-Board Time Correlation to UTC by Ground 21
2.4.1 Overview 21
2.4.2 Calculation of Time Period between two TM(9,2) Packets 22

3 CENTRAL ON-BOARD TIME SYNCHRONISATION REQUIREMENTS 23
3.1 Overview 23
3.2 COBT Time Format and Epoch 24
3.3 COBT Synchronisation without GPSR 24
3.3.1 General 24
3.3.2 COBT Initialisation 24
3.3.3 Internal Synchronisation of OBC OBTs 25
3.3.4 Synchronisation by Ground Command 26
3.4 COBT Synchronisation with GPSR 27
3.4.1 COBT Synchronisation with GPST 27
3.4.2 GPSR Unavailability or GPST Synchronisation Lost 29
3.5 Real Time Clock (RTC) Provision to the CSW 29
3.6 Time Reporting 29

4 UNIT LOBT SYNCHRONISATION WITH COBT 30
4.1 Overview 30
4.2 GPSR LOBT Synchronisation with COBT 30

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4.3 LCT LOBT Synchronisation with COBT 31
4.4 Unit LOBT Synchronisation with COBT 31

5 TIME SYNCHRONISATION ERROR HANDLING 33
5.1 COBT Synchronisation Error Cases 33
5.2 LOBT Loss of COBT Synchronisation....37

TABLES

Table 2.3-1: Time Format of the COBT and LOBT 18
Table 2.3-2: Time Format of the short COBT and LOBT 18
Table 2.3-3: Summary of Time Format and Synchronisation per On-Board Unit 19
Table 2.3-4: Format of the COBT and LOBT “Time/Sync Quality” byte 20
Table 2.3-5: Contents of the COBT “Time/Sync Quality” byte for individual COBT Synchronisation Modes . 21
Table 4.2-1: GPSR LOBT “Time/Sync Quality” byte after synchronisation with COBT (0x1B).... 31
Table 4.4-1: Unit LOBT “Time/Sync Quality” byte contents after synchronisation with COBT (0x1F) 32
Table 5.1-1: Overview of COBT Synchronisation Error Cases 37
Table 5.2-1: Overview of LOBT Synchronisation Error Cases 38
Table 5.2-2: Unit LOBT “Time/Sync Quality” byte contents after loss of synchronisation with COBT due to missing PPS signal or missing or corrupted time broadcast message (0x15) 38

FIGURES

Figure 1.3-1: UT1, UTC, TAI and GPS relationship 10
Figure 2.1-1: Overview of nominal time synchronisation of the COBT and unit LOBT with GPST using the periodic GPSR Sync Pulse 14
Figure 2.2-1: OBC PPS Routing Overview.... 16
Figure 3.1-1: COBT Synchronisation Modes and Transitions 23
Figure 4.1-1: Time Synchronisation of the COBT and Unit LOBT with GPST using the periodic GPSR Sync Pulse 30

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1 INTRODUCTION

1.1 Scope of the Document

This document defines the detailed of On-Board Time Management and Synchronisation concept to be implemented within the EarthCare satellite, including the interface to the LOBT users.

In addition it provides requirements for the CSW supplier on OBC and unit time management.

The following technical aspects are addressed:

- Definition of relevant time formats and time synchronisation quality/status information;
- Definition of COBT Synchronisation Modes;
- Initialisation of COBT by ground command;
- Synchronisation of COBT to GPST when the GPSR is switched-on;
- Internal Synchronisation of COBT within the three OBC OBTs when the GPSR is unavailable;
- Synchronisation of units LOBT to COBT using either a PPS signal or MIL-Bus Major Frame as synchronisation mechanism;
- Synchronisation error handling of COBT, including the three OBC OBTs;
- Synchronisation error handling of LOBT.

1.2 References

1.2.1 Applicable Documents

[AD1]	System Requirements Document	EC.RS.ASD.SY.00005
[AD2]	MIL-Bus Protocol Specification	EC.RS.ASD.SY.00011
[AD3]	CCSDS Un-segmented Time Code Standard	CCSDS-301.0-B-3
[AD4]	EarthCare Software System ICD	EC.ICD.ASD.SY.00027

1.2.2 Reference Documents

[RD1]	Abbreviation List	EC.LI.ASD.SY.00001
[RD2]	Packet Utilisation Standard	EC.STD.ASD.SY.00001
[RD3]	OBC User Manual	GS2.TN.RSE.OBC.00015
[RD4]	GPRS Software User Manual	S1-MA-AAE-SC-00001
[RD8]	Satellite Design Description	EC.TN.ASD.SY.00021
[RD10]	GPSR Command and Housekeeping Data Interface Specification	S1-IF-AAE-SC-0001

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1.3 Definitions

1.3.1 General Terms

Clock Synchronisation. To synchronise means to set two clocks to have one and the same clock reading within a defined error bound (i.e. $t_{clk1} = t_{clk2} + \varepsilon$) at a given instant;

Clock Correlation. To correlate means to establish a relationship between two clocks such that it is possible to determine the value of one clock from the value of the other clock (i.e. to determine $f(t_{clk2})$ where $t_{clk1} = f(t_{clk2})$).

Direct Synchronisation overwrites the existing OBT value with a new value. This method corrects the OBT skew instantaneously but results in jumps in the OBT reading either forward or backward.

MIL-Bus Time-Broadcast Message. The CSW running on the OBC distributes the COBT using the MIL-Bus Time-Broadcast Message. This message is represented by a MIL-Bus broadcast receive command to SA29R and it is sent at least 200 milliseconds before start of the next major frame.

Spacecraft Elapsed Time (SCET) starts at power-on of the satellite and simply counts the seconds since power-on.

Smooth Synchronisation adjust the OBT module clock frequency by setting the NCO thus compensating for initial and ageing effects on clock drift. This method avoids jumps in the OBT reading.

1.3.2 Time References

CCSDS Unsegmented Time Code (CUC). The time from a defined epoch in seconds coded on 4 octets and sub-seconds coded on 3 octets.

$\text{Time} = C_0 * 256^3 + C_1 * 256^2 + C_2 * 256 + C_3 + F_0 * 256^{-1} + F_1 * 256^{-2} + F_2 * 256^{-3}$.

Central On Board Time (COBT) is the time maintained by the On-Board Computer (OBC) and is the time reference for all spacecraft on-board activities including time-tagged command scheduling and telemetry packet time stamping (both instrument data and house keeping telemetry).

Coordinated Universal Time (UTC) is maintained by the Bureau International des Poids et Mesures (BIPM) and follows TAI exactly except for an integral number of leap seconds which are introduced to comply with the international agreement that UTC is kept within 0.9 seconds of UT1. Leap seconds are inserted on the advice of the International Earth Rotation Service (IERS) nominally up to twice yearly, during the last minute of the day of June 30 and December 31. In exceptional cases it is also possible to introduce them during the last minute of the day of March 31 and September 30 (although so far this has never been done). On the day when an adjustment is made the last minute of the day will have either 59 or 61 seconds. UTC is the modern successor of Greenwich Mean Time, GMT, which was used when the unit of time was the mean solar day. For most practical purposes, UTC is equivalent to mean solar time at the prime meridian (0° longitude) such that on average the Sun is overhead within 0.9 seconds of 12:00:00 UTC on the meridian of Greenwich.

The relationship between UT1, UTC, TAI and GPS is illustrated in Figure 1.3-1.

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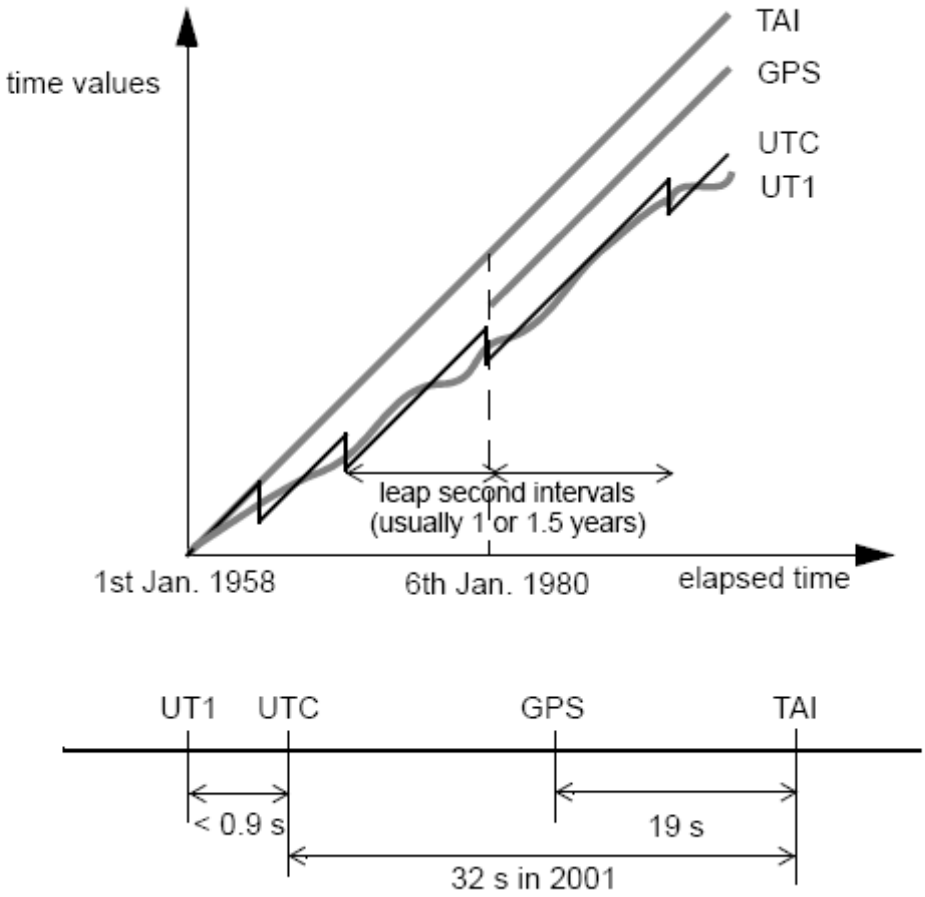

Figure 1.3-1: UT1, UTC, TAI and GPS relationship

Extended GPS Time Format (EGPSTF). This is similar to GPSTF but with the Week Number extended to 32 bits allowing incorporation of the GPS Epoch which is incremented by wrap around of the GPSTF Week Number. The Time Of Week unit is seconds rather than 1.5 seconds. The GPS satellites do not support EGPSTF so the Epoch must be set within the GPS Receiver by the ground.

GPS Time (GPST) is referenced to a UTC zero time-point defined as midnight on the night of January 5 1980 / morning of January 6 1980. GPST increments with TAI. GPST lags TAI by 19 seconds with an error of less than 1 microsecond.

GPS Time Format (GPSTF). The GPS System provides time information in the form of a Week Number, WN, (in the range 0 to 1023 and coded on 10 bits) and Time Of Week, TOW, (in the range 0 to 403199 periods of 1.5 seconds and coded on 19 bits). Consequently the GPST provided by the GPS System wraps around every 1024 weeks (about once per 20 years). The last wrap around of GPST was on 22nd August 1999 and the next wrap around of GPST will be on 7th April 2019. Each period of 1024 weeks is known as a GPS Epoch.

International Atomic Time (TAI) is calculated by the Bureau International des Poids et Mesures (BIPM) from the readings of more than 200 atomic clocks located in metrology institutes and observatories in over 30 countries around the world. TAI is made available every month in the BIPM Circular T. It is estimated that TAI does not lose or gain with respect to an imaginary perfect clock by more than about one tenth of a microsecond (10^{-7} seconds) per year. Its fundamental unit is exactly one Systeme International (SI) second at mean sea level where the SI second is defined as the duration of 9,192,631,770 cycles of radiation corresponding to the transition between two hyperfine levels of the ground state of cesium 133. TAI is a constant and continuous time scale with a zero reference time of zero hours on 1st January 1958.

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Local On Board Time (LOBT) is the time maintained by the individual on-board units, for example GPSR, MMFU, STR, and VCU.

Master TTRM OBT. The OBC provides two hot powered on-board timers in the TTRM module. The CSW selects one of the two TTRM timers to be the master (Master TTRM OBT) while the other timer serves as a slave (Slave TTRM OBT).

PM OBT. Each of the two cold-redundant OBC Processor Modules (PM) provides a on-board timer (PM OBT). The PM OBT of the active PM represents the COBT.

Slave TTRM OBT. The OBC provides two hot powered on-board timers in the TTRM module. The CSW selects one of the two TTRM timers to be the master (Master TTRM OBT) while the other timer serves as a slave (Slave TTRM OBT).

1.4 Abbreviations

General abbreviations are defined in [RD1].

Specific abbreviations used in this document are given below.

CUC	CCSDS Unsegmented Time Code
COBT	Central On-Board Time
FOG	Fiber Optic Gyroscope
LOBT	Local On-Board Time
MIL-Bus	MIL-STD-1553 Digital Internal Time Division Command/Response Multiplex Data Bus
NCO	Numerical Controlled Oscillator
OBC	On-Board Computer
OBT	On-Board Timer
TM	Telemetry
PPS	Pulse per Second
PVT	Position Velocity Time
SIA	Sagnac Interferometer Assembly
SCET	Spacecraft Elapsed Time

1.5 Applicability

This technical note is applicable to the EarthCare system-level and the Central Software (CSW).

This technical note also describes LOBT management of the following EarthCare on-board units:

- Global Positioning System Receiver (GPSR);
- Star Tracker Electronics (STRA-E);
- Mass Memory & Formatting Unit (MMFU);
- ATLID
- BBR

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- CPR
- MSI

Requirements related to on-board time management and synchronisation for units are defined in the individual equipment specifications.

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2 ON-BOARD TIME MANAGEMENT

This section provides an overview of the EarthCare on-board time management concept and of the CSW and the various on-board units involved.

In the following, the specific On-Board Time synchronisation design considerations are provided.

2.1 System Overview

The Satellite on-board time system consists of the following main entities:

•An absolute time provider, the GPS Receiver (GPSR), issuing a 1 Hz synchronisation signal (GPSR Sync Pulse) identifying the GPS time (GPST) system at second roll-over and a GPS time message as part of the Time Correlation Packet;

•A Central On-Board Time (COBT), maintained by the Central Software (CSW) running on the on-board computer (OBC). The CSW distributes the COBT across the satellite by sending on-board time synchronisation messages via the MIL-Bus and PPS signals (OBC PPS) to local units;

•A number of satellite on-board units, which represent datation users, each comprising a Local On-board Time (LOBT) function for standalone operation. The unit synchronises its LOBT with COBT in order to ensure consistent and full performance operation.

There are two classes of datation users defined depending on the accuracy of the synchronised operation:

•Class A datation users will be synchronised by dedicated HW line, the PPS signal;

•Class B datation users will be synchronised by communication protocol embedded synchronisation reference, which is the start of the major frame of the MIL-Bus Protocol.

The COBT is distributed as part of the on-board time synchronisation message, which is provided before the next synchronisation reference signal and contains the time of the next synchronisation reference. Depending on the datation user the reference signal can be represented by either of the following sources:

•Class A datation user: the PPS signal from the OBC;

•Class B datation user: the major frame start of the MIL-Bus Protocol.

In addition to the COBT maintained by the OBC, the following satellite units maintain a LOBT and are synchronised to the COBT:

•Global Positioning System Receiver (GPSR);

•Star Tracker Electronics (STRA-E);

•Mass Memory & Formatting Unit (MMFU);

•ATLID

•BBR

•CPR

•MSI

During nominal operation, the COBT is synchronised to GPST and the LOBT of each unit is synchronised to COBT.

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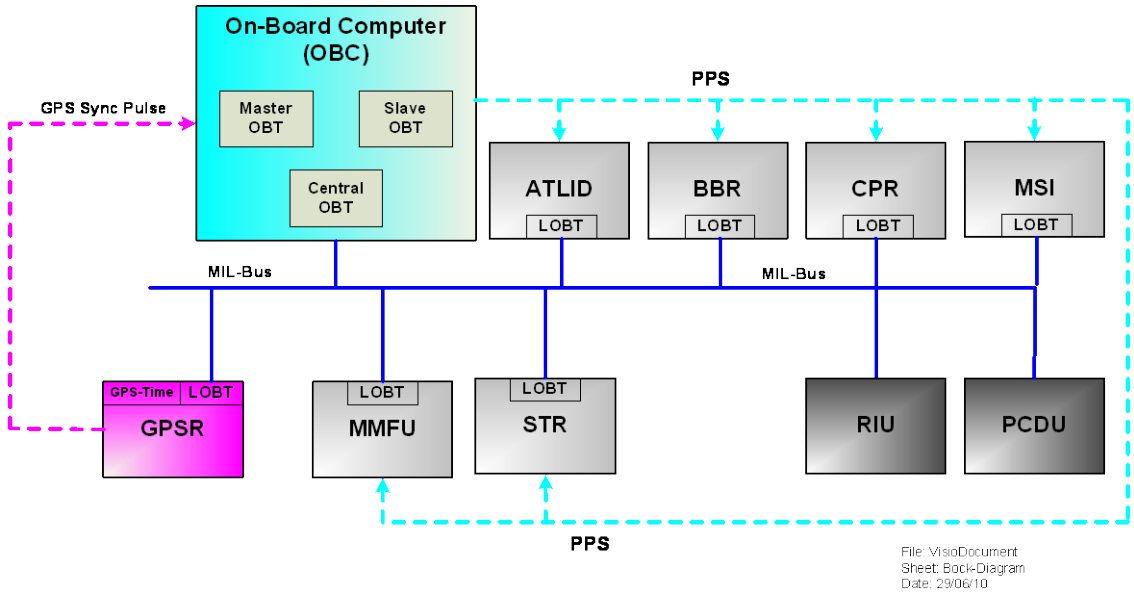

Figure 2.1-1: Overview of nominal time synchronisation of the COBT and unit LOBT with GPST using the periodic GPSR Sync Pulse

2.2 Unit Descriptions

2.2.1 On-Board Computer (OBC)

The OBC implements the timing and synchronisation function by providing three on-board timers (OBT) running in parallel:

- Two hot-redundant on-board timers in the TTRM module;
- A single cold powered on-board timer in the active processor module.

The PM OBT can be kept in sync with the Master TTRM OBT or used standalone.

Since the PM OBT can be accessed much faster by the CSW than the two hot redundant TTRM OBTs, it is used in all software operations that need to sample the COBT.

The OBTs provide the following main functions:

- Maintaining an on-board time counter;
- Supporting synchronisation to an incoming pulse received from the GPSR;
- Direct or smooth synchronisation modes;
- Synchronisation signals outputs;
- Sampling of internal events like software requests and TM frame start.

The OBC OBT functions are based on hardware time counters using the CCSDS Unsegmented Time Code (CUC) format.

In order to be able to use a non-power-of-2 input clock, the OBC uses Numeral Controlled Oscillators (NCO) for generating the clock to the individual OBT counters. The CSW can adjust the NCO value to handle different ratios between the power-of-2 OBT clock and the source clock. The source oscillator of the OBC has a 20 MHz clock and the nominal NCO value is set to 0.8388608 to give a 2^{24} Hz output. The NCO register is 28 bits wide, thus giving a resolution of:

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$$\frac{20\,MHz}{2^{28}} = 74{,}505\,mHz$$

In case an external synchronisation pulse is not available, one of the two TTRM timers is chosen to be the master (Master TTRM OBT) while the other timer serves as a slave (Slave TTRM OBT). By default, the TTRM providing the Master TTRM OBT is selected according to the active TM Encoder selection status in the TTRM. The CSW synchronises the Slave TTRM OBT to the Master TTRM OBT by adjusting the NCO of the slave clock. Similarly, the on-board timer of the active processor module (PM OBT) is synchronised with the Master TTRM OBT. This PM OBT represents the COBT, which the CSW distributes to all units maintaining a LOBT.

The OBC generates the OBC PPS when the sub-seconds of the COBT wrap-around and reach 0.

In case an external synchronisation pulse is available from the GPSR, these pulses are used as synchronisation reference and all OBC OBTs are adjusted accordingly.

The OBC distributes the COBT every second to all other units via MIL-Bus broadcast receive command to SA29R, as defined in the MIL-Bus Protocol Specification [AD2].

The OBC also provides the OBC PPS and the Major Frame sync to the related units. These signals are used for the synchronisation of the units, depending on the datation user class assignment.

An overview of OBC PPS signal routing is shown in OBTM-1002.

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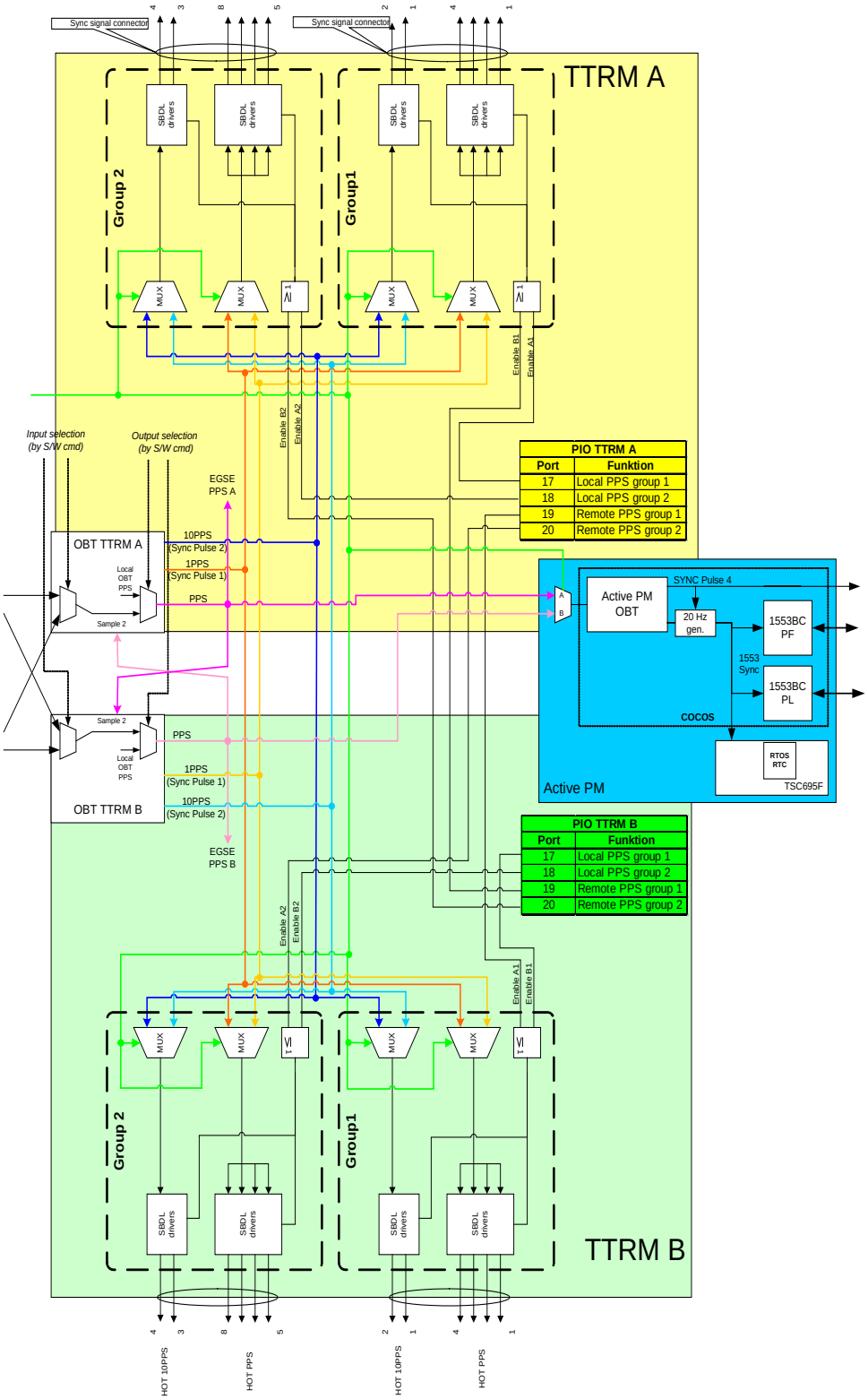

Figure 2.2-1: OBC PPS Routing Overview

2.2.2 Global Positioning System Receiver (GPSR)

The Global Positioning System (GPS) is a space-based radio-navigation system managed and operated by

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the United States Government.

The GPSR receiver is a dual-frequency (L1, L2) GPS navigation receiver for real-time navigation and Precise Orbit Determination. It acquires and tracks carrier phases and C/A - and P(Y)-code of up to 8 satellites simultaneously and provides an accurate time reference related to GPS time (GPST) and a Pulse Per Second (GPSR Sync Pulse) signal generated at a rate of 1 Hz is used to synchronise the COBT to GPST. On board are two GPSR running in cold redundancy.

The GPSR maintains three time bases:

•The GPS Time (GPST) is the GPS System Time derived from the GPS signals processed; this seconds/sub-seconds counter starts at the reference date 06.01.1980, 0:00:00h;

•The Local on-board time (LOBT) using a CUC-based time format. The LOBT is not derived from the GPST but received via MIL-Bus from the OBC. The LOBT is provided in the Data Field Header of every PUS packet used for telemetry;

•The Instrument Measurement Time (IMT), which is used for internal purposes.

2.2.3 Inertial Measurement Unit (IMU)

This section is not applicable.

2.2.4 Star Tracker Electronics (STRA-E)

The ASTRO-APS system is a autonomous star tracker that autonomously provides high accurate 3-axis attitude information with regard to the J2000 inertial reference frame and 3-axis angular rate measurements of the satellite body system.

The star tracker time tags the measured quaternion with an accuracy of < 1 millisecond. The output TM data is time tagged using the STR LOBT with 4 byte coarse and 3 byte fine time. The internal time data structure omitts the last significant byte.

Time synchronization by the OBC is performed by sending a new time value to the STR (via MIL-Bus Time-Broadcast to SA29R). The new provided COBT will become valid, i.e. will become the new LOBT, upon reception of the next external synchronization pulse (1pps pulse).

If no COBT has yet been received by the STR since the last boot or if the 1pps synchronization fails, the time stamp in the DFH of all TM packets delivered by the STR will denote the time elapsed in the STR since last boot and the TimeSync/Quality field of the DFH will be set to indicate ‘SCET’.

STR measuremet data are tagged with a time tag giving the time elapsed relatively in milliseconds, starting from the last received PPS to the centre of the integration time window from which the star centroids and quaternion data respectively were derived.

2.2.5 Mass Memory & Formatting Unit (MMFU)

The Mass Memory Formatting Unit (MMFU) comprises the following main functions:

•Acquire, store and protect the mission data generated by the payload instrument as well as satellite housekeeping data provided by the Onboard Computer (OBC); and

•Retrieve, encode, format and transmit stored instrument and satellite Housekeeping data to the Payload Data Transmission (PDT) subsystem via dedicated communication links for subsequent downlink to earth.

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2.3 Time Format Definition

2.3.1 On-Board Time Format

The On-Board time format for all units (LOBT) and the OBC (COBT) are according to *CCSDS Unsegmented Time Code (CUC)*, see [AD 3].

Note: This time format enables the COBT to count continuously; i.e. there will be no jumps due to leap seconds.

The CUC time format for timers with high sub-second resolution is as defined in the table below.

Format for COBT and LOBT	**Resolution**	**Range (hex)**	**LSB**
Seconds	32 bit	0 to FF.FF.FF.FF	1 second
Sub-Seconds	24 bit	0 to FF.FF.FF	app. 0,0596 µs

Table 2.3-1: Time Format of the COBT and LOBT

The CUC time format for timers with lower sub-second resolution is shown in the table below.

Format for units with short LOBT	**Resolution**	**Range (hex)**	**LSB**
Seconds	32 bit	0 to FF.FF.FF.FF	1 second
Sub-Seconds	16 bit	0 to FF.FF	app. 15,26 µs

Table 2.3-2: Time Format of the short COBT and LOBT

Note: The coarse seconds part wraps around about every 136 years. The CUC P-Code is 0010_1110 bin.

The short COBT and LOBT CUC format representation provides a sufficient resolution for the datation of HK telemetry and MTL time tagging, since a 2 byte sub-seconds field supports a resolution of 15.26 microseconds.

The following table summarises the time format (LOBT or otherwise) of each relevant satellite unit:

Unit	**Format**	**Synchronisation Mechanism**
GPSR	32-bit seconds, 16-bit sub-seconds	MIL-Bus Major Frame
STR (PUS protocol)	56-bit unsigned integer CUC format, b_0-b_{31} = seconds part b_{32}-b_{55} = subseconds part	OBC PPS

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Unit	Format	Synchronisation Mechanism
STR (internal application data stuctures)	48-bit unsigned integer CUC format, b_0-b_{31} = seconds part b_{32}-b_{47} = subseconds part	OBC PPS
MMFU	32-bit seconds, 24-bit sub-seconds	OBC PPS
EC Instruments •ATLID •BBR •CPR •MSI	32-bit seconds, 24-bit sub-seconds	OBC PPS

Table 2.3-3: Summary of Time Format and Synchronisation per On-Board Unit

2.3.2 On-Board Time Epoch Definition

The on-board time is derived from the GPSR and therefore the zero time-point reference of the COBT is the same as of the GPST, i.e. midnight on the *night of January 5 1980 / morning of January 6 1980*.

2.3.3 On-board Time/Sync Quality Byte

The sync-status of each unit will be reported together with each TM packet time-stamp inside the Data Field Header in the “Time/Sync Quality” byte. The format and contents is defined by the following table.

Bit	Description	Value COBT	Value LOBT	COBT Bit Transition Condition
0	Not used; spare	N/A	N/A	N/A
1	Not used; spare	N/A	N/A	N/A
2	Not used; spare	N/A	N/A	N/A
3	Time Type	0 = SCET after boot 1 = OBT	0 = SCET 1 = OBT	0 to 1: Ground issues TC(9,128) “Set Central OBT” or Master TTRM OBT greater than or equal to Initial COBT
4	Sync Source	0 = Internal 1 = External	0 = Internal 1 = External	0: GPS synchronisation lost 1: GPS synchronisation established or commanded by TC(9,133)

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Bit	Description	Value COBT	Value LOBT	COBT Bit Transition Condition
5	Sync Method	1 = 1Hz Pulse	0 = Major frame 1 = 1Hz Pulse	Set to 1 for COBT always
6	Sync Status	0 = NoSync 1 = Synchronised	0 = NoSync 1 = Synchronised	0: No GPS synchronisation 1: GPS synchronisation established
7	Sync Ena/Dis	0 = Disabled 1 = Enabled	0 = Disabled 1 = Enabled	0: TC(9,134) received 1: TC(9,133) received

Table 2.3-4: Format of the COBT and LOBT "Time/Sync Quality" byte

The following table defines the contents of the COBT "Time/Sync Quality" byte for the individual COBT Synchronisation Modes.

Time Type	Sync Source	Sync Method	Sync Status	Sync Ena/Dis	Mode Description (COBT)	COBT Sync Mode
Bit 3	Bit 4	Bit 5	Bit 6	Bit 7		
0 (SCET)	0 (Internal)	1 (1Hz Pulse)	0 (No Sync)	0 (Disabled)	Satellite power-on or Master TTRM OBT less than threshold	INTERNAL_SYNC
1 (OBT)	0 (Internal)		0 (No Sync)	0 (Disabled)	TC(9,128) received from ground or Master TTRM OBT greater than thresholdor TC(9,134) received from ground	

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Time Type	Sync Source	Sync Method	Sync Status	Sync Ena/Dis	Mode Description (COBT)	COBT Sync Mode
1 (OBT)	0 (Internal)		0 (No Sync)	1 (Enabled)	TC(9,133) received from ground No Sync Pulses from GPSR	WAIT_FOR_GPS
1 (OBT)	1 (External)		0 (No Sync)	1 (Enabled)	Sync Pulses received from GPSR but GPSR Quality index below threshold	SYNC_IN
1 (OBT)	1 (External)		1 synchronised with GPSR	1 (Enabled)	COBT synchronised with GPST (GPSR Quality index above threshold)	GPS_SYNC

Table 2.3-5: Contents of the COBT "Time/Sync Quality" byte for individual COBT Synchronisation Modes

Note: The COBT Synchronisation Modes used in the table above are explained in more detail in OBTM-639.

2.4 On-Board Time Correlation to UTC by Ground

2.4.1 Overview

The on-board time correlation concept is based on the time management service defined in the Packet Utilisation Standard [RD2]. The standard Time Report subservice TM(9,2) provides the capability for the generation of Time Reports, such that the satellite time correlation procedures in the Ground segment can be performed. This service has access to Spacecraft Elapsed Time (SCET) after satellite power-on or to the COBT based on GPST after external synchronisation (either by ground or GPSR).

In order to support the correlation between the COBT and the UTC reference on ground the Telemetry Encoder provides a time strobe synchronised to the first bit of nth VC0 CADU, which is used for sampling the COBT for later insertion into the next Standard Spacecraft Time Source Packet.

TC(9,1) is used to modify the Time Report packet generation frequency. The TC updates

the parameter that determines the generation rate used to sample and downlink the satellite time. Its value shall be in the range [0..8]. The corresponding generation rate is equal to once every 2^{Rate} telemetry transfer frames. This parameter is programmed in the telemetry encoder function of the TFG. At initialisation, the Time Report packet generation is enabled, and the generation frequency is set to 2^5.

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2.4.2 Calculation of Time Period between two TM(9,2) Packets

The s-band downlink budget for VC0 is 12 Kbps = 1500 bytes/sec the length of a VC0 transfer frame is 1115 bytes, thus appr. 1.35 VC0 frames are generated in one second in average. Assuming the *generation rate* has been set to 32, a TM(9,2) would be generated with a period of **23.7secs**.

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3 CENTRAL ON-BOARD TIME SYNCHRONISATION REQUIREMENTS

This section provides requirements on the CSW regarding On-Board Time Synchronisation.

3.1 Overview

The following COBT Synchronisation Modes exist and are described briefly:

•**INTERNAL_SYNC:** This is the default Mode entered upon PM boot. In this Mode the COBT is not synchronised with GPST and therefore free running. The Master TTRM OBT provides the time reference for the PM OBT (and thus the COBT) and the Slave TTRM OBT for redundancy purposes. The CSW synchronises every second the COBT and also the Slave TTRM OBT to the Master TTRM OBT using the smooth synchronisation algorithm;
•**WAIT_FOR_GPS:** This mode is entered upon reception of a ground request to initiate synchronisation of the COBT with GPST. The CSW monitors the availability of the Sync Pulses and of the validity bit provided by the GPSR in the time correlation packet. The CSW synchronises every second the COBT and also the Slave TTRM OBT to the Master TTRM OBT using the smooth synchronisation algorithm;
•**SYNC_IN:** Once both GPSR Sync Pulses are detected and the GPSR time correlation packets are valid, the CSW synchronises every second all three OBC OBTs (thus including the COBT) to GPST using the smooth synchronisation algorithm. Once the time difference between COBT and GPST is below 1 microsecond the GPS_SYNC mode will be entered. The GPST validity bit of the time correlation packet must be true and the Sync Pulses vailable, otherwise SYNC_IN mode is left and WAIT_FOR_GPS mode is entered;
•**GPS_SYNC:** The COBT is synchronised to GPST. The CSW continues to perform the smooth synchronisation algorithm for the three OBC OBTs every second. The GPST validity bit of the time correlation packet must be true and Sync Pulses available, otherwise synchronisation is considered lost and WAIT_FOR_GPS mode is entered.

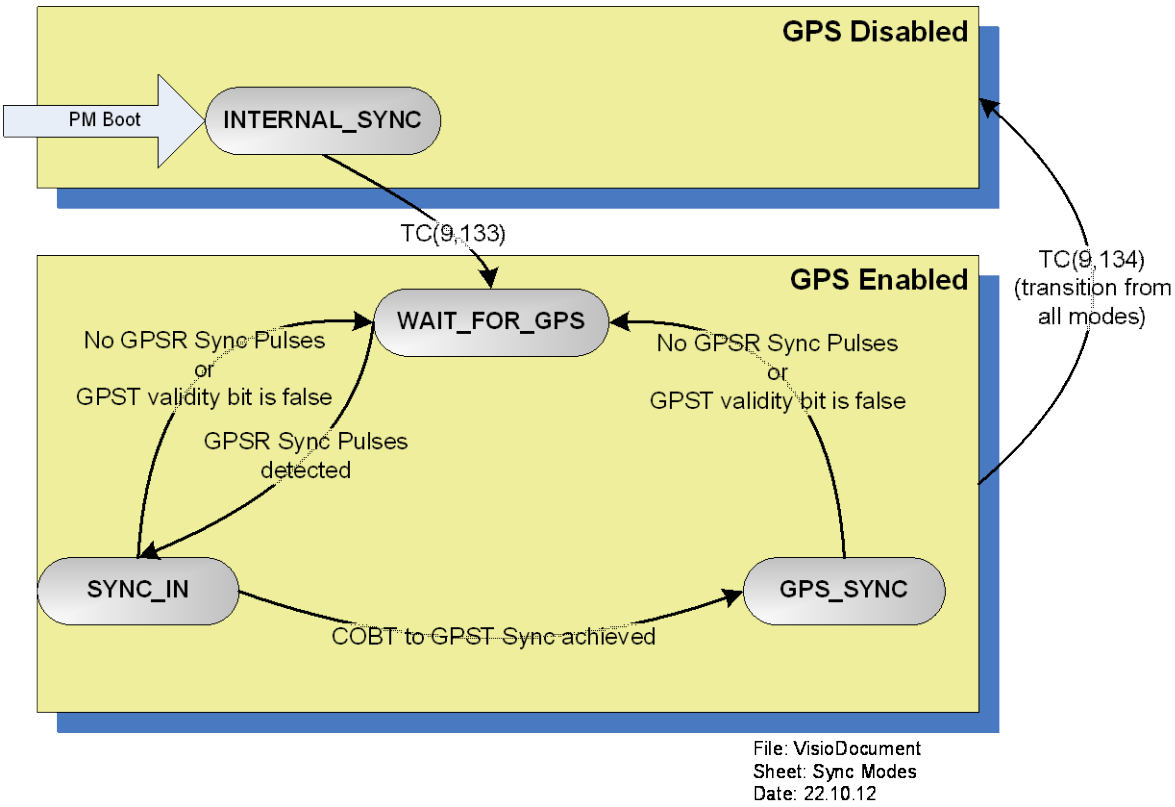

Figure 3.1-1: COBT Synchronisation Modes and Transitions

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3.2 COBT Time Format and Epoch

OBTM-1143 / SRS-1174,SRS-1208 / T

The CSW shall maintain a COBT that will be used to time stamp all time tagged events, mission data, and housekeeping data.

Note: The PM OBT represents the COBT while the Master TTRM OBT and Slave TTRM OBT are used as reference clocks for time synchronisation and initial time source only.

OBTM-1133 / SRS-1179,SRS-11780 / R

The CSW shall implement a COBT format using 56 bits (32 bits coarse time and 24 bit fine time) according to CCSDS Unsegmented Time Code (CUC)*, see [AD 3]:*

- *Coarse Time: full seconds coded on 4 octets C_0 to C_3;*
- *Fine Time: sub-seconds coded on 3 octets F_1 to F_3.*

Time from Epoch:

$$= C_0 * 256^3 + C_1 * 256^2 + C_2 * 256 + C_3 + F_1 * 256^{-1} + F_2 * 256^{-2} + F_3 * 256^{-3}$$

Note: See also Table 2.3-1.

OBTM-1134 / SRS-1174 / R

Deleted.

OBTM-1140 / SRS-1209 / R

The CSW shall use as COBT epoch the initial GPS epoch, i.e. midnight on the night of January 5, 1980 to January 6, 1980.

3.3 COBT Synchronisation without GPSR

3.3.1 General

OBTM-658 / SRS-1181 / T,A

The CSW shall be designed such that time jumps larger than 1 millisecond per second in the COBT cannot occur unless commanded by Ground.

OBTM-1058 / / T

The CSW shall use the smooth synchronisation algorithm provided in the OBC HDSW in order to synchronise the PM OBT and Slave TTRM OBT to the Master TTRM OBT.

3.3.2 COBT Initialisation

OBTM-991 / / T

After PM boot, the CSW shall enter the synchonisation mode INTERNAL_SYNC.

OBTM-1149 / / T

The CSW shall enable the generation of the following PPS signals to external units (LOBT users):

- *Master TTRM PPS and 10PPS (all groups);*
- *Slave TTRM PPS and 10PPS (all groups);*
- *PM PPS.*

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OBTM-650 / / T,R

The CSW shall perform the following steps upon PM (re-)boot in order to synchronise the used PM OBT and Slave TTRM OBT to the Master TTRM OBT:

- *Enable and route the PPS signal of the TTRM OBT selected as active TM Encoder (i.e. Master TTRM OBT) to the used PM;*
- *Read the Master TTRM OBT;*
- *Set the Slave TTRM OBT to the Master TTRM OBT value;*
- *Set the used PM OBT (and thus the COBT) to the Master TTRM OBT value;*
- *Start cyclic internal synchronisation of the PM OBT and Slave TTRM OBT to the Master TTRM OBT.*

OBTM-656 / / R

The CSW shall execute the initial PM and Slave TTRM OBT synchronisation to the Master TTRM OBT as quickly as possible in order to minimise the time offsets between the three OBC OBTs.

Note: This initialisation can result in a jump of the coarse time of the PM OBT. Jumps in the fine time of the PM OBT, however, may cause cyclic task overruns or watch dog triggers due to non-deterministic pulse timing.

OBTM-659 / SRS-1215 / T

The CSW shall set the "Time/Sync Quality" byte in accordance with Table 2.3-5 (INTERNAL_SYNC Mode).

OBTM-666 / / T

The CSW supplier shall use default NCO values according to System Software ICD [AD4] for the Master TTRM OBT, Slave TTRM OBT, and PM OBT, respectively.

OBTM-667 / / T

During initialisation the CSW shall read the default NCO value for the active PM stored in the SGM RAM and set the NCO value for the active PM OBT accordingly.

OBTM-1048 / / T

At initialisation the CSW shall enable the time report generation with a default rate_value = 5 (2^5= 32).

3.3.3 Internal Synchronisation of OBC OBTs

OBTM-661 / SRS-1176 / T

The CSW shall perform internal time synchronisation of the three OBC timers (Master TTRM OBT, Slave TTRM OBT, and PM OBT) in case no external synchronisation of the COBT to the GPST is available, for example, due to GPSR unavailability.

OBTM-662 / / T,R

The CSW shall configure the OBC OBTs as follows for internal time synchronisation:

- *The Master TTRM OBT is free-running using either the default (see below) or last-modified NCO value and provides an OBC internal synchronisation signal to the other two OBTs;*
- *The Slave TTRM OBT is synchronised to the Master TTRM OBT;*
- *The active PM OBT is synchronised to the Master TTRM OBT.*

OBTM-665 / / T

The CSW shall synchronise both the PM OBT and Slave TTRM OBT to the Master TTRM OBT using a smooth synchronisation algorithm as described in the OBC User Manual [RD3].

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OBTM-1032 / / T,A

The smooth sync of the COBT and the corresponding adjustment of the NCO value of the PM OBT shall not violate the deadline of any task and the timing of MILBUS sendlists.

Note: The rationale for the above requirement is that, for example, when accelerating the PM OBT the execution of a task appears to the observer based on PM OBT as being slower and thus may cause a missed deadline in case the deadline is too tight.

OBTM-993 / / T,R

The default maximum value of the cycle deviation (i.e. correction step) between two subsequent Sync Pulses shall be +/- 1 millisecond per second.

OBTM-986 / / T

The CSW shall store the last used NCO values in the SGM upon user request.

OBTM-1145 / SRS-1177 / T

After the CSW receives a TC(9,134) "Disable Synchronisation of GPS to OBC time" from Ground, the CSW shall enter the Synchronisation Mode INTERNAL_SYNC.

3.3.4 Synchronisation by Ground Command

At satellite power-on, the OBC is switched-on automatically while the GPSR remains switched-off. The counter values of all three OBTs inside the OBC start counting from zero, i.e. in this case the COBT is represented as Spacecraft Elapsed Time (SCET).

OBTM-671 / / T

In order to be able to distinguish between SCET and COBT after PM re-boot, the CSW shall compare the Master TTRM OBT value against a predefined threshold.

OBTM-987 / / T,R

The CSW Supplier shall use the threshold defined in the System Software ICD [AD4].

Note: The threshold is defined such that it is less than any time value possible during Satellite AIT and Operations.

OBTM-988 / / T

If the Master TTRM OBT value is below the threshold, the CSW shall interpret the Master TTRM OBT as SCET, or COBT otherwise, and shall set the corresponding bit in the Time/Quality Byte accordingly.

Nominally, the Ground segment performs the first on-board time initialisation by using PUS Service TC(9,128) "Set Central OBT" (see [RD2]). The TC(9,128) parameter contains:

•an *absolute time* value (set new OBT action in TC) in order to set the coarse time in CUC-Format (i.e. seconds) that will be valid at the time of the next OBC PPS;

•a *relative time* value (add/subtract delta time from OBT action in TC) in order to set both the coarse and fine time in CUC-Format that will be used to adjust the current COBT at the time of the next OBC PPS.

OBTM-673 / / T

In case of an absolute time *value, the CSW shall update the COBT using direct synchronisation, i.e. the COBT is overwritten with the new time value (seconds elapsed since Epoch).*

OBTM-674 / / T

In case of a relative time *value, the CSW shall synchronise both the coarse and fine time of the COBT with the provided relative time correction using a smooth synchronisation algorithm:*

•***add delta time****: adjust Master TTRM OBT NCO to* accelerate *clock;*

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- ***subtract delta time****: adjust Master TTRM OBT NCO to* decelerate *clock.*

OBTM-996 / / T

The CSW shall accept a TC(9,128) only while in synchronisation mode INTERNAL_SYNC.

The contents of the COBT "Time/Sync Quality" byte is defined in Table 2.3-5 (INTERNAL_SYNC Mode).

The Ground segment is expected to ensure that the COBT is set to a time value close (i.e. a few seconds) to the current GPST time before synchronisation is enabled. This is to avoid excessive duration until the coarse time is finally synchronised.

OBTM-1067 / / T

Deleted.

OBTM-1066 / / T

The CSW shall reject a TC(9,128) and remain in INTERNAL_SYNC mode in case the given threshold values for relative time correction are exceeded.

3.4 COBT Synchronisation with GPSR

3.4.1 COBT Synchronisation with GPST

OBTM-680 / SRS-1177 / T

After the CSW receives a TC(9,133) "Enable Synchronisation of GPS to OBC time" from Ground, the CSW shall enter the Synchronisation Mode WAIT_FOR_GPS.

OBTM-992 / / T

In addition, the CSW shall set the "Time/Sync Quality" byte in accordance with Table 2.3-5 (WAIT_FOR_GPS).

OBTM-1060 / / T

Deleted (functionality part of requirement OBTM-665).

OBTM-1144 / SRS-1175 / T

The CSW shall synchronise the COBT to GPST with an accuracy better than 1 microsecond using a smooth synchronisation algorithm as described in the OBC User Manual [RD3].

OBTM-1062 / / A

The CSW supplier shall estimate the measurement error and report it in the CSW Budget Report.

OBTM-681 / / T

Deleted.

OBTM-682 / / T

The CSW shall check the presence and correct timing of four consecutive GPSR Sync Pulses and the GPST validy bit, before it starts adjusting the NCO of the OBC OBTs using the smooth synchronisation algorithm.

OBTM-1177 / / T

The CSW shall consider the timing of a GPSR Sync Pulse as being correct if it is received within a [-4 msec; +4 msec] time intervall at the expected time of occurance (time of last pulse + 1 sec).

OBTM-683 / / T,R

The CSW shall adjust the NCO not later than 250 ms after the GPSR Sync Pulse is received.

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Note: The CSW uses a smooth synchronisation algorithm in order to slowly synchronise the phase of the OBC PPS with the phase of the GPSR Sync Pulse thus avoiding jumps in the time. During the synchronisation, the maximum cycle deviation between two subsequent Sync Pulses is +/- 1 millisecond per second. The maximum difference between the OBC PPS and the GPSR Sync Pulse can be up to +/- 0.5 seconds in case the COBT is not synchronised to GPST. During the smooth synchronisation process, frequency and phase of the OBC PPS are brought in-line with the GPSR Sync Pulse, until they are fully synchronised. In addition, the course time of the GPST and of the COBT are synchronised.

Assuming a max. allowed cycle time deviation of +/- 1 millisecond, this will lead up to 0.5 seconds / 1 millisecond per second = 500 seconds = 8 minutes and 20 seconds until both pulses and also the COBT fine time are synchronised.

OBTM-685 / / T

In addition to the smooth synchronisation of the COBT fine time (sub-seconds) with GPST, the CSW shall apply the same algorithm to the synchronisation of the coarse time.

OBTM-687 / / T

Deleted.

OBTM-1064 / / T

Deleted.

Note: Deleted.

The GPSR generates every second a dedicated GPSR Time Correlation Packet, which contains the GPST valid at the occurence of the previous GPSR Sync Pulse. This GPSR TM packet is distributed via MIL-Bus to the OBC.

Deleted.

OBTM-691 / / T

The CSW shall extract the GPST from the GPSR Time Correlation Packet and calculate the time offset from COBT.

OBTM-1147 / / T

Deleted.

OBTM-692 / / T

The OBC PPS will be phase-locked to the GPSR Sync Pulse, as long as the GPSR Sync Pulse synchronisation is considered valid. In this case, the CSW shall enter the COBT Synchronisation Mode GPS_SYNC if GPSR Sync has been enabled by Ground by means of a TC(9,133).

OBTM-994 / / T

In addition, the CSW shall set the "Time/Sync Quality" byte in accordance with Table 2.3-5 (GPS_SYNC Mode).

OBTM-693 / / T

The CSW shall continously check the validity of the synchronisation using the criteria defined in the Section 3.4.2.

OBTM-694 / / T

The CSW shall reject any TC(9,128) while COBT Synchronisation with GPST is enabled, i.e. being either in WAIT_FOR_GPS, SYNC_IN, or GPS_SYNC synchronisation mode. The CSW shall accept TC(9,128) only in Synchronisation Mode INTERNAL_SYNC.

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3.4.2 GPSR Unavailability or GPST Synchronisation Lost

OBTM-696 / / T

The CSW shall treat the COBT external synchronisation to GPST as being lost if any of the following conditions is detected:

- *neither TTRM OBT receives a Sync Pulse from the GPSR (loss of pulse);*
- *at least four consecutive GPSR Sync Pulses are outside the expected time window of 4 ms;*
- *the GPST validity bit has changed to false.*

OBTM-701 / / T

Upon loss of GPST synchronisation (see OBTM-696), the CSW shall also perform the following actions:

- *enter COBT Synchronisation Mode WAIT_FOR_GPS;*
- *Change the PPS input of both the Master TTRM OBT and Slabe TTRM OBT from GPSR Sync Pulse to the Local PPS provided by the TTRM;*
- *Continue to synchronise the COBT with the Master TTRM OBT but let the COBT be free running with respect to GPST.*

Note: Without GPST synchronisation the maximum clock drift of the COBT is 100 microseconds per second (see [RD3]).

3.5 Real Time Clock (RTC) Provision to the CSW

The OBC PM OBT provides a 20 Hz RTC pulse that is used as an interrupt to the CPU of the active PM. It should be noted that this RTC is different from the RTEMS RTC, which is generated internally in the CPU. This allows the operating system to start before the OBT function has been initialised.

OBTM-637 / / T,R

The CSW shall synchronise cyclic tasks to the 20 Hz RTC pulse received from the PM OBT.

OBTM-638 / / T

The CSW shall detect a missing RTC pulse. In case of a missing RTC pulse, the CSW shall raise an event.

Note: Deleted.

3.6 Time Reporting

OBTM-1146 / / T

The CSW shall sample the COBT at the TTRM time strobe event and insert the sampled COBT into the next Standard Spacecraft Time Source Packet.

OBTM-1049 / / T

The CSW shall provide the COBT of the last time strobe as nominal HK.

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4 UNIT LOBT SYNCHRONISATION WITH COBT

This section gives an overview of on-board unit time synchronisation. It does not define any requirements applicable to on-board unit suppliers.

4.1 Overview

External time synchronisation is achieved between the following on-board time entities:

•Synchronisation of the COBT to the GPST;

•Synchronisation of each individual LOBT to the COBT.

During nominal operations, the GPSR is in Navigation mode and the time synchronisation of Unit LOBTs to COBT is performed in a two-step-approach:

•The CSW synchronises the COBT to GPST using a smooth synchronisation algorithm;

•The OBC distributes a synchronisation signal (either OBC PPS or MIL-Bus Major Frame) to all units maintaining a LOBT and sends the COBT + 1 second via MIL-Bus Time-Broadcast Message.

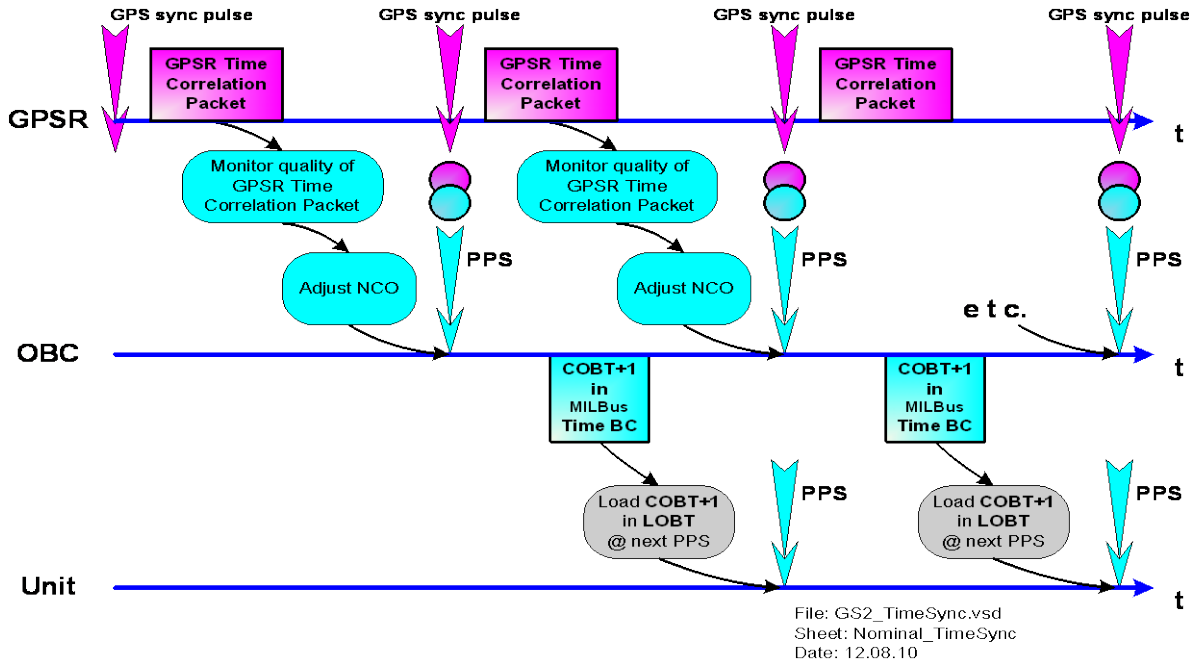

Figure 4.1-1: Time Synchronisation of the COBT and Unit LOBT with GPST using the periodic GPSR Sync Pulse

4.2 GPSR LOBT Synchronisation with COBT

After power-on, the GPSR receives the MIL-Bus Time-Broadcast Message from the OBC. The GPSR reads this Time-Broadcast Message during boot and synchronises its LOBT with this time information at the next MIL-Bus Major-Frame (since there is no PPS reception implemented).

Now the GPSR time-stamps all its TM with the synchronised LOBT. This leads to the ”Time/Sync Quality” byte for the GPSR TM packets as detailed in OBTM-719.

Bit	Description	Value

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Bit	Description	Value
0	Not Used	
1	Not Used	
2	Not Used	
3	Time Type	1 = OBT
4	Sync Source	1 = External
5	Sync Method	0 = MIL-Bus Major Frame (always)
6	Sync Status	1 = synchronised with COBT (always, if no error)
7	Sync Ena/Dis	1 = Enabled (always)

Table 4.2-1: GPSR LOBT "Time/Sync Quality" byte after synchronisation with COBT (0x1B)

After about 20 minutes, the GPSR gets in Navigation mode and calculates the GPS Time and the related GPS quality index. Furthermore, the GPSR generates a Sync Pulse every full second and distributes it to the OBC.

4.3 LCT LOBT Synchronisation with COBT

This section is not applicable.

4.4 Unit LOBT Synchronisation with COBT

The OBC generates the OBC PPS each full second and distributes it to all units. The CSW reads the COBT valid at the most recent OBC PPS, adds 1 second and distributes this COBT+1 second via MIL-Bus Time-Broadcast Message to all units. At the leading edge of the OBC PPS, each unit receives the MIL-Bus Time-Broadcast Message and synchronises its local timer LOBT with this time information at the next OBC PPS.

At unit power ON, the LOBT of the unit will be first synchronised to COBT, before time-stamping all TM packets. Nominally the unit continues reading and synchronising the LOBT each second.

Bit	Description	Value
0	Not Used	
1	Not Used	
2	Not Used	
3	Time Type	1 = OBT
4	Sync Source	1 = External
5	Sync Method	1 = 1Hz Pulse
6	Sync Status	1 = synchronised with COBT (always)

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Bit	Description	Value
7	Sync Ena/Dis	1 = Enabled (always, if no error)

Table 4.4-1: Unit LOBT "Time/Sync Quality" byte contents after synchronisation with COBT (0x1F)

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5 TIME SYNCHRONISATION ERROR HANDLING

5.1 COBT Synchronisation Error Cases

This section defines FDIR measures related to COBT management and synchronisation and is applicable to CSW Version 3. As far as CSW Versions 1 and 2 are concerned, the contents of this sections shall be regarded as for information only.

The following table identifies failure cases relevant to the COBT and its synchronisation with GPST.

Failure Case	**Observability**	**Failure Identification**	**Surveillance / Monitor**
Master TTRM OBT Excessive Drift	Master TTRM OBT cannot be synchronised to external reference clock (GPSR) within predefined time-period	Master TTRM failure (FcgTtr) System FDIR to reconfigure Slave TTRM OBT as new Master TTRM OBT	Modes: SYNC_IN: Excessive duration of OBT synchronisation in mode SYNC_IN Modes: Other Excessive time difference between Master TTRM OBT and Slave TTRM OBT AND Excessive time difference between Master TTRM OBT and PM OBT
Slave TTRM OBT Excessive Drift	Slave TTRM OBT cannot be synchronised to Master TTRM OBT within predefined time-period	Slave TTRM failure (FcgTtr) System FDIR to exclude defective OBT from OBC internal synchronisation	Modes: All Excessive time difference between Master TTRM OBT and Slave TTRM OBT
PM OBT Excessive Drift	PM OBT cannot be synchronised to Master TTRM OBT within predefined time-period	Act PM failure (FcgActPm) System FDIR to reconfigure active PM	Modes: All Excessive time difference between Master TTRM OBT and PM OBT

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Failure Case	Observability	Failure Identification	Surveillance / Monitor
GPSR Sync Pulse missing/timeout	The first indication of this failure case is that the PM OBT no longer receives a PPS from the Master TTRM OBT (timeout to be handled by the CSW). If both the Master TTRM OBT and Slave TTRM OBT receive the GPSR Sync Pulse, the PM OBT is in error or the Master TTRM OBT output is in error.	Master TTRM failure (FcgTtr) OR Act PM failure (FcgActPm) In order to isolate the failure cause the following two-level approach is applied: (1) System monitor to reconfigure Slave TTRM OBT as new Master TTRM OBT; (2) If still no PPS is received while using TTRM B as Master TTRM, the active PM OBT must be in error. System FDIR to reconfigure active PM	Modes: SYNC_IN and GPS_SYNC: Presence of SyncPps1 interrupt on Master TTRM AND Presence of SyncPps1 interrupt on Slave TTRM AND Lack of SyncPps1 interrupt on Active PM Modes: Other N/A

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Failure Case	Observability	Failure Identification	Surveillance / Monitor
GPSR Sync Pulse missing/timeout	Both Master and Slave TTRM OBTs do not receive the GPSR Sync Pulse	External failure (GPSR) GPSR Sync Pulse is lost, e.g. due to GPSR outage. Continue using the PM OBT and Master TTRM OBT in free-running mode using the most recently (i.e. before loss of GPSR synchronisation) NCO settings. System FDIR to switch over to GPSR-B	Modes: SYNC_IN and GPS_SYNC: Lack of SyncPps1 interrupt on Master TTRM AND Lack of SyncPps1 interrupt on Slave TTRM Modes: Other N/A
GPSR Sync Pulse missing/timeout	Slave TTRM OBT receives the GPSR Sync Pulse but not the Master TTRM OBT. In this case the Master TTRM OBT is in error	Master TTRM failure (FcgTtr) System FDIR to reconfigure Slave TTRM OBT as new Master TTRM OBT. System FDIR to exclude defective OBT from OBC internal synchronisation and declare corresponding TTRM unhealthy	Modes: SYNC_IN and GPS_SYNC: Lack of SyncPps1 interrupt on Master TTRM AND Presence of SyncPps1 interrupt on Slave TTRM Modes: Other N/A

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Failure Case	Observability	Failure Identification	Surveillance / Monitor
GPSR Sync Pulse incorrect timing	GPSR Sync Pulse not received within a 4 milliseconds time window	CSW shall switch to a free running mode 'WAIT_FOR_GPS' using the PM OBT and Master TTRM OBT in free-running mode using the most recently (i.e. before loss of GPSR synchronisation) NCO settings. System FDIR to switch over to redundant GPSR	Mode: GPS_SYNC Excessive Master TTRM error AND Excessive Slave TTRM error AND Excessive PM error Mode: SYNC_IN Not observable Mode: Other N/A
GPSR TM missing or corrupted	TM not received within a 4 milliseconds time window and/or GPST corrupted	CSW shall switch to a free running mode 'WAIT_FOR_GPS' using the PM OBT and Master TTRM OBT in free-running mode using the default NCO settings. System FDIR to switch over to redundant GPSR	Covered by AOCS FDIR
No internal PPS Sync (PpsOut from TTR)	Lack of expected SyncPps1 interrupt in the PM OBT Pending Interrupt Register	Master TTRM failure (FcgTtr) System FDIR to reconfigure Slave TTRM OBT as new Master TTRM OBT	See above
No internal PPS Sync to/from Slave TTRM OBT	Lack of expected Sample2 interrupt in the TTR OBT Pending Interrupt Register in Slave TTRM	Slave TTRM failure (FcgTtr) System FDIR to exclude defective OBT from OBC internal synchronisation	Modes: All Lack of Sample2 interrupt in Slave TTRM

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Table 5.1-1: Overview of COBT Synchronisation Error Cases

5.2 LOBT Loss of COBT Synchronisation

Time synchronisation with COBT of units maintaining a LOBT needs the following two inputs:

- a time stamp (distributed via MIL-Bus);
- a synchronisation signal (OBC PPS or start of MIL-Bus Major Frame).

In case one of these inputs is missing, the unit shall autonomously switch to its local clock (LOBT) and continue incrementing the time locally.

Also, in case of missing or corrupted time broadcast message the unit will autonomously switch to a local clock and continue incrementing the time locally.

The various synchronisation error cases are summarised in Table 5.2-1.

Function	**Failure Case**	**Detection**	**Measure**
MIL-Bus Time Broadcast	Time stamp missing		The unit shall continue using the LOBT without synchronisation to the COBT
MIL-Bus Time Broadcast	Time stamp transmission error		The unit shall continue using the LOBT without synchronisation to the COBT
MIL-Bus Major Frame	Major Frame missing	After Minor Frame #19, Major Frame #0 is not received MIL-Bus Major Frame not received within 200 milliseconds before its expected arrival	The unit shall continue using the LOBT without synchronisation to the COBT
OBC PPS	PPS missing	PPS is not received within 4 milliseconds *after* the expected time of the next PPS	The unit shall continue using the LOBT without synchronisation to the COBT. The unit shall generate a “Missing PPS” event

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Function	Failure Case	Detection	Measure
OBC PPS	PPS spurious	PPS is received before 4 milliseconds *before* the expected time of the next PPS	The unit shall continue using the LOBT without synchronisation to the COBT. The unit shall generate a “Spurious PPS” event In case multiple spurious signals are received within one second, the unit shall generate only one event message.

Table 5.2-1: Overview of LOBT Synchronisation Error Cases

On-Board Units will set the LOBT ”Time/Sync Quality” byte as defined in OBTM-904.

Bit	Description	Value
0	Not Used	
1	Not Used	
2	Not Used	
3	Time Type	1 = OBT
4	Sync Source	0 = Internal
5	Sync Method	1 = 1Hz Pulse
6	Sync Status	0 = NoSync
7	Sync Ena/Dis	1 = Enabled (always, if no error)

Table 5.2-2: Unit LOBT “Time/Sync Quality” byte contents after loss of synchronisation with COBT due to missing PPS signal or missing or corrupted time broadcast message (0x15)

Note: Synchronised operation of any datation user needs to be compatible with a variation of the synchronisation reference signal period of 4 milliseconds of the expected arrival of the synchronisation reference.

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Requirement/Section Cross Reference

OBTM-637	3.5	29	OBTM-685	3.4.1	27	OBTM-1049	3.6	29
OBTM-638	3.5	29	OBTM-687	3.4.1	27	OBTM-1058	3.3.1	24
OBTM-650	3.3.2	24	OBTM-691	3.4.1	27	OBTM-1060	3.4.1	27
OBTM-656	3.3.2	24	OBTM-692	3.4.1	27	OBTM-1062	3.4.1	27
OBTM-658	3.3.1	24	OBTM-693	3.4.1	27	OBTM-1064	3.4.1	27
OBTM-659	3.3.2	24	OBTM-694	3.4.1	27	OBTM-1066	3.3.4	26
OBTM-661	3.3.3	25	OBTM-696	3.4.2	29	OBTM-1067	3.3.4	26
OBTM-662	3.3.3	25	OBTM-701	3.4.2	29	OBTM-1133	3.2	24
OBTM-665	3.3.3	25	OBTM-986	3.3.3	25	OBTM-1134	3.2	24
OBTM-666	3.3.2	24	OBTM-987	3.3.4	26	OBTM-1140	3.2	24
OBTM-667	3.3.2	24	OBTM-988	3.3.4	26	OBTM-1143	3.2	24
OBTM-671	3.3.4	26	OBTM-991	3.3.2	24	OBTM-1144	3.4.1	27
OBTM-673	3.3.4	26	OBTM-992	3.4.1	27	OBTM-1145	3.3.3	25
OBTM-674	3.3.4	26	OBTM-993	3.3.3	25	OBTM-1146	3.6	29
OBTM-680	3.4.1	27	OBTM-994	3.4.1	27	OBTM-1147	3.4.1	27
OBTM-681	3.4.1	27	OBTM-996	3.3.4	26	OBTM-1149	3.3.2	24
OBTM-682	3.4.1	27	OBTM-1032	3.3.3	25	OBTM-1177	3.4.1	27
OBTM-683	3.4.1	27	OBTM-1048	3.3.2	24			

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