**3GPP TSG RAN WG2 Meeting #116-e R2-21xxxxx**

**Electronic meeting, 1st – 12th Nov, 2021**

**Source: Huawei, HiSilicon**

**Title: [Post115-e][607][POS] Integrity assistance data (Huawei)**

**Agenda item: 8.11.5**

**Document for:** **Discussion and Decision**

# Introduction

The following email discussion has been planned during RAN2#115 for the issues with integrity assistance data.

* [Post115-e][607][POS] Integrity assistance data (Huawei)

 Scope: Discuss the supported assistance data for UE-based integrity determination, considering at least the following candidates that were proposed to RAN2#115-e:

* Quality indicators (standard deviation or variance) of the GNSS error sources
* Mean values of the GNSS error sources
* Information describing the time variation of the GNSS error sources
* Probability of satellite fault
* Probability of constellation fault
* “Do Not Use” assistance data alerts
* “Do Not Use” SV and/or GNSS constellation alerts

Assistance data can be considered in relation to the following categories of feared events from the TR:

* Feared events in the GNSS Assistance Data (category 1)
* GNSS feared events (category 3)
* LMF feared events (category 5)

 Intended outcome: Report to next meeting

 Deadline: Long

This questionnaire intends to handle the issues defined within the scope of the email discussion.

# Contact Information

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| Swift Navigation | Grant Hausler (grant@swiftnav.com) |
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# Discussion Phase I

In the phase I of the email discussion, we will handle the following issues regarding the integrity assistance data:

* Error bounding techniques
* State space representation vs Observation space representation
* Identify the set of possible integrity assistance data for the 3 categories of feared events
* Identify the set of possible integrity assistance data for GNSS integrity service

Error bounding techniques

[6] has discussed on limitations with the zero-mean assumption for bounding the error distribution and proposed an alternative method of “paired overbounding”, which consists of bounding the true distribution by two non-zero mean Gaussians, shifted by $-μ$ and $+μ$. In [3], it has also been mentioned that the error bound should at least include the variance/standard deviation of error sources. In [4], deviation has been proposed for bounding the error sources for satellite orbit, clock, bias, ionosphere, and troposphere.

The main difference between [6] and [3][4] is that [6] propose to add mean values of the error in the assistance data to further bound the error. Thus, companies are invited to answer the following question:

###### Question1-1: Do companies agree that we should adopt the “paired overbounding” technique for bounding the probability distribution of the errors for GNSS integrity?

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| **Company** | **Yes/No** | **Comments** |
| Swift Navigation | Yes | Paired overbounding enables tighter bounding of the error distributions (to better reflect their real-world error properties), leading to smaller PLs. The paired overbounding method in [5] is also compatible with the proposals in [3] and [4] given the mean (µ) can be set to zero if the provider only chooses to report the sigma (σ). Hence, paired overbounding leads to greater flexibility in the choice of implementation by sending both µ and σ in the assistance data. |
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###### Question1-1 Summary:

TBD

## Representation of error sources

Positioning errors can be represented in the following different ways as introduced in different releases in 3GPP

* Observation state representation (OSR) in R15, e.g., RTK
* State space representation (SSR) in R16, e.g., PPP and PPP-RTK.

The main difference between OSR and SSR is that SSR has independent characterization of each error source while OSR aggregates all the error sources.

In [6], it has been pointed out that SSR has the following advantages:

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| * Alignment with the SSR representation of errors.
* SSR representation can be converted to OSR but not vice versa, therefore SSR is more general.
* Better integrity KPIs, from tighter bounding of the error distribution (see ‘error overbounding’ above).
* OSR representation is specific to a single user location whereas SSR representation can cover any number of users within a geographic area, leading to much enhanced scalability.
* As OSR uses an aggregate of all errors, a single feared event will make integrity unavailable. With SSR individual components are sent separately so if one component is impacted by a feared event, the other components may still be used to allow for graceful degradation.
 |

During RAN2#115e, the following agreement has been achieved for the supported GNSS methods for GNSS integrity:

Agreements:

Proposal 1: Agree that the GNSS feared events will be addressed in the WI.

Proposal 2 (modified): Agree that all for A-GNSS positioning methods, positioning integrity determination is supported in LPP.

Proposal 3: Agree that additional IEs are needed in LPP to support A-GNSS positioning integrity determination.

Proposal 4: The specific algorithms used for positioning integrity shall be up to implementation.

Proposal 5: For interoperability, the use of “hard-coded” parameters should be minimized and instead the needed parameters should be sent explicitly in the assistance data.

Proposal 6: RAN2 agrees that the PL will be reported in the Integrity Results. It is FFS whether Mode 2 and the TIR, AL, TTA that were used in the integrity calculation will also be reported in the integrity results.

Proposal 8: Agree that the UE feared events will be handled in the implementation for UE-based (network-assisted) methods of positioning integrity determination.

Proposal 10: Agree that the LMF feared events can be handled via implementation for the UE-based (network-assisted) and UE-assisted (LMF-based) methods of positioning integrity determination.

Proposal 11: RAN2 agrees to use Common Positioning IEs to transfer the KPIs and Integrity Results.

Proposal 12: RAN2 agrees that the LPP procedures can be used to transfer the KPIs and Integrity Results. For UE-assisted, the LCS procedures remain FFS in the case of MO-LR.

While in the summary for GNSS integrity in RAN2#115 [2], it has also been argued by the feature lead that we should not do prioritization between SSR and OSR since the objective defined in the WID is to support GNSS integrity for all the GNSS positioning methods up to now, a.k.a. all the GNSS positioning methods since R9.

While based on the understanding from the rapporteur, the intention from [6] is not to deprioritize OSR and prioritize SSR. It is argued in [6] that the assistance data for SSR is a superset of OSR, that if we support the error representation with SSR for GNSS integrity, the GNSS integrity for OSR is naturally supported.

Based on the above, companies are invited to answer the following question regarding the error representation of OSR and SSR for GNSS integrity.

###### Question1-2: What additional assistance data are needed for the feared event whose error source is represented by OSR and please provide the corresponding TP (including the field by ASN.1 and field description)?

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| **Company** | **Comments** |
| Swift Navigation | None – SSR representation of integrity supports all the positioning methods including RTK/OSR.Note however that the converse is not true, OSR representation would not satisfy the PPP-RTK and PPP positioning methods (i.e. SSR methods). |
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###### Question1-2 Summary:

TBD

In [7], it has been mentioned that in terms of SSR, the current spec already has basic support for GNSS integrity with the URA, specifically

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| * SSR Orbit corrections are provided as radial, along track and cross track corrections, with an optional velocity component in each of these dimensions. Corresponding uncertainty extensions per field is a natural extension
* SSR clock corrections are provided as a parameterized polynomial where an uncertainty per parameter is natural, but also an uncertainty representing the correction as a whole
* SSR code bias and phase bias are naturally extended with an uncertainty per field
* SSR atmospheric delay models already come with quality indicators for the STEC and gridded corrections
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In [3], it has also been mentioned that current LPP already has basic system-level and user-level support for GNSS integrity

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| ***3GPP: Is there already a solution in LPP?***Yes, the *GNSS-RealTimeIntegrity* IE. This is the most basic form of integrity capability.***3GPP: Is there already a solution in LPP?***Yes, the *navURA* fields and *GNSS-SSR-URA* IE. |

Furthermore, in the TR [1] during the study item phase, we have defined integrity KPI for the key use cases of automotive, tail, and IIoT as follows:

Table 9.2.4: KPI examples for the Automotive, Rail and IIoT use cases [34][35][36][37].

NOTE: KPIs are defined by the service provider implementation.

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| **AUTOMOTIVE EXAMPLES** |
| **APPLICATION CATEGORIES** | **TIR** | **AL** | **TTA** | **Integrity Availability** |
| **Safety-Critical Applications**- Warnings (red light, obstacle, queue, curve speed, blind spot lane change, pedestrians etc)- Automated Driving (lane-level or better)- Emergency Brake Assist- Forward Collision Avoidance | Typical range: ≥10-8/hr to ≤10-6/hr | Typical range: ≥1.5m to <5m | Typically ranges from 100s of milliseconds to <10 seconds | Typically ranges from 95% to 99.9% or greater |
| **Payment Critical Applications**- Road User Charging (RUC)- Pay Per Use Insurance- Taxi Meter- Parking Fee Calculation | Typical range: ≥10-6/hr to ≤10-4/hr | Typical range: ≥1.5m to <25m | Typically ranges from 95% to 99.9% or greater |
| **Smart Mobility** - Freight and Fleet Management- Cargo/Asset Management- Vehicle Access/Clearance- Emergency Vehicle Priority- Speed Limit Information- In-Vehicle Signage- Reduce Speed Warning- Dynamic Ride Sharing |
| **RAIL EXAMPLES** |
| **APPLICATION CATEGORIES** | **TIR** | **AL** | **TTA** | **Integrity Availability** |
| **Safety-Critical Applications** - Absolute Positioning- Train Awakening- Cold Movement Detector- Track Identification- Level Crossing Protection- Train Integrity and Train Length Monitoring | Typical range: ≥10-9/hr to ≤10-8/hr | Typical range: ≥2.5m to <25m | Typically <7s | Typically ranges from 95% to 99.9% or greater |
| **Liability-Critical Applications** - Trackside Personal Protection- Management of Emergencies- Train Warning Systems- Infrastructure Charging- Hazardous Cargo Monitoring- On-Board Train Monitoring and Recording Unit- Traffic Management Systems | TBD | Typical range: ≥25m to <62.5m | Typically ranges from seconds to <30s | Typically ranges from 95% to 99.9% or greater |
| **IIOT EXAMPLES** |
| **APPLICATION CATEGORIES** | **TIR** | **AL** | **TTA** | **Integrity Availability** |
| **AGV Applications** - Mobile device tracking- Asset tracking- Process automation- Inbound logistics | Typical range: ≥10-8/hr to ≤10-1/hr | Typical range: ≥0.5m to <30m (vertical/horizontal) | Typically ranges from 100s of milliseconds to <10 seconds | Typically ranges from 95% to 99.9% or greater |

With the above, companies are invited to answer the following question to help to give a justification for the what we are doing for GNSS integrity and why this enhancement is needed for the use cases in R17.

###### Question1-3: Which use case do companies think that the current support of GNSS integrity in R16 LPP is already sufficient for?

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| **Company** | **Use Case** | **Comments** |
| Swift Navigation | None | We do not believe any of the use cases in the table will be satisfied using the existing IEs alone. The existing IEs are not useful in assisting the UE in computing a Protection Level as they are incomplete and no statement is made in the R16 specification as to the statistical meaning of these indicators (e.g. residual risk). |
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###### Question1-3 Summary:

TBD

Assistance data for different feared events

During the study item of the R17 positioning, the following categories for feared events have been defined in the TR [1], illustrated by the following Figure 1:



**Figure 1: Categorization of Integrity Feared Events**

During the RAN2 discussion in R2#115, the following agreements have been made in the feared events. Thus, we have agreed that (2) can be excluded with the following agreement.



We have almost agreed on the reprioritization of LMF-based integrity calculation and with the scope of the email discussion, the part (4) can also be excluded

In addition, for the LMF-feared events for UE-based integrity, the following has been agreed, and thus we don't need to discuss on category (5):

Proposal 10: Agree that the LMF feared events can be handled via implementation for the UE-based (network-assisted) and UE-assisted (LMF-based) methods of positioning integrity determination.

Then, the assistance data for feared events in the categories (1) and (3) are open for discussion. In the following, we further discuss what assistance data are needed for the remaining 2 types of feared events.

For the text proposals submitted to the last meeting and the discussion papers, the following parameters have been provided mainly under the following contributions:

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| Swift Nav et al [5] | The assistance data for feared events are highlighted as follows(a)Integrity Bounds (b) Residual Risks (c) Correlation Times (d) Alerts (e) Validity Times (f) Service Parameters* *GNSS-CommonAssistData*
	1. gnss-Integrity-ServiceParameters
		+ irMinimum
		+ irMaximum
	2. gnss-Integrity-ServiceAlert
		+ serviceDoNotUse
		+ ionosphereDoNotUse
		+ troposphereDoNotUse
	3. gnss-Integrity-TroposphereParameters
		+ epochTime
		+ iod-ssr
		+ validityPeriod
		+ pTroposphereFault
		+ tTroposphereFault
		+ tCorrelationTroposphere
		+ tCorrelationTroposphereRate
	4. gnss-Integrity-TroposphereErrorBounds
		+ epochTime
		+ iod-ssr
		+ correctionPointSetID
		+ validityPeriod
		+ gridList SEQUENCE (SIZE(1..64)) OF Integrity-TroposphereGridElement
			- meanTroposphereVerticalHydroStaticDelay
			- stdDevTroposphereVerticalHydroStaticDelay
			- meanTroposphereVerticalWetDelay
			- stdDevTroposphereVerticalWetDelay
			- meanTroposphereVerticalHydroStaticDelayRate
			- stdDevTroposphereVerticalHydroStaticDelayRate
			- meanTroposphereVerticalWetDelayRate
			- stdDevTroposphereVerticalWetDelayRate
* GNSS-PeriodicAssistData
	1. gnss-Integrity-PeriodicServiceAlert
	2. gnss-Integrity-PeriodicTroposphereErrorBounds
	3. gnss-Integrity-PeriodicConstellationAlert
	4. gnss-Integrity-PeriodicConstellationParameters
	5. gnss-Integrity-PeriodicBiasErrorBounds
	6. gnss-Integrity-PeriodicOrbitClockErrorBounds
	7. gnss-Integrity-PeriodicIonosphereParameters
	8. gnss-Integrity-PeriodicIonosphereErrorBounds
* GNSS-GenericData
	+ - gnss-Integrity-ConstellationAlert
		- constellationDoNotUse
		- integrity-svAlertList SEQUENCE (SIZE(1..64)) OF Integrity-SVAlertElement
			* svID
			* svDoNotUse
	1. gnss-Integrity-ConstellationParameters
		+ epochTime
		+ iod-ssr
		+ validityPeriod
		+ pConstellationFault
		+ tConstellationFault
		+ pSatelliteFault
		+ tSatelliteFault
		+ tCorrelationRangeOrbit
		+ tCorrelationRangeClock
		+ tCorrelationRangeRateOrbit
		+ tCorrelationRangeRateClock
	2. gnss-Integrity-BiasErrorBounds
		+ epochTime
		+ iod-ssr
		+ validityPeriod
		+ integrity-biasErrorBoundsList SEQUENCE (SIZE(1..64)) OF Integrity-BiasErrorBoundsElement
			- svID
			- meanCodeBias
			- stdDevCodeBias
			- meanCodeBiasRate
			- stdDevCodeBiasRate
			- meanPhaseBias
			- stdDevPhaseBias
			- meanPhaseBiasRate
			- stdDevPhaseBiasRate
	3. gnss-Integrity-OrbitClockErrorBounds
		+ epochTime
		+ iod-ssr
		+ validityPeriod
		+ orbitClockErrorMeanShapeVector
		+ orbitClockErrorCovarianceShapeMatrix
		+ orbitClockRateErrorMeanShapeVector
		+ orbitClockRateErrorCovarianceShapeMatrix
		+ orbitClockErrorBounds List SEQUENCE (SIZE(1..64)) OF Integrity-OrbitClockErrorBoundsElement-r17
			- svID
			- orbitClockErrorScaleFactor
			- orbitClockRateErrorScaleFactor
	4. gnss-Integrity-IonosphereParameters
		+ epochTime
		+ iod-ssr
		+ validityPeriod
		+ pIonosphereFault
		+ tIonosphereFault
		+ tCorrelationIonosphere
		+ tCorrelationIonosphereRate
	5. gnss-Integrity-IonosphereErrorBounds
		+ epochTime
		+ iod-ssr
		+ correctionPointSetID
		+ validityPeriod
		+ gridList SEQUENCE (SIZE(1..64)) OF Integrity-IonosphereGridElement-r17
			- satList SEQUENCE (SIZE(1..64)) OF Integrity-IonosphereSatElement-r17
				* svID
				* meanIonosphere
				* stdDevIonosphere
				* meanIonosphereRate
				* stdDevIonosphereRate
 |
| ESA et al [3] | Proposal 1. Add at least the quality indicator (standard deviation or variance) to each GNSS SSR IE in the Rel17 of LPP. Additional parameters are FFS at this moment. |
| Qualcomm [4] | Proposal 6: The assistance information that will be used to support integrity determination comprise quality indicators which can either be added to the SSR assistance data IEs or defined as a separate new IE:- Uncertainty of the satellite orbit;$ σ\_{SV orbit}^{2}$ - Uncertainty of the satellite clocks; $ σ\_{SV clocks}^{2}$- Uncertainty of the GNSS signal code bias; $σ\_{code bias}^{2}$ - Uncertainty of the GNSS signal phase bias; $σ\_{phase bias}^{2}$- Uncertainty of the ionosphere model; $σ\_{Iono}^{2}$- Uncertainty of the troposphere model; $σ\_{Tropo}^{2}$ |

### Feared events in the GNSS Assistance Data

According to [1], the feared events in the GNSS assistance data is defined as incorrect computation of the GNSS Assistance Data and External feared event impacting the GNSS Assistance Data. While for the contributions submitted to the previous meeting, there are no proposals relating to this aspect. Hence, we propose the following question on whether assistance data for the feared event in GNSS assistance data should be defined, and if needed, what assistance data are needed.

###### Question1-4: Do we need to define assistance data for feared events in GNSS assistance data? If the answer is Yes, what parameters do companies think are needed for GNSS assistance data and please provide the TP for the parameters (including the field by ASN.1 and field description)? If the answer is No, please also clarify the reasons in the comments

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| **Company** | **Yes/No** | **Comments** |
| Swift Navigation | Yes (see comment) | The Alert parameters in [5] (e.g. Do Not Use (DNU) flags) are used to address both the ‘GNSS Feared Events’ and ‘Feared Events in the GNSS Assistance Data’. Although feared events may come from different sources, their net effect at the positioning function is the same, so they may share the same alert flag.For example, a Satellite Vehicle (SV) alert means the system has detected a potential feared event on a given satellite which could impact integrity (meaning the error will likely exceed the corresponding Integrity Bound). This event may result from a satellite fault (e.g. a GNSS feared event) or from the inability of the service to validate the assistance data to a sufficient level for integrity (e.g. a Feared Event in the GNSS Assistance Data). Either way, the SV DNU flag is sent in the assistance data to avoid the corrections being used for the purpose of integrity.NOTE: The DNU flag does not prohibit the user from continuing to use the corrections (SSR, RTK etc) to improve positioning accuracy (e.g. for applications which do not have an integrity requirement). DNU specifically refers to the usability for integrity. |
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###### Question1-4 Summary:

TBD

### GNSS feared events

At RAN2#115, there were proposals from several contributions [3][4][5][6] suggested to capture the following integrity assistance information and this was also captured in the summary document [2].

(1) Standard deviations, quality indicators, variances of the GNSS error sources.

(2) Mean values of the GNSS error sources.

(3) Information describing the time variation of the GNSS error sources.

(4) Probability of satellite fault.

(5) Probability of constellation fault.

(6) "Do Not Use" assistance data alerts

(7) "Do Not Use" SV and/or GNSS constellation alerts

In particular, the discussion in [4] has also proposed to categorize the integrity parameters as follows:

1. Integrity Bounds
2. Residual Risks
3. Correlation Times
4. Alerts
5. Validity Times

Then, from the rapporteur’s understanding, the integrity parameters listed in [2] can be mapped to the categories in [4] as follows:

* **Integrity bounds**

(1) Quality indicators (standard deviation or variance) of the GNSS error sources

(2) Mean values of the GNSS error sources.

* **Correlation Times**

(3) Information describing the time variation of the GNSS error sources.

* **Alerts**

(6) "Do Not Use" assistance data alerts

(7) "Do Not Use" SV and/or GNSS constellation alerts

* **Residual risk**

(4) Probability of satellite fault.

(5) Probability of constellation fault.

In addition, we think that the following assistance data have also been defined in [4] according to the categorization in [2]

* **Validity times**

*(8) “Validity Period” defined for Constellation, Ionosphere and Troposphere parameters and their error bounds.*

We would first like to ask the question whether companies think the above categorization is reasonable for the assistance date for GNSS feared event. From the rapporteur’s perspective, we think that understanding this question will help us having a better understanding of the structure of the assistance data for GNSS-feared event and can be helpful to capture in the stage2 spec.

###### Question1-5: Do companies agree that the assistance data for GNSS-feared event can be categorized into the five categories of (a)Integrity Bounds (b) Residual Risks (c) Correlation Times (d) Alerts (e) Validity Times?

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| **Company** | **Yes/No** | **Comments** |
| Swift Navigation | Yes | ‘Applicability’ might be an alternative name for Validity Times, given some fields in this category are not only determined with respect to time (e.g. iod-ssr). However, these categories are only intended to aid interpretation of the concepts, whereas the actual naming and description of the fields will depend on the IEs we agree to define in the WI. Hence, we don’t think these specific categories need to be defined in the specification itself. |
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###### Question1-5 Summary:

TBD

From the understanding of the rapporteur, with the parameters listed in the TP and the proposal, we think the proposal in [3] and [4] are already included in the current TP in [5].

Then, we would like to ask the following question:

###### Question1-6: Do companies agree that we need additional assistance data for GNSS feared event other than those defined in text proposal in [5]? If so, what additional parameters do companies think are needed for GNSS-feared events and please provide the TP for the parameters (including the field by ASN.1 and field description)?

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| **Company** | **Yes/No** | **Comments** |
| Swift Navigation | No |  |
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###### Question1-6 Summary:

TBD

Assistance data for GNSS integrity service

In [5], Integrity Risk (IR) has been defined as assistance data for UE-based integrity calculation under the IE *GNSS-Integrity-ServiceParameters-r17* for the associated assistance data. This allows the UE to check if its TIR requirement (KPI) is within a range supported by the corrections service (based on the min/max IR).

We would like to ask the following question regarding assistance data for GNSS integrity service.

###### Question1-7: Do companies think other assistance data for GNSS integrity service is needed and please provide the corresponding TP (including the field by ASN.1 and field description)?

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| **Company** | **Yes/No** | **Comments** |
| Swift Navigation | No | We believe *irMinimum* and *irMaximum* are the only service parameters needed currently. Note that the IR min/max are not actually used (directly) for the purpose of checking the TIR KPI. They are used for computing the bounds according to the formula from [5]:[bound = ] *mean* + *Kmin* \* *stdDev* where *Kmin* = *normInv*(*irMaximum* / 2). |
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###### Question1-7 Summary:

TBD

Any other issues

For the following open question, companies are invited to input any other issues relating to assistance data for GNSS integrity. We may be able to address the issue in phase II.

###### Question1-8: Do companies think there are other issues relating to assistance data of GNSS integrity?

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| **Company** | **Comments** |
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###### Question1-8 Summary:

TBD

Conclusion of Phase I

TBD

# References

1. TR 38.857, Study on NR Positioning Enhancements (Release 17), V17.0.0.
2. R2-2109029, Summary on agenda item 8.11.5 on GNSS positioning integrity, Qualcomm.
3. R2-2108340, "Bounding GNSS errors for positioning integrity", ESA, Nokia, Nokia Shanghai Bell.
4. R2-2108385, "Considerations on GNSS positioning integrity support", Qualcomm Incorporated.
5. R2-2108475, "Text Proposal on GNSS Integrity Assistance Data", Swift Navigation, Ericsson, Mitsubishi Electric Corporation.
6. R2-2108474, "Discussion on GNSS Integrity Assistance Data", Swift Navigation, Ericsson, Mitsubishi Electric Corporation.
7. R2-2108396, " GNSS positioning integrity ", Ericsson
8. R2-2106596 LS to RTCM on GNSS integrity assistance data ESA LS out To:RTCM SC134 Cc: RTCM, RTCM SC104