SAPA Interface Control Document

Version 1.7

Explanatory Notes

Scottsdale, May 2019

Table of Contents

1. Revision Control

Version	Date modified	Changes/updates
1.0	May 17, 2019	- Initial draft

2. Preface

This document provides explanatory notes and discussion on the updates performed in for version 1.7 of the SAPA ICD. Not all changes are described, instead discussion is only provided when deemed beneficial.

3. General Fixes and Minor Updates

Item	Decsription
Renamed System ID (SF006) and System Processor ID (SF007) to Solution ID and Solution Processor ID respectivly	Possible confusion between the use of system to mean constellation, therefore deemed beneficial to rename to Solution
Restrict satellite reference datum to be consistent across all messages within a Solution ID	Previous version was non-specific about the need to provide all orbits within the same datum. This increases complexity for the user and for interoperability testing.
Increased maximum number of grid points to 127	Area definition message (SM 2-0) could be configured to be larger than the maximum number of grid points contained in the atmosphere message (SM 1-0/1-1). The total number of grid points was increased to support larger area definitions which may be defined.
Offset large troposphere coefficient (SF048)	In same manner as the small troposphere coefficient (SF045) was offset by 0.252m, the large troposphere coefficient is now also offset by 0.252m.
Addition of 1 reserved bit to each message header	Reserved bit was added to allow for extending messages without breaking backwards compatability if required in the future.

4. Tracking Specific Satellite Biases

Origional Requester	Organization	Date
Yuki Sato	MelCo	2019/03/14
Description		
On GPS phase/code bias mask (SF025 and 027), I would like to confirm which observation L2P and L2C particularly indicates. For L2P, I would guess L2W is a default. Is it correct? Could you also please tell about L2C? Does it depend on network?		
Discussion		
Code biases on L2 for GPS have been shown to be small but there is no published data to certify that this is the case. Additionally, GPS L5 analysis has shown half meter level biases between various track types, so specification of the exact track type is required (Montenbruck et al. (2014). Therefore, we have updated the specific track types to precisely define the track types of the code and phase biases defined in the ICD.		

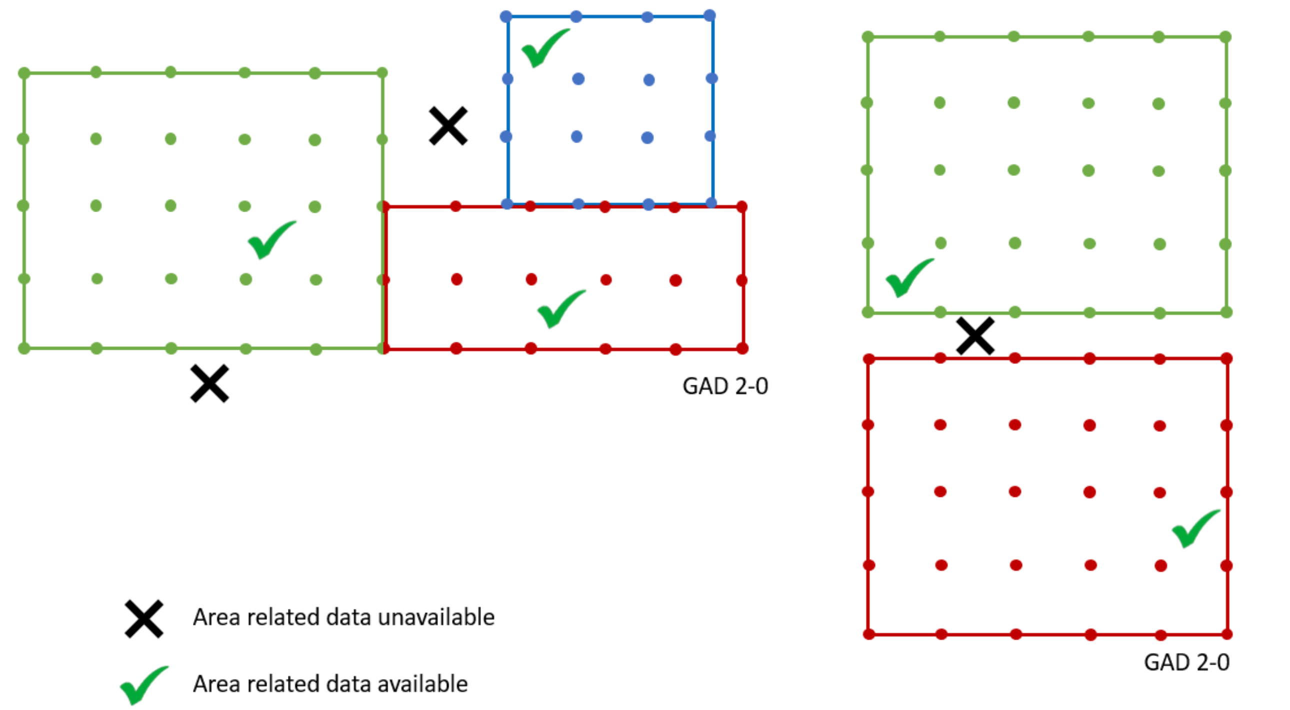
The selection of the bias types is provided in Table 1.

Constellation	Pseudo range	Carrier phase
GPS	C1C, C2W, C2L	L1C, L2W, L2L
GLONASS	C1C, C2C	L1C, L2C

Montenbruck, O., Hauchild, A., and Steigenberger, P. (2014) Differential Code Bias Estimation using Multi-GNSS Observations and Global Ionosphere Maps, ION NTM Jan 27-29, San Diego, USA

5. End-of-Set in Area Definition Message

Origional Requester	Organization	Date
Yuki Sato	MelCo	2019/02/27
Description		
Depending on the size of network, HPAC of the same epoch would be divided into several payloads (1024 byte maximum) and transported by different Messages. From rover's point of view, if the rover receives HPAC message which does not contain correction of nearby grids, if more HPAC is expected by EOS=0, the rover would wait for another message which may contain correction of nearby grids. In the above case, if the rover does not know if more HPAC is coming or not, the rover would start navigating by using grids which are very far.		
Discussion		
We believe the addition only an end-of-set marker to the GAD messages would be insufficient for this purpose. For example, due to outages or data corruption, users may receive incomplete area information even though an EOS marker has arrived. Therefore, adding an EOS marker will not necessarily allow the user to identify when all areas have been received. To remove the uncertainty in the usage of the area definition information we propose the following solution: 1) users may only use area information if they are located within the boundaries of the area. Users would "subscribe" to a single area for all of their area related data. 2) The subscribed area would be chosen on the approximate position of the user. This is will help ensureconsistent interpolation of both polynomial and gridded data and prevent usage of the polynomial or gridded data beyond the validity regions. Based on this concept, below is the proposed layout of the new GAD for single grid point areas as well as examples showing availability of area data with respect to various configurations.		



This decision comes at the expense of bandwidth as there will be some overlapping nodes to ensure that areas offer complete coverage. However, the advantage of this is to reduce the complexity of interpolation algorithms at the intersection of area definitions.

6. Merging of message sub-types

Origional Requester	**Organization**	**Date**
Iain Webster	Hexagon	2019/03/10
Description		
With the parallelism between the messages, this format document could be shorter and more easily structured by just having an OCB message, an HPAC message, and describing the limited system-specific behaviour within the messages (as is done with RTCM MSM).That would mirror the most likely implementation.		
Discussion		
The merging of sub-types was deemed beneficial. In addition to shortening the document it reduces the likelihood of copy/paste errors and mirrors the way an implementor reads the document.		

7. Area Continuity

Origional Requester	Organization	Date
Maxim Koehler	UBlox	2019/03/10
Description		
The area definition message doesn't contain a time tag. However, the area data block links to a defined area with the ID and a continuity indicator. How should this continuity indicator be used, if the area definition is not time tagged?		
Discussion		

As the GAD message (SM 2) does not contain a time tag it is not possible to relate the continuity time present in the High Precision Atmosphere Correction (HPAC) messages (SM 1-0 and SM 1-1) area block and the received area definition message. This makes it unclear for how long the received area definition information can be used.

Therefore, we have replaced the Area Continuity Indicator (SF015) in the Area Data Block (SM 1-0 and SM 1-1) with an Area Issue of Update with the following definition:

ID	Name	# Bits	Range	Resolution	Special values	Notes
SFXXX	Area Issue of Update (AIOU)	4	0 to 15	1	none	The AIOU controls when and if messages may be combined with the GAD messages described in SM 2. The AIOU cannot change more than once per 30 seconds. User must assume that an AIOU has changed over outages of 450 seconds or more even if the AIOU before and after the outage matches.

The intended behavior would be for the AIOU to update if ANY SINGLE area definition changes, the AIOU changes.

- The addition of the AIOU as described increases the header by 4 bits and the continuity indicator has been removed from the Area Block definition.
- The maximum outage duration has been increased from 320 seconds to 450 seconds.
- To minimize the number of bits, the constraint of preventing the AIOU from increasing more than once per 30 seconds has been included. This requires some new logic in during correction generation to prevent the area definition from changing more than once every 30 seconds.

8. Troposphere Height Reduction Description

Origional Requester	Organization	Date
Landon Urquhart	Sapcorda	2019/02/09
Description		
Require a consistent descrition for reducing the average zenith hydrostatic delay to a zero height.		
Discussion		

Below are two changes required for troposphere modelling, reference values obtained from UNB3m (Leandro et al., 2006).

Height Correction for Average Hydrostatic Zenith Delay:

The height correction to adjust the area average hydrostatic delay from a zero orthometric height to the user height can be performed as follows:

$$\delta T_h^z = T_h^z(H_{user}) - T_h^z(H_0)$$

Where

H_{user} is the receiver height in kilometers

H_0 is the reference height, 0 kilometers

$$T_h^z(H) = \frac{10^{-6} k_1 R}{g_m} \cdot P_0 \cdot \left(1.0 - \frac{\beta H}{T_0}\right)^{\frac{g}{R\beta}}$$

$k_1$is the refractivity constant with a value of 77.60 $K \cdot mbar^{-1}$

R is the gas constant for dry air 287.054 $J \cdot kg^{-1} \cdot K^{-1}$

g_m is the acceleration of gravity at the atmosphereic column centroid in units of $m \cdot s^{-2}$ computed as:

$$g_m = 9.784 \cdot (1.0 - 2.66 \cdot 10^{-3} \cos(2\phi) - 2.8 \cdot 10^{-7} \cdot H)$$

P_0, T_0 and β are computed via the look up tables

H is the height to be evaluated, in kilometers

	Average		
Latitude (degrees)	Pressure (mbar)	Temperature (Kelvin)	Temperature Lapse Rate (Kelvin / meter)

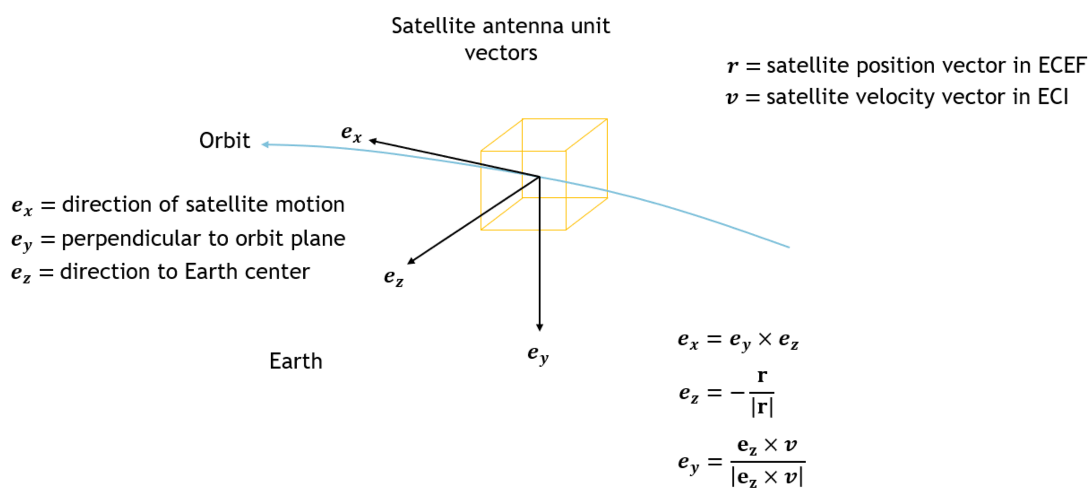
15	1013.25	299.65	6.30e-3
30	1017.25	294.15	6.05e-3
45	1015.75	283.15	5.58e-3
60	1011.75	272.15	5.39e-3
75	1013.00	263.65	4.53e-3

	Amplitude		
Latitude (degrees)	**Pressure (mbar)**	**Temperature (Kelvin)**	**Temperature Lapse Rate (Kelvin / meter)**
15	0.0	0.0	0.0
30	-3.75	7.00	0.25e-3
45	-2.25	11.00	0.32e-3
60	-1.75	15.00	0.81e-3
75	-0.50	14.50	0.62e-3

Leandro R.F., M.C. Santos, and R.B. Langley (2006). UNB Neutral Atmosphere Models: Development and Performance. Proceedings of ION NTM 2006, the 2006 National Technical Meeting of The Institute of Navigation, Monterey, California, 18-20 January 2006; pp. 564-573.

9. Phase Windup Convention

Origional Requester	Organization	Date
Landon Urquhart	Sapcorda	2019/02/13
Description		
Require a consistent descrition for modeling satellite yaw angle.		
Discussion		
Clarification required on handling of phase windup for the SAPA corrections: If the yaw angle is not provided, the satellite yaw angle should be considered zero. The nominal satellite phase windup is computed according to Wu et al. (1993) with the satellite fixed frame defined as follows:		



10. GLONASS Leap Second and Time Scale Consistency

Origional Requester	Organization	Date
Maxim Koehler	UBlox	2019/03/05
Description		
SF004: The description says, the counter starts on January 1st 2010, 00:00:00 and is represented in the system time of the GNSS constellation. So for GPS this seems quite straightforward, since it's just counting the seconds since 1564:432000.0 (Start date in GPS time excluding leap seconds). However for Glonass, it's not clear, how the discontinuities due to leap seconds are handled. Is the SAPA time tag a continuous counter and therefore the time tag offset between Glonass and corresponding GPS messages would be constant (= 3h + leap seconds at start date). Or, what I would assume, is it discontinuous as the Glonass time? In the latter case, to which time instant would the correction correspond during a leap second event? On a related note, I would expect, that the GPS time tag 0 corresponds to the Glonass time ttag 10786 (3h – 14 leap seconds as of 01/01/2010)		
Discussion		
In the existing ICD how to handle the time scale during leap second events is undefined as to whether the time scale was intended to be continuous or not. Additionally, the start time of the GLONASS along with other time scales was not clearly defined. As each message time tag is in the time system of the constellation, GLONASS messages will have an ambiguous time tag occur for each negative leap second event. To handle this safely, it is required that an encoder not provide the epoch prior (UTC tune 23:59:60) nor the epoch of (UTC time 00:00:00) of the event. A decoder shall ignore these epochs if received from a service provider. Below provides an example of a leap second event for midnight UTC on Dec 31, 2016. Parameters as defined in GPS ICD section 20.3.3.5.2.4 AdjWeek = 1929 AdjDayOfWeek = 7 LsBeforeLsAdjTime = 17 LsAfterLsAdjTime = 18 For a user operating at this time, the following sequence of GLONASS time tags should be observed:		

UTC Time hh:mm:ss	GPS Seconds since Jan 6,1980 0h UTC	SAPA Full Time Tag (SM 0-0/1-0)(GPS)	SAPA Full Time Tag (SM 0-1/1-1)(GLN)	Effective # of LS	GLN Encoder Behavior
23:59:57	1167264014	220924814	220935597	17	Send
23:59:58	1167264015	220924815	220935598	17	Send
23:59:59	1167264016	220924816	220935599	17	Send
23:59:60	1167264017	220924817	220935600	17	
00:00:00	1167264018	220924818	220935600	18	
00:00:01	1167264019	220924819	220935601	18	Send
00:00:02	1167264020	220924820	220935602	18	Send
00:00:03	1167264021	220924821	220935603	18	Send

In the SAPA Full Time Tag GLONASS messages, the epoch 220935600 is repeated. It is required that in order to avoid the ambiguity of the leap second event, that an encoder drop GLONASS messages for the epoch prior (UTC Time 23:59:60) and the epoch of (UTC Time 00:00:00) the event as indicated in the GLN Encoder Behavior column.

The following test cases can also be used to verify the SAPA time tags for several instances including leap second events. In summary, the offset between GPS and GLONASS SAPA time tags will be 10800 + (UTC – GPS offset).

Date Epoch Mth Day Year	hh:mm:ss	Time Sys	SAPA Full Time Tag (SM 0-0/1-0)(GPS)	SAPA Full Time Tag (SM 0-1/1-1) (GLN)	Delta time (s)	Comment
Jan 1, 2010,	00:00:00	(GLN time)	N/A	0	N/A	
Jan 1, 2010,	00:00:00	(GPS time)	0	10785	10785	Offset if 10800s(3hours) + (-15) leap second offset
Jan 1, 2010,	06:00:00	(GLN time)	10815	21600	10785	Offset if 10800s(3hours) + (-15) leap second offset
Jun 30, 2012,	23:59:00	(GPS time)	78796740	78807525	10785	Offset if 10800s(3hours) + (-15) leap second offset
Jul 1, 2012,	00:00:59	(GPS time)	78796859	78807643	10784	Offset if 10800s(3hours) + (-16) leap second offset
Dec 31, 2016,	23:59:00	(GPS time)	220924740	220935523	10783	Offset if 10800s(3hours) + (-17) leap second offset
Jan 1, 2017,	00:00:59	(GPS time)	220924859	220935641	10782	Offset if 10800s(3hours) + (-18) leap second offset
Mar 15, 2019,	15:42:21	(GPS time)	290360541	290371323	10782	Offset if 10800s(3hours) + (-18) leap second offset

11. Invalid Field Representation

Origional Requester	Organization	Date
Maxim Koehler	UBlox	2019/03/05
Description		
Specifically, there was some confusion while comparing chapter 6.3 Floating-point numbers conversion with the “Range” and the “Special values” fields of SF020, SF029, SF043-SF053, and SF057-SF067. For SF020 and SF029, the specification seems clear about which encoded values correspond to the invalid value and the valid value range. But I’m not sure for the other fields. As I understand it, the values of a hypothetical 8-bit field would be as follows: • 0x00: invalid value • 0x01: minimum value (negative range limit) • 0x80: 0.0 • 0xFF: maximum value (positive range limit) However, that would contradict the formula mentioned in chapter 6.3, which would map value 0x00 to the minimum value. Could you provide a clarification of that?		
Discussion		
Removed the ambiguity in the handling of the encoding and decoding of the integer values due to not specifying either two’s complement or unsigned nature of the encoding integer. This was particularly true for special values being encoded as floating-point numbers. In the section on floating point conversion, state that all encoding decoding operations shall be performed on unsigned integers and specify that for cases of invalid or special values, encoders shall directly encode the special value as an unsigned integer. And that decoders must check for special values prior to performing the conversion to a floating-point number. Invalid and special values were deemed unnecessary in cases of polynomial coefficients as the data is simply not sent. Therefore, having special values may lead to confusion in implementation and broadcasting of non-essential data. Specifying special values in hexadecimal notation will avoid ambiguity in evaluating floating point numbers. Remove special/invalid values from fields which are simply not sent when data is out of range. For all special values that remain, specify their hexadecimal notation. The following data fields will have their special values removed: SF043, SF045 – SF050, SF052, SF053, SF057 – SF062. The following data fields will have their special values represented using hexadecimal notation: SF064 – SF067.		