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EUROPEAN GNSS (GALILEO) OPEN SERVICE

SIGNAL-IN-SPACE OPERATIONAL STATUS DEFINITION: RESULT OF THE PUBLIC CONSULTATION

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ACRONYMS

AOCS	Attitude & Orbit Control System
CRC	Cyclic Redundancy Check
DVS	Data Validity Status
EC	European Commission
FOC	Full Operational Capability
GSC	GNSS Service Centre
GST	Galileo System Time
ICD	Interface Control Document
IOD	Issue of Data
MPL	Minimum Performance Level
NAPA	No Accuracy Prediction Available
OS	Open Service
OSD	Operational Status Definition
RD	Reference Document
SHS	Signal Health Status
SIS	Signal In Space
SISA	SIS Accuracy
SoL	Safety of Life
TOW	Time Of Week
UTC	Universal Time Coordinated

SECTION 1: INTRODUCTION

The Galileo Open Service Signal-In-Space Operational Status Definition (OS SIS OSD) document describes the encoding and use of the Galileo Signal-In-Space (SIS) status (i.e. the operational status of the OS SIS broadcast by each one of the Galileo satellites), and complements the Galileo OS SIS Interface Control Document (OS SIS ICD).

In September 2015, the first version of the OS SIS OSD was made available by the European Commission (EC) to the public through the internet site of the European GNSS Service Centre (GSC, www.gsc-europa.eu) for a period of Public Consultation.

Users were invited to address their comments and suggestions to the OS SIS OSD through a functional mailbox addressing the GSC. Responses to this public consultation were received until the deadline of the consultation process, on November 16th, 2015.

This document elaborates the questions, comments and suggestions received from the participants in the Public Consultation and where appropriate provides answers and clarification.

SECTION 2: IMPORTANT NOTE TO THE READERS

This document is a complement to the OS SIS OSD Annex A[2] published by the EC for the purpose of the Public Consultation. Therefore it must be read and understood in the light of and in parallel with that version of the OS SIS OSD Annex A[2].

This document aims at presenting the main outcome of the Public Consultation on the OS SIS OSD Annex A[2] and it is not a reference document for the Galileo users who have to the refer, for these topics, to the most recent version of the OS SIS OSD.

SECTION 3:
OS SIS OSD PUBLIC CONSULTATION OUTCOME

3.1 INTRODUCTION: OVERVIEW OF THE USERS' FEEDBACK

More than 50 questions, comments and suggestions were received during the two months duration of the Public Consultation. The feedback received from users on the OS SIS OSD touched upon various topics but was principally focused on:

- Navigation message (definition and validity)
- Data Validity Status (DVS) flag operations
- Validity time of broadcast parameters
- Issue of Data (IOD) usage.

In the present document, the questions and comments received have been clustered into four subsets. Each of these subsets is presented in the next sections, where the topic is first introduced, then the specific issues raised are reported and finally the respective answers and clarifications are provided. The subsets identified are the following:

- Navigation Message.
- Data Validity Status (DVS) Flag.
- Other SIS Status Flags: Signal Health Status (SHS) and SIS Accuracy (SISA).
- Validity Time and Refresh Rate of the Navigation Message.

3.2 NAVIGATION MESSAGE

3.2.1 INTRODUCTION

The Galileo Navigation Message contains all the necessary parameters and information that enables users to exploit the Galileo OS. This includes:

- time parameters and clock corrections, needed to compute satellite clock offsets and time conversions;
- ephemeris parameters, needed to compute the satellite coordinates with sufficient accuracy;
- service parameters with satellite health information;
- the ionospheric parameters model, needed for single frequency receivers;
- the almanacs, allowing computation of the position of all satellites in the constellation, which is needed for a fast acquisition of the signal by the receiver.

3.2.2 QUESTIONS

The questions and requests for clarification concerning the navigation message can be summarised as follows:

- What is the definition of a navigation message in this document?
- What is the definition of valid and non-valid navigation message? Is it related to the CRC?
- What is the definition of dummy navigation message?
- How are the "Alert Pages" within the navigation message managed?

The next section answers these questions and clarifies the doubts expressed by the users on these topics.

3.2.3 RESPONSE

The purpose, structure and content of the Galileo navigation message are explained in the Galileo Open Service Interface Control Document (OS SIS ICD, Annex A[1]). As detailed there, the complete navigation message data is transmitted on each data component as a sequence of frames. A frame is composed of several sub-frames, and a sub-frame in turn is composed of several pages.

In the context of this document, by "navigation message" a sub-frame is meant (50 seconds for F/NAV and 30 seconds for I/NAV [1]) that contains ephemeris and clock corrections or SIS health information, that is, Page Type 1 to 4 for the F/NAV and Word Type 1 to 6 for the I/NAV.

When no valid navigation data is to be transmitted by a satellite, dummy pages are generated and downlinked.

1……*Please, refer to the OS SIS ICD (Annex A[1]) for details about the different types of navigation message.*

Dummy pages are defined in the Galileo OS SIS ICD Annex A[1] (Page/Word Types 63 for F/NAV and I/NAV, respectively). Such dummy pages, if transmitted, replace the whole navigation message which is then defined as a dummy navigation message.

As described in SIS OS OSD Annex A[2] and in Annex C, a dummy navigation message indicates Unhealthy SIS. Therefore, as soon as a dummy page, i.e. Page/Word Types 63, is decoded, the respective SIS must be considered Unhealthy.

Once the transmission of the dummy message terminates and normal transmission is recovered, users must follow the appropriate procedure to check the SIS Status, as described in the SIS OS OSD Annex A[2], before starting to reuse the SIS.

Note that in the case of Dual Frequency (DF) users, a dummy navigation message on one of the frequencies implies that the DF service is not Healthy (as explained in in the SIS OS OSD Annex A[2]).

Navigation parameters shall not be used beyond the maximum possible broadcast period of a healthy navigation message data set, currently set to 3 hours [2]. A navigation message data set may be superseded before the expiration of these 3 hours by the broadcast of a new navigation message data set.

Users can follow the procedure described in Annex B of this document to estimate the age of ephemeris. In addition, Annex C presents the updated procedure to derive the SIS Status.

Concerning the topic of valid navigation message, it must be underlined that the available cyclic redundancy check (CRC) is not involved in the definition of such validity. To detect the reception of corrupted data within the navigation message, a checksum is used, which employs a CRC technique. The definition of this checksum is provided in the OS SIS ICD Annex A[1]. The CRC is therefore not used to indicate any problem at satellite level, i.e. on transmitter side. The CRC checksum is related exclusively to the errorless reception of the transmitted bits, i.e. to the transmission channel, not to the correctness of structure or of the transmitted content of the message as transmitted by the Galileo system. The CRC available within the navigation message of Galileo is therefore not involved in the definition of the SIS Status. If the CRC checksum is not passed, the data is rejected. Once a navigation message is finally received with a successful CRC the user can then proceed to the SIS Status determination, as described in SIS OS OSD Annex A[2] and in Annex C, and eventually to the utilisation of such SIS.

The navigation message, specifically the I/NAV, transmitted on E1 and E5b, has been designed to include Alert Pages (see OS SIS ICD, Annex A[1] for a detailed definition). The transmission of Alert pages is a capability that the Galileo system is currently not exploiting.

3.3 DATA VALIDITY STATUS (DVS) FLAG

3.3.1 INTRODUCTION

The Data Validity Status Flag is one of the flags used for notifying, through the SIS to the Galileo user, some specific aspects of service, notably concerning the health status of the SIS itself. The DVS is a one bit flag that can assume the values defined in the OS SIS ICD, Annex A[1] (reported also in Table 1 below for convenience). For E1 and E5b, the DVS flags are included in the I/NAV navigation data stream while for E5a, the DVS flag is included in the F/NAV navigation data stream.

DATA VALIDITY STATUS (DVS)	DEFINITION
0	Navigation data valid
1	Working without guarantee (WWG)

Table 1. Data Validity Status Bit Values.

3.3.2 QUESTIONS

The questions and requests for clarification concerning the DVS can be summarised as follows:

- Why is the DVS relevant?
- Which navigation data are addressed by the DVS?
- How should navigation data stored before a DVS event be considered?
- What is the Time To Alert between occurrence of an event and the setting of the DVS?

2....... This time interval might be modified in the future.

3.3.3 RESPONSE

The DVS flag can be triggered in two ways:

- When the time passed since the last navigation message uplink to the satellite is greater than a predefined threshold.
- By the satellite in case of certain anomalies.

In the first case, the DVS acts as a timer accounting for the age of the navigation message. The time interval threshold for its triggering is set by the system to ensure the service performance.

In the second case, as the DVS is triggered on-board in case of specific events, its value can change at any time.

As an example, the DVS flag could be set to WWG in case the respective SIS cannot be considered Healthy but, depending on the value of the other flags, only Marginal. This means that neither the SIS nor any of the parameters obtained through such SIS should be used. As soon as receivers detect that the DVS value has been set back to 0 and that, taking into account the other relevant flags, the SIS Status is Healthy, they will have to retrieve the most recent navigation data set newly broadcast in order to use such SIS.

It is only under this condition that the navigation solution is expected to meet the Minimum Performance Level. In other words, all the parameters requested by a receiver have to be retrieved once the SIS is (back to) Healthy in order to ensure that the MPL is expected to be met.

The Time To Alert between occurrence of an event and the setting of the DVS is under definition and no performance can be provided at this time.

3.4 OTHER SIS STATUS FLAGS: SIGNAL HEALTH STATUS (SHS) AND SIS ACCURACY (SISA)

3.4.1 INTRODUCTION

As explained in the OS SIS OSD Annex A[2], apart from the DVS, there are two other flags associated with the SIS Status: the Signal Health Status (SHS) and SIS Accuracy (SISA). The values that each flag can assume and their position within the various types of navigation message can be found in the OS SIS ICD Annex A[1] and OS SIS OSD Annex A[2].

Both the SHS and the SISA, just like the DVS, are used for notifying through the SIS to the Galileo user some specific aspects of service performance, notably concerning the health status of the SIS itself. The SISA, though, has been designed also to potentially provide information about the quality of a healthy SIS. This fact has provoked some questions that will be addressed in this section.

3.4.2 QUESTIONS

The questions and requests for clarification concerning the SHS and SISA can be summarised as follows:

- Why is the SHS not tagged by the IOD value?
- Are the SHS and the DVS independent?
- What is the Time To Alert between occurrence of an event and the setting of the SHS?
- Is SISA provided for Single Frequency users?
- How should the spare values of the SISA be considered concerning the SIS Status?

3.4.3 RESPONSE

The SHS is, along with the broadcast group delay (BGD), ionospheric corrections, GST-UTC and GST-GPS conversion parameters, and the DVS, one of the parameters provided by the navigation message that is not time-tagged by the IOD value. The SHS flag, in fact, can be raised by the system at any moment, completely decoupled from the data stream. For this reason it is not IOD tagged. This lack of tagging might give rise to a possible issue in case users want to make use of old navigation data stored in the memory of the receiver instead of using the most recent transmission. As explained in the OS SIS OSD Annex A[2], this is done by users at their own risk.

In fact, to compute the navigation solution (position and time), receivers must retrieve the values of the parameters relevant to the type of navigation solution to be computed (as an example, DF users do not need to decode iono parameters) from the most recent navigation data set, broadcast on healthy SIS 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. Note that the conditions for a SIS to be healthy are reported in the OS SIS OSD Annex A[2] and specifically that the SHS can be read (and taken into account) independently from the DVS value.

As for the DVS, the Time To Alert between occurrence of an event and the setting of the SHS is under definition and no performance can be provided at this time.

Concerning the SISA, although as indicator of performance for healthy SIS it is computed for frequency pairs, i.e. for Dual Frequency users, when it is used to determine the status of the SIS, it must be checked by users of any service, both Single Frequency and Dual Frequency, and must be taken into account as described in the OS SIS OSD Annex A[2] and in the OS SDD.

When the SISA is used as one of the means for determining the SIS Status, it must be considered as a binary indicator, as its only meaningful values are “No Accuracy Prediction Available” (NAPA, when SISA=255) or “not NAPA” (when SISA≠255). Note that those SISA values described in the OS SIS ICD Annex A[1] as Spare (from 126 to 254) are to be considered as not NAPA.

3.5 VALIDITY TIME AND REFRESH RATE OF THE NAVIGATION MESSAGE

3.5.1 INTRODUCTION

As explained in the OS SIS OSD Annex A[2], the navigation dataset refresh rate is a parameter defined by the system. The typical refresh rate of the navigation data set through upload from Galileo Ground Segment to satellites can range from a minimum of 10 minutes to about 3 hours.

3.5.2 QUESTIONS

The questions and requests for clarification concerning the validity time and refresh rate of the navigation message can be summarised as follows:

- Is it foreseen that the time interval during which a navigation data set can be used could change in future Galileo system configurations?
- What are the validity time and refresh rate of GST-UTC conversion parameters?
- What are the validity time and refresh rate of almanacs?
- What is the meaning of the variable tr in the algorithm provided for the estimation of the validity of navigation data?
- The proposed calculation for taking into account the week change in the algorithm provided for the estimation of the validity of navigation data implies that there could be negative t_{oe}.

3.5.3 RESPONSE

In the medium term, the time interval during which a navigation data set can be used, i.e., the maximum possible broadcast period of a healthy navigation message data set is not foreseen to change.

Concerning the GST-UTC conversion parameters, in the current system configuration they are updated daily (although this may change in a future configuration). With respect to the almanacs, their refresh rate is the same as for the ephemeris. Minimum Performance Levels on the almanac and their validity time are not currently provided.

In the OS SIS OSD, a procedure is described in Annex 1 to estimate the age of ephemeris as prediction time from reference Time of Ephemeris ($t - t_{oe}$). Applying this algorithm, users are able to compare the age of the navigation parameters they have available with the maximum possible broadcast period of a healthy navigation message data set. Within this algorithm, the variable tr indicates the Time of Reception of the message in GST time [s] based on the broadcast Time Of Week (TOW), defined as the number of seconds that have occurred since the transition from the previous week, ranging from 0 to 604799 seconds and reset to zero at the end of each week (00:00 Sunday). For consistency with the ICD, this variable will be renamed as "t" in the updated version of the OS SIS OSD.

Moreover, concerning the possibility of having negative values of t_{oe}, the algorithm has been modified. The new version of the algorithm is presented in Annex B of this document.

ANNEX A: REFERENCE DOCUMENTS

REFERENCE	TITLE	ISSUE
[1]	European GNSS (Galileo) Open Service Signal-In-Space Interface Control Document (OS SIS ICD).	Issue 1.2, European Union, 2015.
[2]	Galileo Open Service – Signal In Space Operational Status Definition	Issue for Public Consultation, European Union, 2015

ANNEX B:
ESTIMATING THE AGE OF EPHEMERIS

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

$$t_k = t - t_{oe}$$

where:

t is the Time of Reception of the message in GST time [s] based on the broadcast Time Of Week (TOW), defined as the number of seconds that have occurred since the transition from the previous week, ranging from 0 to 604799 seconds and reset to zero at the end of each week (00:00 Sunday).

t_{oe} 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 Ephemeris of a navigation data set is within a certain validity time VT it will have to evaluate the following inequality:

$$0 \leq t_k \leq VT$$

Note that, as explained in Annex A[1] (see Note to Table 58), tk is the actual total time difference between the broadcast GST and the Time of Ephemeris, accounting for the possible beginning or end of week crossover. To take this into account, if t_k is greater than 302400 seconds, 604800 seconds must be subtracted from t_k. If t_k is less than -302400 seconds, 604800 seconds must be added to t_k.

ANNEX C: PROCEDURE TO DETERMINE THE SIS STATUS

In order to determine the Status of a specific SIS broadcast by a Galileo satellite, the user will have to ensure that the navigation message has been properly received, i.e. that it successfully passes the CRC check.

The first condition to be fulfilled by the navigation message in order for the user to proceed with the determination of the SIS Status is that it cannot be a dummy message. If it is a dummy message the respective SIS must be considered Unhealthy.

If the message is not dummy, the user can proceed with checking the other conditions to determine the SIS Status as specified in Table 2, where the mapping between the values of the SIS Status Flags and the three values of the SIS Status is provided. The order in which the flags are checked by a receiver on a not dummy navigation message is arbitrary and up to the manufacturer. The value of each flag can be read (and taken into account) independently from the value of the other flags. Note also that the value of SIS Status flags applies to the whole subframe they belong to. As an example, the DVS flag in the I/NAV message is located in Word Type 5 but its value is applicable also to the content of the Word Type 1, 2, 3 and 4.

An example of a possible decision tree for the determination of the SIS Status is provided in Figure 1.

SIS STATUS	DUMMY MESSAGE	SIS FLAGS		
		SHS	DVS	SISA
Healthy	No	OK	NDV	not NAPA
Unhealthy	No	Out of Service	Any Value	Any Value
	No	In Test	Any Value	Any Value
	Yes	N/A	N/A	N/A
Marginal	No	Ok	WWG	Any Value
	No	Ok	Any Value	NAPA
	No	Will be out of Service	Any Value	Any Value

Table 2. Galileo Open Service SIS Status vs SIS Status flags

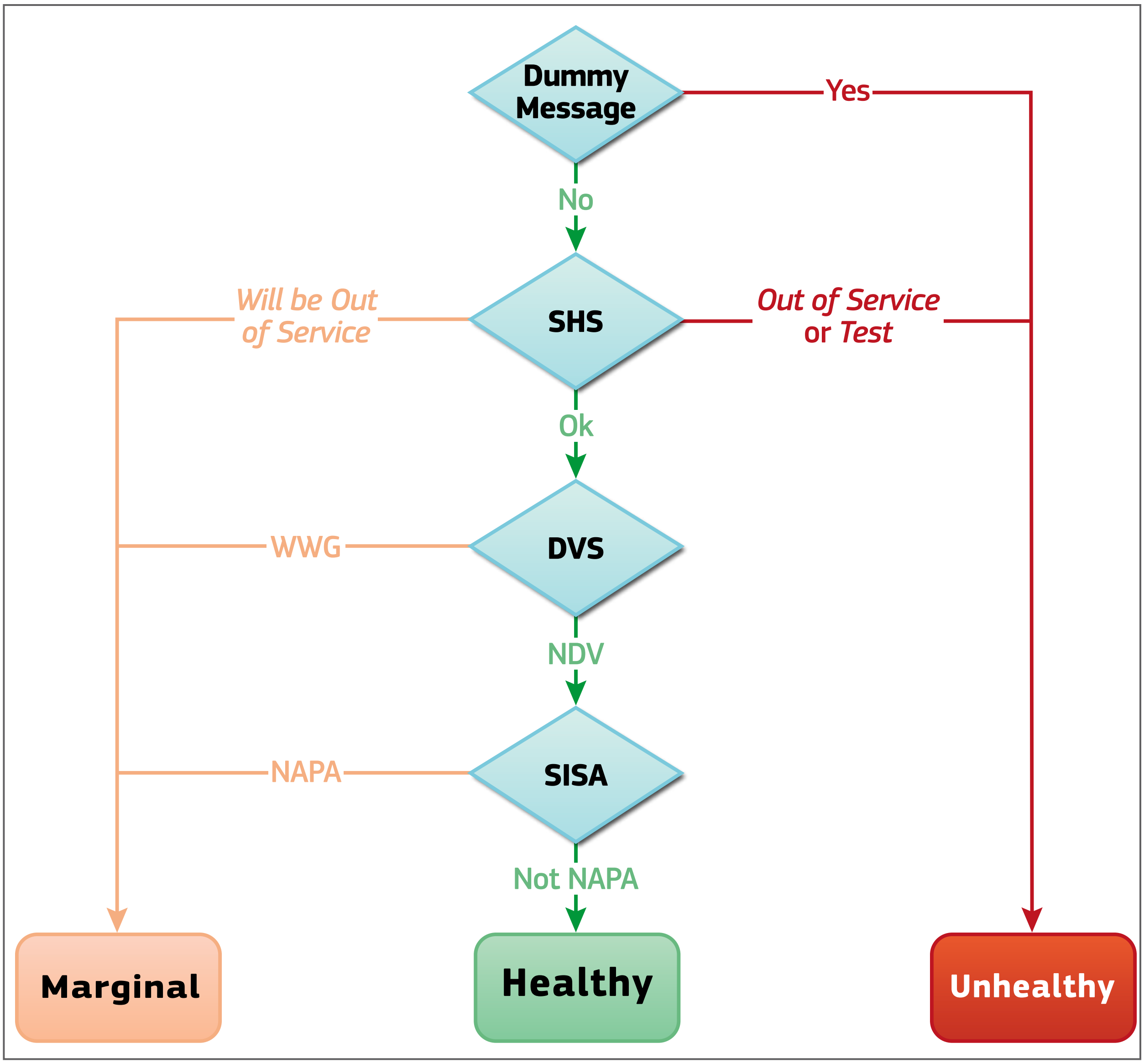

Figure 1. Example of a decision tree for the determination of the SIS Status

ANNEX D:
DIRECT ANSWERS TO USER QUESTIONS

Users who participated in the Public Consultation on the OS SIS OSD will find most of their questions answered in the core of this document and reflected in the future release of the OS SIS OSD. Those questions not answered there are answered separately in this Annex. They have not been included in the main document since they have not resulted in any change to the OSD document.

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1. *Question:*

The current three "SIS Status" values could be substituted by the four following values:

- *Healthy:* *unchanged*
- *Don't use:* *is clearer than "Unhealthy"*
- *Outdated:* *used to indicate that the navigation message is outdated*
- *Critical:* *used to indicate that the service might be discontinued and that its continuity is thus at risk*

1. Answer:

This proposed set of status values would certainly allow the user to have more insight of the status of the message, but it would add more complexity and it does not match the current SIS flags management concept, nor the ability of the system itself to clearly identify all these states.

Healthy and Unhealthy are the two extreme cases, equivalent to Use and Don't Use, respectively. The Marginal state is a transition state not fully known by the system, triggered mainly by automatic functions through DVS=WWG and SISA=NAPA.

---

2. *Question:*

The DVS flag is set by the satellite if an uplink was unsuccessful. In this case, the satellite may continue transmitting its old navigation message. [...] If this interpretation is correct, the flag could be virtually disabled by the "SIS-ICD Operational Status Definition." Currently this mechanism seems not to have been implemented correctly and thus this option may be a quick work around. In this case, the bits associated with that flag should be marked "reserved."

2. Answer:

The DVS can be triggered in two ways:

i) As an expiration timer from the last navigation message uplinked to the satellite.

ii) Triggered on-board by the satellite in case of certain anomalies.

Therefore it is also an important automatic alerting feature of the system at satellite level (SISA and SHS can only be set on-ground).

The value of DVS expiration timer is set by the system to ensure the service performance.

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3. *Question:*

If we provide Table 5, there should also be an entry "Triple Frequency".

3. Answer:

A triple frequency service is currently not contemplated. Should it be recognised that such a possibility has to be suggested to users by a Galileo public document, then it may be properly addressed in future versions of the OS-SDD.

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4. *Question:*

It might be useful to add that the dual frequency service E1/E5 is currently not supported.

4. Answer:

A dual frequency E1/E5 service is currently not contemplated and has never been mentioned in any Galileo Programme public document, therefore it is not considered necessary to specify that it is not supported.

5. Question:

The user suggests to replace the paragraph "Navigation Parameter and Issue of Data" with a different text suggested.

5. Answer:

The reformulation proposed for the chapter is considered somewhat too complex to be used in the frame of the OS SIS OSD. Moreover, as this chapter specifically concerns the IOD, the suggested mention here of the DVS and SISA may be unclear.

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6. Question:

Clarify how end-users wanting to use the AltBOC E5 signal as a whole should interpret the SIS statuses (question possibly out of scope for the OS?)

6. Answer:

This is out of the scope of the OSD since no service is defined using AltBOC, so far.

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7. Question:

The section on iono correction is not understood with respect to the scope of the document. Does it mean that DVS covers the validity of NeQuick *G correction parameters?*

7. Answer:

The reason for including this section, is to simply provide the reference to the Iono document.

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8. Question:

What is the repetition interval of the IOD values?

8. Answer:

This information, relevant for SoL users, will be provided in the future, in view of the FOC phase.

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