3GPP TSG-RAN WG2 Meeting #117 ***R2-220xxxx***

Electronic Meeting, February 21 – March 3, 2022

**Agenda item:** 8.11.1

**Source:** ESA

**Title:** [Pre117-e][610][POS] Open issues on GNSS positioning integrity (ESA)

**Document for:**  Discussion

# 1. Introduction

The following email discussion has been triggered after RAN2#116bis-e:

**[Pre117-e][610][POS] Open issues on GNSS positioning integrity (ESA)**

The discussion below is mainly based on the open issues provided by the following contributions:

* R2-2201722 Summary of [Post116bis-e][628][POS] 37.355 running CR (Qualcomm)
* R2-2202005 Report of email discussion [Post116bis-e][634][POS] Positioning open issues list (Intel)
* R2-2201765 GNSS integrity – Extended Discussion (Stage 3) (Swift Navigation)

# 2. Contact Information

|  |  |
| --- | --- |
| Company | Contact: Name (E-mail) |
| ESA | Florin-catalin.grec@esa.int |
| Swift Navigation | grant@swiftnav.com |
| Huawei, HiSIlicon | yinghaoguo@huawei.com |
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# 3. Open issues

## 3.1 Summary Open Issues

- The below issues have been extracted from the R2-2202005 after cross-checking their status with R2-2201722 and R2-2201765.

- As a reminder, an open issue is an issue critical to the completion of the WI as marked in the R2-2202005.

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| **Topic** | **Open issues****Note:** Open Issues should be defined for aspects that need to be closed, important to make already agreed functionality work in a reasonable way. Not yet agreed optimizations that may not be needed shall not be listed as Open Issues. | **Related to the completion of WI?** **The topic has to be removed from Rel-17 scope if the corresponding open issues cannot be resolved.**  | **Remark** |
| **Stage 3 details** | #1. RAN2 to discuss whether to modify the existing GNSS-RealTimeIntegrity IE or create a new IE to accommodate the Alerts for the satellite/constellation specific DNUs under GNSS-GenericAssistData. Discuss whether a Constellation DNU and per-signal DNU should be included in addition to the SV DNU. | Yes | **Status:** Discussion in R2-2201765. check the status of LPP email discussion 116bis-628 |
| #2. RAN2 to discuss whether or not the cross-covariance should be included for the Orbit and Clock integrity bounds and whether these bounds should be included as a new IE or within the existing SSR Orbit and Clock IEs. | Yes | **Status:** Discussion in R2-2201765. check the status of LPP email discussion 116bis-628 |
| #3. RAN2 to discuss whether the Residual Risk parameters proposed in Table 3.2-2 (R2-2201765) should be integrated into their corresponding SSR correction IEs or within a separate standalone IE. | Yes | **Status:** Discussion in R2-2201765. check the status of LPP email discussion 116bis-628 |
| #4: RAN2 to discuss whether a validity period needs to be defined for each of the bounds and what value ranges are appropriate if so. | Yes | **Status:** Discussion in R2-2201765. check the status of LPP email discussion 116bis-628 |
| #5: RAN2 to discuss which of the assistance data should be sent as periodic assistance data. | Yes | **Status:** Discussion in R2-2201765. check the status of LPP email discussion 116bis-628 |
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# 4. Open issues discussion

## 4.1 Open Issue 1: Update *GNSS-RealTimeIntegrity* or a new IE for DNU flag

R2-2201765 (ED 116bis-611) includes a first discussion on the need to add a new IE to accommodate the alerts for the satellite/constellation specific DNUs under GNSS-GenericAssistData. The possibility to reuse the existing *GNSS-RealTimeIntegrity* IE has been touched on as well in the past.

We also note that RAN2 already agreed that assistance data in GNSS-RealTimeIntegrity can be reused for GNSS integrity in R17.

Agreement captured in R2-2201722 116bis-628

Proposal2-11: The assistance data in GNSS-RealTimeIntegrity can be reused for GNSS integrity in R17

For completion, the GNSS-RealTimeIntegrity is copied below:

#### *GNSS-RealTimeIntegrity*

The IE *GNSS-RealTimeIntegrity* is used by the location server to provide parameters that describe the real-time status of the GNSS constellations. *GNSS-RealTimeIntegrity* data communicates the health of the GNSS signals to the mobile in real‑time.

The location server shall always transmit the *GNSS-RealTimeIntegrity* with the current list of unhealthy signals (i.e., not only for signals/SVs currently visible at the reference location), for any GNSS positioning attempt and whenever GNSS assistance data are sent. If the number of bad signals is zero, then the *GNSS-RealTimeIntegrity* IE shall be omitted.

-- ASN1START

GNSS-RealTimeIntegrity ::= SEQUENCE {

 gnss-BadSignalList GNSS-BadSignalList,

 ...

}

GNSS-BadSignalList ::= SEQUENCE (SIZE(1..64)) OF BadSignalElement

BadSignalElement ::= SEQUENCE {

 badSVID SV-ID,

 badSignalID GNSS-SignalIDs OPTIONAL, -- Need OP

 ...

}

-- ASN1STOP

| *GNSS-RealTimeIntegrity* field descriptions |
| --- |
| ***gnss-BadSignalList***This field specifies a list of satellites with bad signal or signals.  |
| ***badSVID***This field specifies the GNSS *SV‑ID* of the satellite with bad signal or signals. |
| ***badSignalID***This field identifies the bad signal or signals of a satellite. This is represented by a bit string in *GNSS-SignalIDs*, with a one‑value at a bit position means the particular GNSS signal type of the SV is unhealthy; a zero‑value means healthy. Absence of this field means that all signals on the specific SV are bad.  |

**Q1: Do you agree that GNSS-RealTimeIntegrity can be used as it already mentions the unhealthy satellites (therefore, implicitly, also the constellation) and the bad signals? If not, please clarify what the new IE would achieve that GNSS-RealTimeIntegrity cannot.**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA | Y |  | We think this IE represents a good structure for achieving the signalling of unhealthy satellites and even signals. Extension of this IE, if needed, seems more appropriate than duplication. |
| Swift Navigation |  | N | For Integrity, the DNU concept has a specific meaning and RAN2 already supports the DNU concept in Stage 2 and Stage 3 (e.g. *GNSS-Integrity-ServiceAlert*).If we reuse *GNSS-RealTimeIntegrity* IE we may need to rename the fields with the DNU terminology, which can lead to issues of backward compatibility for existing implementations which do not support R17 integrity functionality. This is why in R2-2201214 we propose to include the *GNSS-Integrity-ConstellationAlert* IE as a standalone message (copied below for reference) to specifically address the functionality of R17:*– GNSS-Integrity-ConstellationAlert*The IE *GNSS-Integrity-ConstellationAlert* is used by the location server to indicate whether the GNSS constellation can be used for integrity related applications.-- ASN1STARTGNSS-Integrity-ConstellationAlert-r17 ::= SEQUENCE { constellationDoNotUse-r17 BOOLEAN, integrity-svAlertList-r17 Integrity-SVAlertList-r17, ...}Integrity-SVAlertList-r17 ::= SEQUENCE (SIZE(1..64)) OF Integrity-SVAlertElement-r17Integrity-SVAlertElement-r17 ::= SEQUENCE { svID-r17 SV-ID,  svDoNotUse-r17 BOOLEAN, ...}-- ASN1STOP

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| ***GNSS-Integrity-ConstellationAlert* field descriptions** |
| ***constellationDoNotUse***This field specifies the Constellation DNU Flag which indicates whether the GNSS constellation can be used for integrity related applications (FALSE) or not (TRUE). |
| ***svID***This field specifies the satellite for which *svDoNotUse* applies to. |
| ***svDoNotUse***This field specifies the SV DNU Flag which indicates whether the satellite can be used for integrity related applications (FALSE) or not (TRUE). |

Alternatively we could supplement the documentation/description of the *GNSS-RealTimeIntegrity* to clarify that this content can be interpreted as DNU flags for the purpose of integrity. But we think this adds unnecessary complexity and it’s preferable to add a self-contained Alert IE (as above) rather than conflating it with *GNSS-RealTimeIntegrity* (which is a more generic form of integrity compared to the Principle of Operation described in Stage 2). Furthermore, if existing implementations already implement the *GNSS-RealTimeIntegrity* IE, they may not guarantee to satisfy the Principle of Operation summarised by Equation 8.1.1a-1 in Stage 2. |
| Huawei, HiSilicon |  |  | No strong view. Both solutions by swift and ESA can work. But if a self-contained alert as shown by swift is introduced, it should be clarified that the indication of DNU should be aligned with that in GNSS-RealTimeIntegrity. |
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**Q2: Do you agree that a Constellation DNU needs included, in addition to SV DNU?**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA |  | N | In *GNSS-RealTimeIntegrity* constellation is not needed as badSVID can achieve that feature. |
| Swift Navigation | Y |  | The reason we include the Satellite Vehicle (SV) and Constellation DNUs is to simplify the Alert if the entire constellation is impacted (rather than needing to Alert on each satellite individually). If we only flag the satellite, how do we ensure that all satellites have been accounted for as part of the constellation, i.e. how do we ensure that no satellites are omitted from the list (e.g. if a new satellite is added to the system and the Network software has not yet been updated with this information, but the user software is using the satellite).  |
| Huawei, HiSilicon |  |  | Constellation DNU can save signalling overhead than signalling DNU individually |
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**Q3: Do you agree that a signal DNU needs to be included, in addition to SV DNU?**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA |  | N | In *GNSS-RealTimeIntegrity* constellation already includes this field. Of course, if RAN2 decides to define a new IE instead of using GNSS-RealTimeIntegrity than signal DNU should also be included. |
| Swift Navigation |  |  | We are fine to add a signal DNU within the proposed *GNSS-Integrity-ConstellationAlert* but we don’t think the additional granularity is needed (e.g. we are not aware of a case where there is an issue with one signal but you would want to continue using other signals from the same satellite). |

## 4.2 Open Issue 2: Cross-covariance and inclusion of integrity bounds for Clock and Orbit in a new or existing IEs.

From pervious discussion it was not clear why these parameters, for the Orbit and Clock integrity bounds, lead to improved performance in accordance with the principle of operation. There was no strong preference expressed for including these parameters therefore more discussions were recommended.

**Q4: Do you agree that the cross-covariance terms should be included for the Orbit and Clock integrity bounds? Please clarify the reason for your choice.**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA |  | Not yet | We think mean and variance are enough. Sending also the cross-covariance is increasing the size of the information to be signalled and its need/criticality is not stated until now. |
| Swift Navigation | Y |  | Based on the questions raised in prior discussions we think this topic warrants an extended explanation to highlight why this message is directly equivalent to the MT28 message already standardised for SBAS (which was added to achieve necessary performance and is considered state-of-the-art).**Background*** For paired overbounding we derive a mean and standard deviation to bound the error distribution. For the SSR Orbit Corrections, these are further decomposed into their radial, along-track and cross-track components/axes, and for integrity the error covariances between each axis must be considered. This is why, for example, the MT28 message (described below) was developed to model these covariances as they occur for SBAS services.
* By sending the full covariance a user has more information available to model all error sources with greater precision, thereby reducing the magnitude of these errors when the errors are projected along the satellite line-of-sight using SSR methods. If only the mean and standard deviation are used, we must be conservative and overinflate the distribution to protect against errors which have not been modelled explicitly (i.e. the covariances), which in turn will inflate the Protection Level.

**Comparison to SBAS Message Type 28 (MT28)*** The cross-covariance message in R2-2201214 is based on SBAS Message Type 28 (Clock-Ephemeris Covariance Matrix) from the GPS MOPS (A.4.4.16) [1]. The matrix shape and parametrisation are equivalent to MT28, including only sending 10 values given the matrix is symmetrical. For further context, a brief introduction to MT28 is available on the [ESA Navipedia](https://gssc.esa.int/navipedia/index.php/The_EGNOS_SBAS_Message_Format_Explained#Message_type_28) website.
* The main differences to MT28 are that in 3GPP we need higher resolution in the message contents because we are bounding the precise SSR orbit corrections rather than the satellite’s native ephemeris, which is much lower in accuracy, i.e. we need to satisfy Alert Limits down to 1m in 3GPP (using SSR) rather than 40m (at best) using SBAS. These requirements are why we also use a smaller scale factor (0.004) as part of the value range, to mitigate potential quantization errors that would otherwise impact the size of the bound (e.g. as described in [2]).
* Also, a recent [performance analysis](https://satellite-navigation.springeropen.com/articles/10.1186/s43020-021-00045-z) from using MT28 with GPS + BDS corrections across China provides a useful demonstration of applying this message in a dual-frequency, multi-constellation SBAS context.
* We suggest [2][3][4] for further technical background and performance assessments relating to MT28 and for deriving covariances [5]:
1. DO-229D, RTCA, "RTCA DO-229D Minimum Operational Performance Standards for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment," 2013.
2. Walter, T., Hansen, A., Enge, P. (2001) “**Message Type 28**,” Proceedings of the 2001 National Technical Meeting of The Institute of Navigation, Long Beach, CA, January 2001, pp. 522-532, < <https://www.researchgate.net/publication/242405363_Message_Type_28>>.
3. Blanch, J., Walter, T., Enge, P., Stern, A., Altshuler, E. (2014) "**Evaluation of a Covariance-based Clock and Ephemeris Error Bounding Algorithm for SBAS**," Proceedings of the 27th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2014), Tampa, Florida, September 2014, pp. 3270-3276, <<https://web.stanford.edu/group/scpnt/gpslab/pubs/papers/Blanch_IONGNSS_2014_covUDRE_paper.pdf>>.
4. Authié, T., Trilles, S., Fort, J-C, Azaïs, J-M. (2017) "**Integrity Based on MT28 for EGNOS: New Algorithm Formulation & Results**," Proceedings of the 30th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2017), Portland, Oregon, September 2017, pp. 1077-1088, < <https://hal.archives-ouvertes.fr/hal-01646740/document>>.
5. Yu, S., Kim, D., Song, J., Kee, C. (2021), “**Covariance Analysis of Real-Time Precise GPS Orbit Estimated from Double-Differenced Carrier Phase Observations**,” Remote Sensing. 2019; 11(19):2271, <<https://doi.org/10.3390/rs11192271>>.

To summarise, although there is some additional bandwidth required (and possibly a new IE), it is already demonstrated by existing standards that the covariance parameters are needed to improve user integrity performance. |
| Huawei, HiSilicon |  | N | According to the backgrounds provided by Swift, the covariance parameters can be considered as an optimization for improving user integrity performance. We think the agreed mean and variance parameters already work well for Rel-17. |
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**Q5: Do you agree that the integrity bounds should be included as a new IE or within the existing SSR Orbit and Clock IEs? Please clarify the reason for your choice.**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA | Y |  | We would like to include these parameters in existing IEs in order to minimize the number of new IEs. |
| Swift Navigation |  |  | We’re unclear which option corresponds to Y or N, but regardless our preference is for a new IE because we think it is the most efficient method when including the full covariance. If, however, we decide to combine with the existing IEs, we agree with the option suggested by Qualcomm in R2-2201761 which is to duplicate the content but let the Network decide which IE to send it in. |
| Huawei, HiSilicon |  | Y | Even if the co-variance is needed, it still can be included by extending the existing SSR orbit and clock IEs |
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## 4.3 Open Issue 3: Residual Risk parameters

RAN2 to discuss whether the Residual Risk parameters proposed in R2-2201765 should be integrated into their corresponding SSR correction IEs or within a separate standalone IE. These parameters are used to provide the residual risk parameters related to the satellite, constellation, ionosphere, and troposphere residual risk probabilities.

We first recall past agreements relevant to this point:

Proposal 5: RAN2 agrees to include the Integrity Residual Risk Parameters into their existing corresponding GNSS IEs (as per Appendix A (R2-2201761). This discussion is also subject to the Stage 3 outcomes regarding which Ies and associated fields to define for integrity.

The corresponding mapping between the Stage 2 and Stage 3 fields is shown in Table 3.2-2 extracted from R2-2201765. RAN2 has all agreed to add Mean Fault Duration parameters (in green).

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|  | **Stage 2 Fields (Table 8.1.2.1b-1)** | **Stage 3 Parameters (R2-2201214)** |
| **Integrity Residual Risk Parameters** | ***GNSS-Integrity-OrbitClockErrorBounds*** |
| Block 1 | Probably of Onset of Constellation Fault | *pConstellation* |
| Mean Constellation Fault Duration | *tConstellation* |
| Probability of Onset of Satellite Fault | *pSatellite* |
| Mean Satellite Fault Duration | *tSatellite* |
|  |  | ***GNSS-SSR-STEC-Correction*** |
| Block 2 | Probability of Onset of Ionosphere Fault | *pIonosphere* |
| Mean Ionosphere Fault Duration | *tIonosphere* |
|  | ***GNSS-SSR-GriddedCorrection*** |
| Probability of Onset of Troposphere Fault | *pTroposphere* |
| Mean Troposphere Fault Duration | *tTroposphere* |

 **Table 3.2-2: Mapping between the Stage 2 and Stage 3 field descriptions for the Residual Risks.**

In previous discussions several companies have expressed their preference to keep satellite parameters in *GNSS-SSR-OrbitCorrections* IE and clock parameters in *GNSS-SSR-ClockCorrections* IE which raises objection to creation of the a new *GNSS-Integrity-OrbitClockErrorBounds* IE.

To make things simpler, we believe it would be easier to advance by splitting the table from above in two distinct blocks.

**Q6: Do you agree with the mapping from Stage 2 to Stage 3 in Table 3.2-2 for Block 1 parameters, and that these new parameters should be included in the corresponding IEs? Please detail your understanding.**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA |  | Not yet | We think the new parameters in Block 1 should be included in the corresponding IEs as suggested by an old agreement we have (recalled in the beginning of this section). Furthermore, we think the resolution of this point depends on Open Issue 2.We understand the static nature of these parameters but we do not see any fundamental problem in repeating (unchanged) values at the rate of the GNSS-SSR-OrbitCorrections and GNSS-SSR-ClockCorrections. |
| Swift Navigation | Y |  | Consistent with Q5, our preference is for a new IE, but we are also ok to include in the existing IEs if the group thinks this is better. |
| Huawei, HiSilicon |  |  | See reply to Q5 |
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**Q7: Do you agree with the mapping from Stage 2 to Stage 3 in Table 3.2-2 for Block 2 parameters, and that these new parameters should be included in the corresponding IEs? Please detail your understanding.**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA | Y |  | We think the new parameters in Block 2 should be included in the proposed IEs. |
| Swift Navigation | Y |  | As proposed already (R2-2201723). |
| Huawei, HiSIlicon | Y |  | This has already been captured in the current LPP CR, isn’t it? |
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## 4.4 Open Issue 4: Validity period for each error bound and value ranges

In R2-2201214 there are certain common parameters proposed to accompany the bounds parameters to indicate validity and applicability of the bound.

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| ***validityPeriodSeconds***This field specifies the Validity Duration in seconds. The integrity values are only valid for the time interval from *epochTime* to *epochTime* + *validityPeriod*.Scale factor 1 s; range 1-86,400 s. |
| ***validityPeriodDays***This field specifies the Validity Duration in days. The integrity values are only valid for the time interval from *epochTime* to *epochTime* + *validityPeriod*. A day is defined to be 86,400 seconds.Scale factor 1 day; range 1-365 days.  |

From past discussions two main options emerged:

* Option 1 – add two new parameters to denote the validity of the new integrity assistance data: ValidityPeriodSeconds and validityPeriodDays
* Option 2 – no need for an validity time as bounds are now included directly in the SSR assistance data

The bounds are valid until new data are received. If something happens between updates, we have the DNU flags. Therefore, the need for a validity time is unclear.

**Q8: Please express your preference for one of the two opinions and motivate your choice.**

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| **Company** | **OP1** | **OP2** | **Comments** |
| ESA |  | X | We think option 2 is enough and validity of bounds lasts until new data is received. |
| Swift Navigation | Y |  | Several conditions for integrity validity and applicability were summarised in the last email discussion (R2-2201765). The most important requirement is to ensure that at future times (i.e. after the bounds are issued) the user is able to determine whether the bounds are still valid. To elaborate:* The Alerts are used to indicate that the bounds are still valid. If there is no Alert (i.e. all corresponding DNU flags are false) then the bound is still valid.
* However, the network does not know necessarily which users have received which bounds, therefore when it issues an Alert message it must verify that all the bounds that were previously issued are still valid.
* To make this practical, the bounds should have a validity period such that they expire and the network only needs to check that all bounds that are still within their validity period are still valid.
* To meet these requirements, it is sufficient to have a validity period on each set of bounds (unless the equivalent functionality already exists in LPP?) to ensure that the integrity system can fail safely.

To be more explicit, as stated above the challenge is if “the bounds are valid until new data are received” and we do not know when the client has received the data (due to loss of connectivity), without a validity period it is never safe to clear the DNU flag, as any user regaining connectivity after an outage may be using stale data. The solution is to bound the maximum validity period and then keep the DNU asserted until the validity period expires. |
| Huawei, HiSilicon | Y |  |  |
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Another delegate raised the need for validityPeriodDays. Therefore,

**Q9: If you replied with OP1 at Q8, please clarify what validity parameters should we add.**

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| **Company** | **validityPeriodSeconds** | **validityPeriodDays** | **both** | **Comments** |
| Swift Navigation | Y |  | optional | The days field gives some flexibility but practically speaking we don’t see a need for a validity period greater than 24 hours |
| Huawei, HiSilicon |  |  | Optional  | We are ok with both granularities if there are applicable use cases. |
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## 4.5 Open Issue 5: Periodic Assistance data for GNSS integrity

It was acknowledged the need to discuss which of the assistance data should be sent as periodic assistance data. This procedure enables a target to request a server to send assistance data periodically. In Rel-16 37.355 specifications, periodic assistance data transfer is supported for HA GNSS (e.g., RTK) positioning only.

**Q10: Do you agree that periodic assistance data for GNSS integrity is needed?**

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| **Company** | **Yes** | **No** | **Comments** |
| ESA | Y |  | Essentially, GNSS integrity feature is an extension of the SSR feature and therefore we find naturally to include GNSS integrity assistance data in the list with Periodic Assistance Data |
| Swift Navigation | Y |  | This is a natural extension of the SSR periodic assistance data.  |
| Huawei, HiSilicon | Y |  | Aligned with the existing GNSS assistance data. |
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**Q11: Which assistance data should be sent as periodic assistance data?**

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| **Company** | **Comments** |
| ESA | We think new IEs for GNSS integrity need to be provided also periodic, same as it was the case for RTK and SSR features. However, we think that a more clear picture will emerge once we clarify the points from above as they impact Stage 3 and final list of new IEs needed in support of GNSS integrity.  |
| Swift Navigation | The integrity AD included in existing IEs will already be sent periodically within the periodic IEs, e.g.:gnss-SSR-PeriodicCodeBias-r15 gnss-SSR-PeriodicPhaseBias-r16gnss-SSR-PeriodicSTEC-Correction-r16gnss-SSR-PeriodicGriddedCorrection-r16For the Common Alerts, we support the new periodic IE proposed in R2-2201723:gnss-Integrity-PeriodicServiceAlert-r17Subject to Q1 and Q5, a new periodic IE would also be needed for the Constellation Alerts (Q1) and orbit/clock bounds (Q5), e.g. (R2-2201214):gnss-Integrity-PeriodicConstellationAlert-r17gnss-Integrity-PeriodicOrbitClockErrorBounds-r17Regarding the *GNSS-Integrity-ServiceParameters* (R2-2201723), these are typically static and there’s no need to send periodically. |
| Huawei, HiSilicon | All the new IEs introduced for integrity |
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