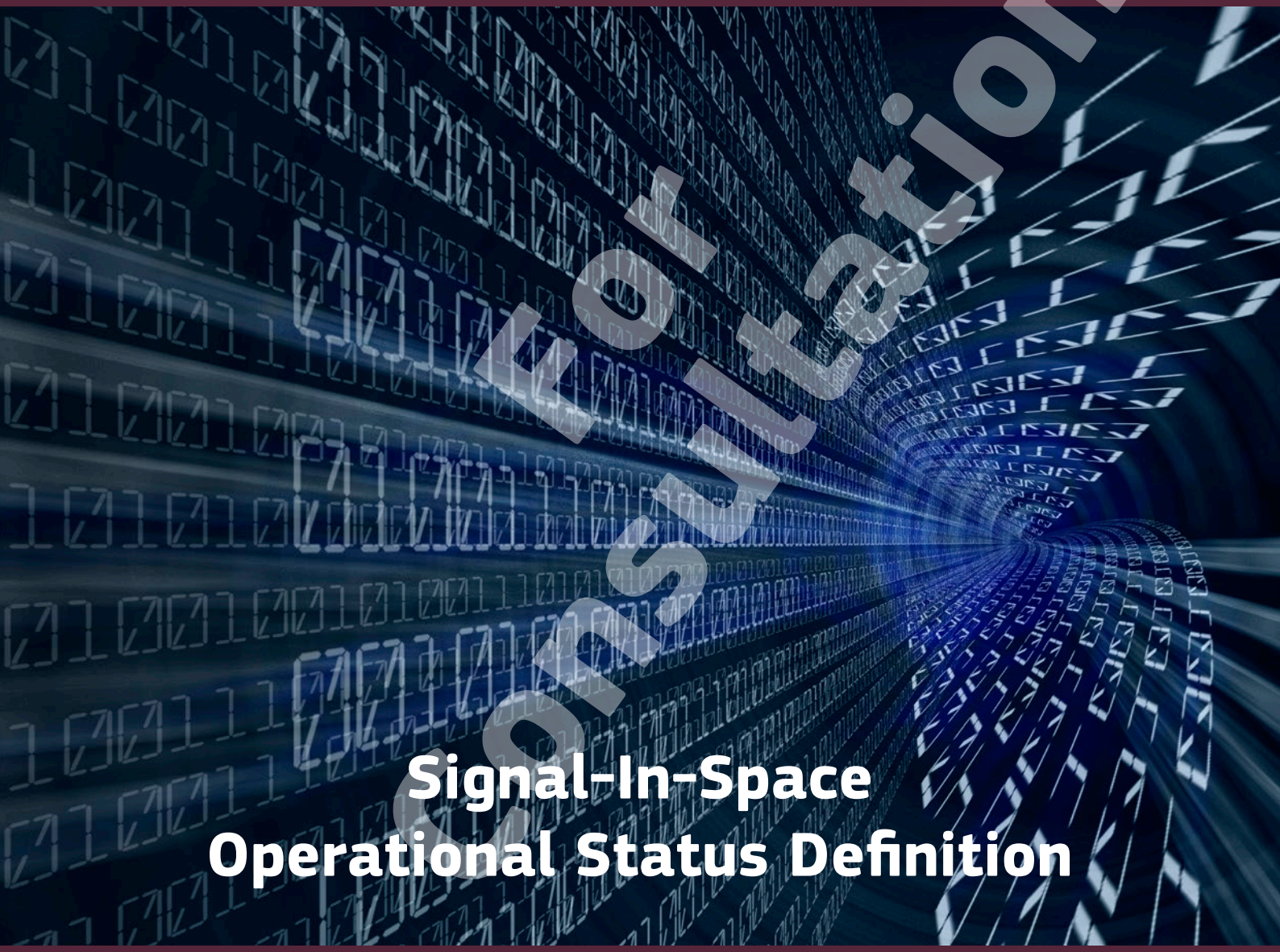
European GNSS (Galileo) Open Service



For consultation

Signal-In-Space Operational Status Definition

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1. Introduction

1.1. Background

Galileo is the European Global Navigation Satellite System (GNSS), providing a highly accurate and global positioning service under civilian control. Galileo, and in general current GNSS, are based on the broadcasting by satellite of electromagnetic ranging signals in the L frequency band. The performance achievable through Galileo, in terms of position, velocity and time determination accuracy depends on the availability of a number of such signals, uncorrupted and compliant with the system specifications. In order to enable Galileo receivers to properly handle each signal, the signal itself, within the associated Navigation Message, contains information about its operational status.

Because of the inherent complexity of a Global Navigation Satellite System, the quality of Galileo signals depends on a wide variety of factors. Nonetheless, the status of signals has been encoded using a minimal set of parameters that receivers can extract and decode in order to determine the status of each signal.

1.2. Document Scope

This document complements the Galileo Open Service Signal-In-Space Interface Control Document (OS SIS ICD, ref. Annex A[1]) by describing the encoding and use of the European GNSS Signal-In-Space (SIS) Status for the Galileo Open Service (OS). The SIS Status (i.e. the operational status of the OS SIS broadcast by each one of the Galileo satellites) is an important parameter whose value determines the applicability of the Minimum Performance Level of services as described by the Service Provider in the Galileo Open Service – Service Definition Document (OS-SDD), which will be published before the Galileo OS is declared available (hereinafter the "Minimum Performance Level").

The content of this document is specifically targeted towards manufacturers of Galileo receivers. The first part provides a comprehensive guide of how the status of the Galileo SIS is disseminated by the signal itself through specific data within the Navigation Message. In the second part, some considerations about the use of navigation parameters are presented and the reference for the ionospheric model used by Galileo is recalled. Finally, in the last chapter, some considerations are provided concerning the validity of navigation parameters.

2. Galileo Open Service SIS Status

2.1. SIS Status

Users of the Galileo Open Service (OS) can obtain information about the Signal-In-Space (SIS) Status, i.e. about the operational status of the OS SIS[1] broadcast by each one of the Galileo satellites, through the signals themselves.

The Galileo SIS Status can assume one of the following three values:

- HEALTHY,
- UNHEALTHY,
- MARGINAL.

The meaning of the three possible values of the SIS Status is the following:

- SIS "HEALTHY": The SIS is expected to meet the Minimum Performance Level[2].
- SIS "UNHEALTHY": The SIS is out of service or under test.
- SIS "MARGINAL": The SIS is in neither of the two previous statuses..

2.2. SIS Status Dissemination

Users can determine the status of each Galileo signal involved in the provision of OS either by reading the SIS Status information embedded in the navigation message or by recognising a specific type of message that may replace the standard navigation message (the so called dummy message, defined in the OS SIS ICD, see Annex A[1]).

2.2.1. SIS Status Flags

The status of the Signal-In-Space is encoded within the navigation message through three SIS Status Flags (see Annex A[1] for the complete definitions of the different flags):

- The Signal Health Status (SHS) flag.
- The Data Validity Status (DVS) flag.
- The Signal-In-Space Accuracy (SISA) value.

Signal Health Status (SHS)

For each Galileo OS signal (E1, E5a or E5b), the SHS flag is contained in the navigation data and the almanac messages. For E1 and E5b, the SHS flags are included in the I/NAV navigation data stream. For E5a, the SHS flag is included in the F/NAV navigation data stream. The SHS flags to be used is the one broadcast in the navigation data transmitted by the satellite whose SIS is being used.

Note: The SHS flags broadcast as part of the Almanac data are provided for convenience in support of satellite acquisition but should not be used operationally to determine the SIS Status.

1..... The Galileo OS SIS comprises signals broadcast on the E1B, E5a, and E5b carriers (see the OS SIS ICD, ref. Annex A[1] or the OS-SDD for more details).

2..... Note that this assertion does not apply to the Minimum Performance Level for the provision of the GPS-Galileo System Time Offset (GGTO). GGTO is independent from the SIS Status and a specific value of the GGTO broadcast parameters indicates a non-valid GGTO (ref. Annex A [1] for more details).

The SHS flags can assume the values defined in the OS SIS ICD, ref. Annex A[1] and recalled for convenience in Table 1.

Signal Health Status (SHS)	Definition
0	Signal OK
1	Signal out of service
2	Signal will be out of service
3	Signal component currently in Test

Table 1. Signal Health Status Bit Values

Data Validity Status (DVS)

For each Galileo OS signal (E1, E5a or E5b), the DVS flag is contained in the navigation data. For E1 and E5b, the DVS flags are included in the I/NAV navigation data stream. For E5a, the DVS flag is included in the F/NAV navigation data stream. The flag can assume the values defined in the OS SIS ICD, ref. Annex A[1], and recalled for convenience in Table 2.

Data Validity Status (DVS)	Definition
0	Navigation data valid
1	Working without guarantee (WWG)

Table 2. Data Validity Status Bit Values

Signal-in-Space Accuracy (SISA)

For E1 and E5b, the SISA Index is contained in the I/NAV navigation data stream.

For E5a, the SISA Index is contained in the F/NAV navigation data stream.

The SISA Index values relevant to the assessment of the SIS Status, as defined in the OS SIS ICD, ref. Annex A[1], are recalled for convenience in Table 3.

SISA Index	SISA Value
255	No Accuracy Prediction Available (NAPA)
0.....254	Not NAPA

Table 3. SISA Index values relevant to the assessment of the SIS Status

2.3. Mapping Between SIS Status Flags and SIS Status

The mapping between the values of the SIS Status Flags and the three values of the SIS Status is provided in Table 4 and also represented in the form of a decision tree in Figure 1. It should be noted that the order in which the flags are checked by a receiver on a valid[3] and non-dummy navigation message is arbitrary and up to the manufacturer.

3.....A valid navigation message is one compliant with the Galileo OS SIS ICD. Note that a dummy navigation message is a valid navigation message. The definition of dummy navigation message is included in the Galileo OS SIS ICD (Page/Word Types 63 for F/NAV and I/NAV, respectively).

SIS Status	SIS Validity, Message and Status Flags
Healthy	Valid navigation message **AND** Non-dummy navigation message **AND** SHS = OK **AND** DVS = OK **AND** SISA ≠ NAPA
Unhealthy	Non valid navigation message **OR** Dummy navigation message **OR** SHS="Out of service" (whatever DVS and SISA) **OR** SHS=Test (whatever DVS and SISA)
Marginal	**[**Valid navigation message **AND** Non-dummy navigation message **AND** SHS = OK **AND** (SISA=NAPA, OR DVS=WWG)**]** **OR** **[**Valid navigation message **AND** Non-dummy navigation message **AND** SHS="Will be out of service" (whatever DVS and SISA)**]**

Table 4. Galileo Open Service SIS Status vs SIS Status flags

Table 5 shows a summary of the SIS Status Flags to be checked by the different Galileo OS users for both Single Frequency (SF) and Dual Frequency (DF) services[4]. Users wishing to exploit the DF Open Service need to ensure that the status of each of the SIS they intend to use is "healthy". In case either or both of the SIS are declared "unhealthy", the DF service associated is "unhealthy". In any other case, the DF service is "marginal".

4.....For more details about SF and DF services please refer to the OS-SDD.

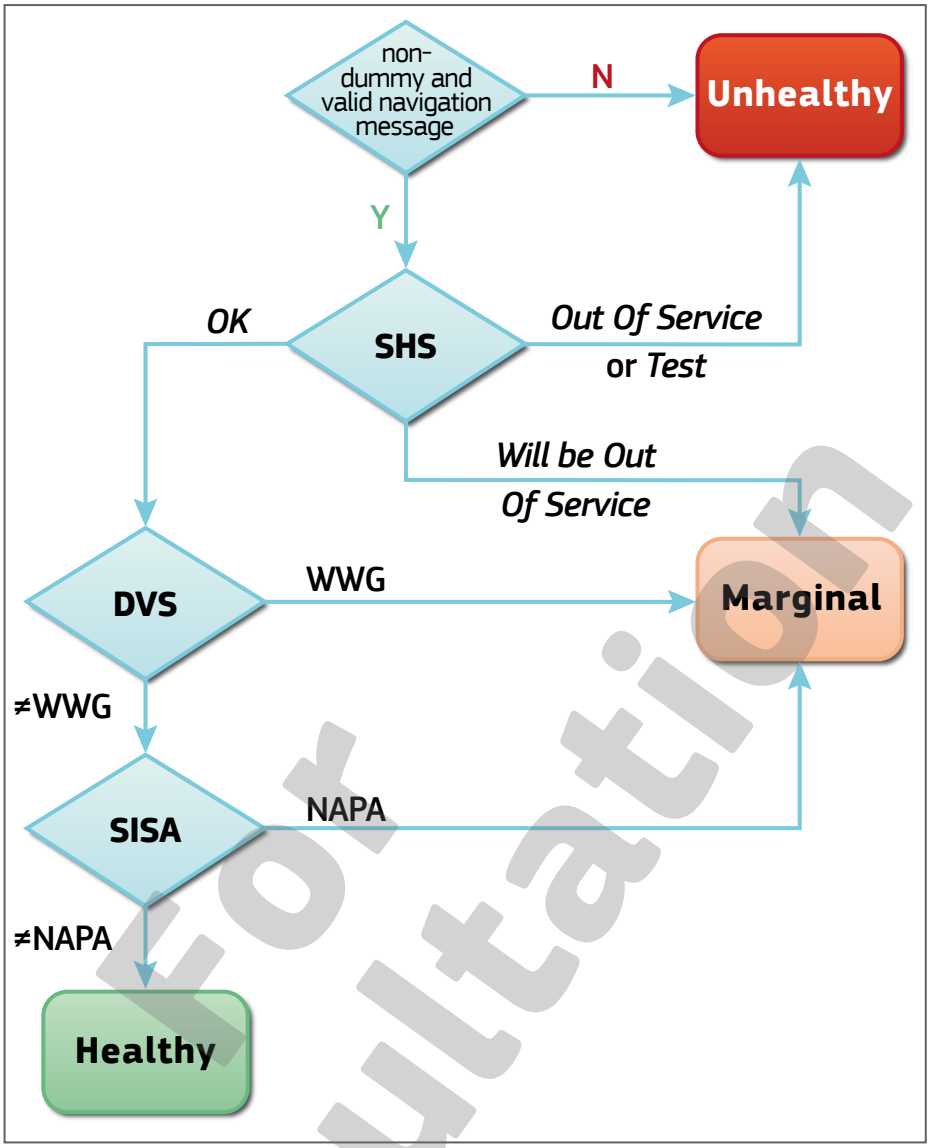


Figure 1. Decision tree for SIS Status

Users		F/NAV			I/NAV				
		$E5a_{HS}$	$E5a_{DVS}$	SISA(E1,E5a)	$E1B_{HS}$	$E1B_{DVS}$	$E5b_{HS}$	$E5b_{DVS}$	SISA(E1,E5b)
Single Frequency	E1				X	X			X
	E5a	X	X	X					
	E5b						X	X	X
Double Frequency	E1/E5a	X	X	X	X	X			
	E1/E5b				X	X	X	X	X

Table 5. Summary of SIS flags to be checked by the different Galileo OS users to compute the Status of Signals-In-Space

3. Navigation Parameters and Issue of Data

As defined in the OS SIS ICD, ref. Annex A[1], the navigation data is disseminated in data batches each identified by an Issue of Data (IOD). In nominal operations, the navigation data (ephemeris, clock correction and SISA) have limited validity duration depending on the data type. The identification of each batch by an IOD value enables:

- the users to distinguish the data in different batches received from each satellite;
- to indicate to the user's receiver the validity of the data (which have to be updated using new issue of navigation data);
- the user receiver to compute the full batch of data even if it misses some pages or starts receiving the data somewhere during the transmission.

Two independent IODs are defined for:

- the ephemeris, satellite clock correction parameters and SISA;
- the almanacs.

Another set of navigation data, the broadcast group delay (BGD), ionospheric corrections, GST-UTC and GST-GPS conversion parameters, navigation data validity status (DVS) and signal health status (SHS), is not identified by any Issue of Data value.

3.1. Parameters Identified by an IOD Value

To compute position, velocity and clock corrections, receivers must use, for each satellite, IOD-tagged parameters corresponding to the same IOD Value. These parameters must be retrieved from the most recent navigation data set broadcast by the Galileo system after the start of the current receiver operation. These are the two conditions under which the navigation solution is expected to meet the Minimum Performance Level. The utilisation of parameters identified by different IOD Values from a single satellite is not recommended and the resulting navigation performance is not expected to meet the Minimum Performance Level.

Galileo satellites are not expected to all transmit the same IOD. For positioning, users can combine SIS from different satellites with different IOD Values provided that the navigation parameters derived from each satellite are indeed tagged by a unique IOD Value.

It is relevant to note that IOD Values are not necessarily incremented in steps of one and that an IOD with higher value does not necessarily mean more recent data. The only valid comparison between IOD Values is whether they are equal or not.

3.2. Parameters Not Identified by an IOD Value

The broadcast group delay (BGD), ionospheric corrections, GST-UTC and GST-GPS conversion parameters, navigation data validity status (DVS) and signal health status (SHS) are not identified by an IOD Value.

To compute the navigation solution, receivers must retrieve the values of these parameters from the most recent navigation data set broadcast by the Galileo system after the start of the current receiver operation. This is the condition under which the navigation solution is expected to meet the Minimum Performance level.

The satellite specific parameters (BGD, DVS, SHS) have to be obtained from each satellite and for each frequency while system parameters (ionospheric corrections, GST-UTC and GST-GPS conversion parameters) can be obtained from any healthy SIS.

4. Ionospheric Model

The ionospheric delay is usually the largest contributor to the pseudorange error for single-frequency users. This delay can be partially mitigated using ionospheric models such as Klobuchar or NeQuick. The ionospheric model adopted by Galileo is the NeQuick model (ref. Annex A[2]). The Galileo navigation message includes several parameters which are used by receivers implementing the NeQuick model to compute the ionospheric effect.

5. Validity of Navigation Parameters

As already stated in the previous chapters, the Galileo OS Minimum Performance Level is expected to be met only if the navigation solution is computed by a receiver using the navigation parameters from the most recent navigation data set broadcast by the Galileo system after the start of the current receiver operation.

The utilisation by a receiver of navigation parameters stored during previous receiver operations implies that the navigation performance that can be achieved is not expected to meet the Minimum Performance Level.

In the next section, the typical validity time duration of navigation parameters is discussed and suggestions are provided regarding how to calculate the validity of navigation parameters stored by a receiver during previous navigation sessions.

5.1. Navigation Parameters' Validity Time and Refresh Rate

The navigation dataset refresh rate and the time interval during which the data remains accurate are Galileo system configuration parameters. The typical refresh rate of the navigation data set through upload from Galileo Ground Segment to satellites is 100 minutes[5] although the maximum validity time of each navigation data set is 4 hours[6].

Receivers intending to use navigation parameters stored during previous receiver operations can check the validity of navigation parameters following the algorithm provided in Annex C. Using this algorithm, users are able to compare the age of the navigation parameters they have available with the maximum validity time.

5.....A lower refresh rate may be observed during initial system deployment and operations with a reduced number of satellites.
6.....Note that the validity time may change in future Galileo system configurations.

6. Annex A - Reference Documents

[1] European GNSS (Galileo) Open Service Signal-In-Space Interface Control Document (OS SIS ICD), Issue 1.2, European Union, 2015

[2] Ionospheric Correction Algorithm for Galileo Single Frequency Users, Issue 1.1, European Union, June 2015

7. Annex B - Acronyms and Definitions

BGD ..... Broadcast Group Delay
DF ..... Dual Frequency
DVS ..... Data Validity Status
EC ..... European Commission
ESA ..... European Space Agency
GNSS ..... Global Navigation Satellite System
GPS ..... Global Positioning System
GSA ..... European GNSS Agency
GST ..... Galileo System Time
HS ..... (Signal) Health Status (also known as SHS)
IOD ..... Issue of Data
ICD ..... Interface Control Document
NAPA ..... No Accuracy Prediction Available
OS ..... Open Service
PVT ..... Position, Velocity and Time
RF ..... Radio Frequency
SF ..... Single Frequency
SHS ..... Signal Health Status
SIS ..... Signal In Space
SISA ..... Signal In Space Accuracy
UTC ..... Universal Coordinated Time
WWG ..... Working Without Guarantee

8. Annex C - Estimation of the Validity of Navigation Data

The age of Time of Ephemeris t_k is defined as follows (see also Annex A[1]):

$$t_k = t - t_{0e}\,[s]$$

where t is the Galileo System Time $[s]$

t_{0e} is the Time of Ephemeris in GST time $[s]$ (as for t ranging from 0 to 604799 seconds), as broadcast by the navigation message.

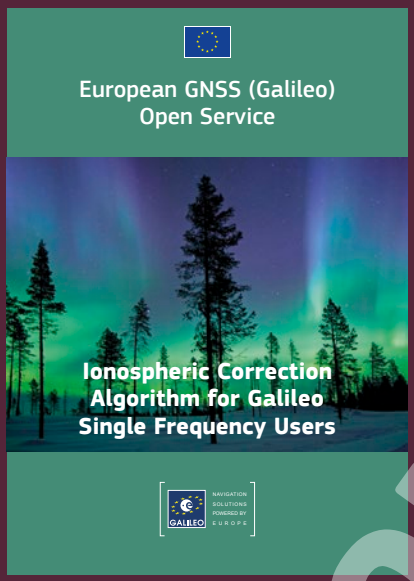
If a receiver wishes to check whether the age of the navigation data available is within a certain validity time VT it will have to evaluate the following inequality:

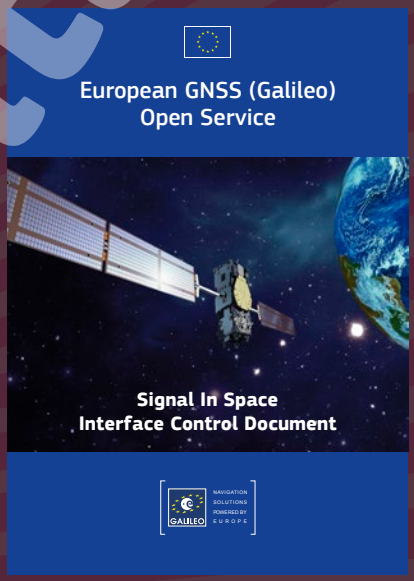
$$t_k < VT$$

Note that, as explained in ref. Annex A[1] (see Note to Table 58 in OS SIS ICD), t_k is the actual total time difference between the broadcast GST and the Time of Ephemeris ***accounting for the eventual beginning or end of week crossover***. To take this into account, in practice, users might perform the following simple check before calculating t_k:

$$\text{if } t_r - t_{0e} < VT - 604800 \text{ then } t_{0e} = t_{0e} - 604800$$

t_k must be then calculated using this value of t_{0e} corrected for week crossovers.





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