PEPPUS

PROJECT: PEPPUS		WP Number: WP-0000001
TITLE Positioning Engine for Precise Point USers		**Issue**: 1.0
LEAD CONTRACTOR	GNSS Academy	
CUSTOMER	ESA	**LEADER**: Student
ESTIMATED EFFORT	4 Months	

MISSION and SCOPE

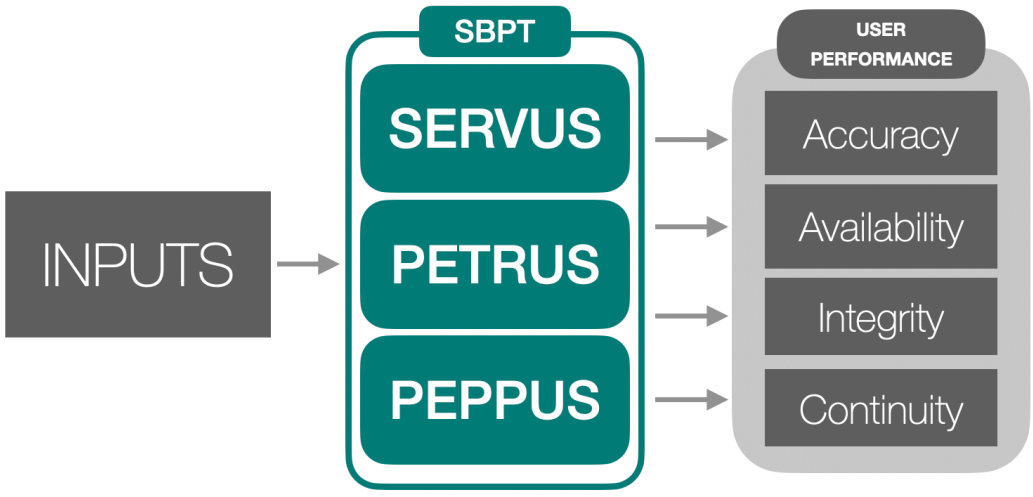
PEPPUS stands for Positioning Engine for Precise Point USers.

The PEPPUS main mission is the assessment of Receiver Performances from the computation of a PPP solution for a dual-frequency user. The solution will use precise satellite orbits coming from IGS SP3 files and satellite clock offsets coming from RINEX CLK files. The ionosphere delay will be removed by applying the Iono-free combination.

PEPPUS is the Positioning Engine Module of a software-embedded. It removes the contributors to the Range Error down to cm accuracy and estimates the receiver PVT applying a Kalman Filter in which the floating ambiguities will be estimated. PEPPUS takes the following files as inputs:

- ✓ The Raw measurement observables: Code and Phase measurements.
- ✓ The SP3 files containing very precise satellite orbits every 10/15min.
- ✓ ANTEX files containing Antenna Phase Offsets to transform satellite Center of Mass Position to Center of Phase position.
- ✓ The RINEX CLK files containing very precise satellite clock biases every 30s (alternatively, files at a 300s timestep could be used, but the 30s timestep is preferred).
- ✓ Receiver Precise Coordinates.

The main outputs of PEPPUS are the Positioning Performances at User level.



PEPPUS mission is described through the following requirements:

PEPPUS REQ. ID	TYPE	TITLE	BODY
SBPT-PEPPUS-REQ-0010	GEN	PEPPUS mission	The PEPPUS shall be in charge of assessing the performances of a dual-frequency multi-constellation receiver performing a PPP solution that involves floating Ambiguity resolution.
SBPT-PEPPUS-REQ-0020	GEN	GPS Constellation	The PEPPUS shall handle GPS Constellation
SBPT-PEPPUS-REQ-0030	GEN	Galileo Constellation in DF	The PEPPUS shall handle Galileo Constellation
SBPT-PEPPUS-REQ-0040	GEN	Minimum scenario duration	The PEPPUS shall be able to run a scenario of at least 30 days long
SBPT-PEPPUS-REQ-0050	GEN	Daily analyses	The PEPPUS shall perform daily analyses for every receiver and scenario day
SBPT-PEPPUS-REQ-0060	OPS	Call Command line	The PEPPUS shall have the capability to be executed from the command line.
SBPT-PEPPUS-REQ-0070	OPS	Processing in Batch mode	The PEPPUS shall run in batch mode for several receivers and scenario days.
SBPT-PEPPUS-REQ-0200	PERF	Runtime in Mono-constellation	The PEPPUS shall run 24H analysis for one receiver in less than 5 minutes at 1Hz in Mono-constellation mode
SBPT-PEPPUS-REQ-0210	PERF	Runtime in Multi-constellation	The PEPPUS shall run 24H analysis for one receiver in less than 5 minutes at 1Hz in Multi-constellation mode
SBPT-PEPPUS-REQ-0220	IF	Input arguments	The PEPPUS shall be invoked with the full scenario path with scenario name as a unique mandatory input argument.
SBPT-PEPPUS-REQ-0240	IF	Input folders arborescence	The PEPPUS shall respect the following scenario arborescence as follows: SCENNAME/INP/OBS/ SCENNAME/INP/SP3/ SCENNAME/INP/ATX/ SCENNAME/INP/CLK/ SCENNAME/INP/RCVR/
SBPT-PEPPUS-REQ-0250	IF	Output folders arborescence	The PEPPUS shall produce the outputs on a predefined scenario arborescence as follows: SCENNAME/OUT/PPVE SCENNAME/OUT/CORR SCENNAME/OUT/USR/PVT SCENNAME/OUT/ USR/PERF
SBPT-PEPPUS-REQ-0260	IF	INP: Reader of RINEX Observation files	The PEPPUS shall read and process RINEX Observation files
SBPT-PEPPUS-REQ-0270	IF	INP: Reader of SP3 files	The PEPPUS shall read and process SP3 files format
SBPT-PEPPUS-REQ-0280	IF	INP: Reader of ANTEX files	The PEPPUS shall read and process ANTEX files format

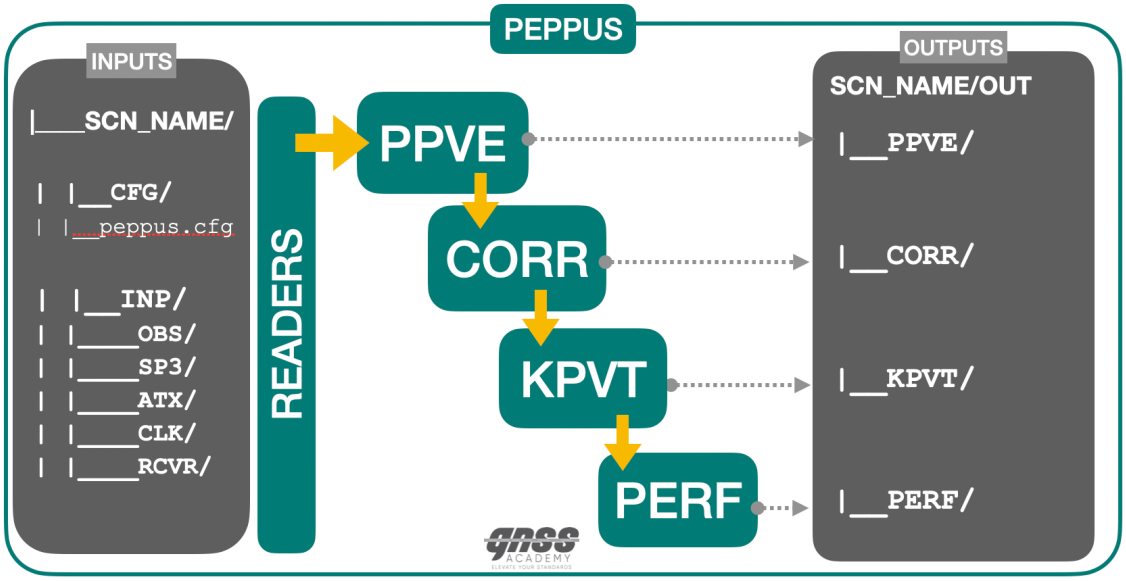
SBPT-PEPPUS-REQ-0290	IF	INP: Reader of RINEX CLK files	The PEPPUS shall read and process RINEX CLK files format
SBPT-PEPPUS-REQ-0300	IF	INP: RCVR Positions information	The PEPPUS shall be able to read and process input files containing the Receiver Position Coordinates information: * Receiver Selection flag * Receiver acronym * Receiver Identifier * Receiver longitude, latitude and Height * Receiver Mask Angle * Receiver Acquisition Time

PEPPUS shall produce the following MAIN outputs:

REQ. ID	TYPE	TITLE	BODY
SBPT-PEPPUS-REQ-0310	IF	Satellites Visible/Used	The PEPPUS shall output and plot the instantaneous time-series of the visible satellites and used satellites
SBPT-PEPPUS-REQ-0340	IF	PDOP & TDOP time-series	The PEPPUS shall output and plot the instantaneous time-series of the PDOP and TDOP
SBPT-PEPPUS-REQ-0350	IF	EPE, NPE, UPE time-series	The PEPPUS shall output and plot the instantaneous time-series of the position error in the east (EPE), North (NPE) and Up (UPE) directions
SBPT-PEPPUS-REQ-0360	IF	HPE, VPE histogram	The PEPPUS shall output and plot Horizontal and Vertical position error, HPE and VPE histograms.
SBPT-PEPPUS-REQ-0370	IF	H/VDOP histogram	The PEPPUS shall output and plot Horizontal and Vertical DOP histograms.
SBPT-PEPPUS-REQ-0380	IF	User Performances	The PEPPUS shall output and plot User Performances

PEPPUS ARCHITECTURE

PEPPUS global architecture can be depicted as follows:



These modules are described in the table here-below:

MODULE	*DESCRIPTION*
[PPVE]	***PPVE*** module is the Pre-processing Validation and Exclusion Module in charge of the producing the pre-processed measurement. The main tasks are tasks are: • Implement the different Validation Checks in front of configuration thresholds. • Satellite Health and Geometry, Channels checks • Measurement Quality Checks (Jumps, Rates, Divergence, Cycle Slips, C/N0) • Build Iono-free combination
[CORR]	***CORR*** module is the Corrections Module in charge of correcting GNSS preprocessed measurements and compute the first pseudo range residuals. The main tasks are: • Compute the Satellite Antenna Phase Center position at the transmission time and corrected from the Sagnac effect interpolating the SP3 file positions • Compute the Satellite Clock Bias interpolating the biases coming from the RINEX CLK file and applying the Relativistic Correction (DTR) • Estimate the Slant Troposphere delay (STD) using MOPS model (ZTD) and its mapping function. • Correct the Pre-processed measurements from Geometrical Range, Satellite clock and Troposphere. • Build the Corrected Measurements and Measurement Residuals • Build the Sigma UERE
[KPVT]	***KPVT*** module is the Kalman PVT navigation solution Module in charge of the PVT computation through a Kalman Filter (KF) The main tasks are tasks are: • Update State Vector through the Process Matrix [F] • Update Covariance Matrix through the Process Noise Matrix [Q] • Build the Observation [G] and Weighting Matrices [W] • Build the [S] Matrix and DOP Matrix [D] • Build the Measurement Residuals Vector [rho] • Apply the Kalman Filter • Estimate the Receiver Position Coordinates and Clock

	• Estimate the Position Error (HPE, VPE) • Estimate the DOPs (PDOP, GDOP, HDOP, VDOP)
[PERF]	***PERF*** module is in charge of computing and displaying the final User Performances.

PEPPUS MAIN PROCESSING LOGIC

This is PEPPUS **Pseudo-Cod**e to guide you through the process.

Note that this is not real code but it helps to understand the main processing logic and SW architecture.

```
PEPPUS(CONF, OBS, SP3, ATX, CLK)

# First, Check input arguments:
# - Check Scenario Path and Name existence.
# - Check configuration file existence on the configuration folder
check_input_arguments(scen_path, scen_name)

# Read and process configuration file:
# - Read and load configuration parameters
#-------------------------------------------------------------------------------------------
conf = read_peppus_cfg(scen_path, scen_name)

# Read Receiver Positions
#-------------------------------------------------------------------------------------------
rec = read_receiver_pos(scen_path, scen_name)

# Loop over all selected receivers
for iRec in rec.NUM_REC:

    # Loop over all the scenario days
    for iDay in Conf.NUMBER_OF_DAYS:

       # Read and load all input files information: RNB, NAV and OBS
       #-----------------------------------------------------------------------------------------
       Obsinfo, SatPosInfo, SatApoInfo, SatClkInfo = readExternalFiles(conf,siRx,iDay)

        # Loop over all seconds of the current processing day
        #-------------------------------------------------------------------------------
        for Time in INITIME:ENDTIME

            # [PPVE] Pre-processing and Validation at 1Hz
            #-----------------------------------------------------------------
            PreproOutputs = runPreProcMeas(ObsInfo)

            # Rest of analyses are executed every configured sampling rate
            #-----------------------------------------------------------------
            if Time % Conf.SAMPLING_RATE == 0

                # [CORR] Correct Measurements and Estimate variances
                #-----------------------------------------------------------------
                CorrOutputs = runCorrectMeas(PreproOutputs, SatPosInfo, …,)

                # [KPVT] Compute the PVT Solution
                #-----------------------------------------------------------------
                PvtOutputs = runPvtSolution(CorrOutputs, …)

                # [PERF] Compute Daily Performances
                #-----------------------------------------------------------------
                PerfOutputs = computePerformances()

                # [WRITE] Write Instantaneous Outputs
                #-----------------------------------------------------------------
                writeOutputsInFile(PreprocOutputs,
```

```
                                    CorrecteOutputs,
                                    PvtOutputs)

            # End of if Time % Conf.SAMPLING_RATE == 0

        # End of for Time in INITIME:ENDTIME
    # End of for iDay in Conf.NUMBER_OF_DAYS:
#End of for siRec in Conf.NUM_REC):

# END OF PEPPUS()
```

INPUTS

Next table summarizes PEPPUS input files required:

TYPE	FORMAT	FOLDER	DESCRIPTION
OBS	RINEX v2.11, v3.03	OBS/	RINEX Observation files containing the different observables (Code P/CA, Phase, Doppler, C/N0) for all the constellations (GPS/GAL/GEO) and frequencies (L1/L2/L5/E1/E5)
SP3	SP3c	SP3/	SP3 files containing GPS and/or Galileo coordinates w.r.t the Center of Masses, at a given sampling rate (typically, 10 or 15 minutes)
ANTEX	ANTEX	ATX/	ANTEX files containing the Antenna Phase Offsets for GPS and/or Galileo.
CLK	RINEX CLK	CLK/	CLK RINEX files containing GPS and/or Galileo Clock Offsets on L1L2 or L1L5 (GPS) or E1E5 (Galileo) at a given sampling rate (typically, 30s or 5 minutes).
RCVR	RCVR	RCVR/	File containing the reference precise RCVR coordinates, mask angles, acquisition time and other RCVR-related information

OUTPUTS

PEPPUS shall produce the following files:

TYPE	FOLDER	DESCRIPTION
[PPVE]	PPVE/	Daily Receiver Files with pre-processed Information
[CORR]	CORR/	Daily Receiver Files with Corrected Measurements Information
[KPVT]	KPVT/	Daily files containing the Receiver Position Computation instantaneous information
[PERF]	PERF/	Daily files containing the Receiver Performance info.

WORK PACKAGES

ID	DESCRIPTION	
WP1: PPVE	**Pre-processing & Validation & Exclusion**	

	This PPVE module aims at pre-processing, cleaning, validation, exclusion and computation of the combinations of the input receiver observables by implementing:
	
	• Measurements Cleaning and Exclusion due to different criteria as follows:
	
	  ○ Minimum Masking angle
	  ○ Maximum Number of channels
	  ○ Minimum Carrier-To-Noise Ratio (CN0)
	  ○ Pseudo-Range Output of Range
	  ○ Maximum Pseudo-Range Rate
	  ○ Maximum Pseudo-Range Rate Step
	  ○ Maximum Carrier Phase Rate
	  ○ Maximum Carrier Phase Rate Step
	  ○ Data Gaps checks and handling
	  ○ Cycle Slips detection
	
	• Build Iono-free combination	

WP2: CORR	**CORRECTIONS Module**	
	CORR module is in charge of performing all the tasks at range level for every single valid and pre-processed Line-Of-Sigh that will be later used in the PVT solution. The tasks are summarized as follows: • Compute the Satellite Antenna Phase Center position at the transmission time and corrected from the Sagnac effect interpolating the SP3 file positions • Compute the Satellite Clock Bias interpolating the biases coming from the RINEX CLK file and applying the Relativistic Correction (DTR) • Estimate the Slant Troposphere delay (STD) using MOPS model (ZTD) and its mapping function. • Correct the Pre-processed measurements from Geometrical Range, Satellite clock and Troposphere. • Build the Corrected Measurements and Measurement Residuals • Build the Sigma UERE	
WP3: KPVT/PERF	**KALMAN PVT/PERF Module**	
	KPVT module is in charge of computing the PVT navigation solution through a Kalman Filter. It performs the following tasks: • Update State Vector through the Process Matrix [F] • Update Covariance Matrix through the Process Noise Matrix [Q] • Build the Observation [G] and Weighting Matrices [W] • Build the [S] Matrix and DOP Matrix [D]	

	• Build the Measurement Residuals Vector [rho] • Apply the Kalman Filter • Estimate the Receiver Position Coordinates and Clock • Estimate the Position Error (HPE, VPE) • Estimate the DOPs (PDOP, GDOP, HDOP, VDOP) PERF module is in charge of computing and displaying the final Receiver Performances as well as different statistics of other related indicators.	
WP4: DELIVERY	**DELIVERY, REPORTING AND FINAL ACCEPTANCE**	
	Delivery of the following Products: • PEPPUS SW Sources + Configuration files. • Scenario Execution Outputs: files and figures • A Technical Note: ✓ Tool Mission and Scope ✓ Technical Understanding and Main Requirements ✓ Architecture, Design & I/O Interfaces ✓ Algorithms Definition. ✓ Validation results w.r.t the Reference Scenario data ✓ Main Conclusions ✓ Recommendations and Way forward	