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DOCUMENT

Generic E2E Performance Simulator and L1/L2 Processor Requirement Document and Inputs to SoW

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APPROVAL

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CHANGE LOG

Reason for change	Issue	Revision	Date
First issue	1	0	02-10-2014
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CHANGE RECORD

Issue 1	Revision 0		
Reason for change	Date	Pages	Paragraph(s)
First issue	02-10-2014	all	all

Issue 1	Revision 1		
Reason for change	Date	Pages	Paragraph(s)
Release of openSF	14-06-2016	all	all
Clarification on active instrument	14-06-2016	all	all
Update of baseline sw tools	14-06-2016	all	all

1 SCOPE

<NB This documents is a generic template at the Technical Specification level addressing system and software aspects (and NOT algorithms). It needs to be reviewed and customised for each mission>

This document defines the requirements and deliverables for the <MISSION-X> End-to-End Performance Simulator (E2P) and Level 1 and 2 Prototype (L1PP/L2PP) and Operational Processors (L1OP/L2OP) applicable to the -<MISSION-X> industrial team during the -<MISSION-X> Project Phases B2, C, D and during support to Phase E1.

These requirements address both user and implementation aspects to the level of ECSS-E-ST-40C SSS (Software System Specification), IRD (Interface Requirement Document) and TS (Technical Requirement Specification) and used as support the corresponding Statement Of Work including the identification of input, outputs and deliverables of the procurements of these 2 items.

The nomenclature used is adapted specific for Data Processor and, at least for documentation, differs slightly from the ECSS one. The correspondence is however given.

E2E Performance Simulator and L1PP/L2PP are software tools that will evolve and serve multiple purposes since they will be used:

a) to support the development and verification of the Space Segment
b) to support development of the Ground Segment
c) to support commissioning and exploitation

The typical evolution of these items in the different phases of the project is shown in Fig 1:

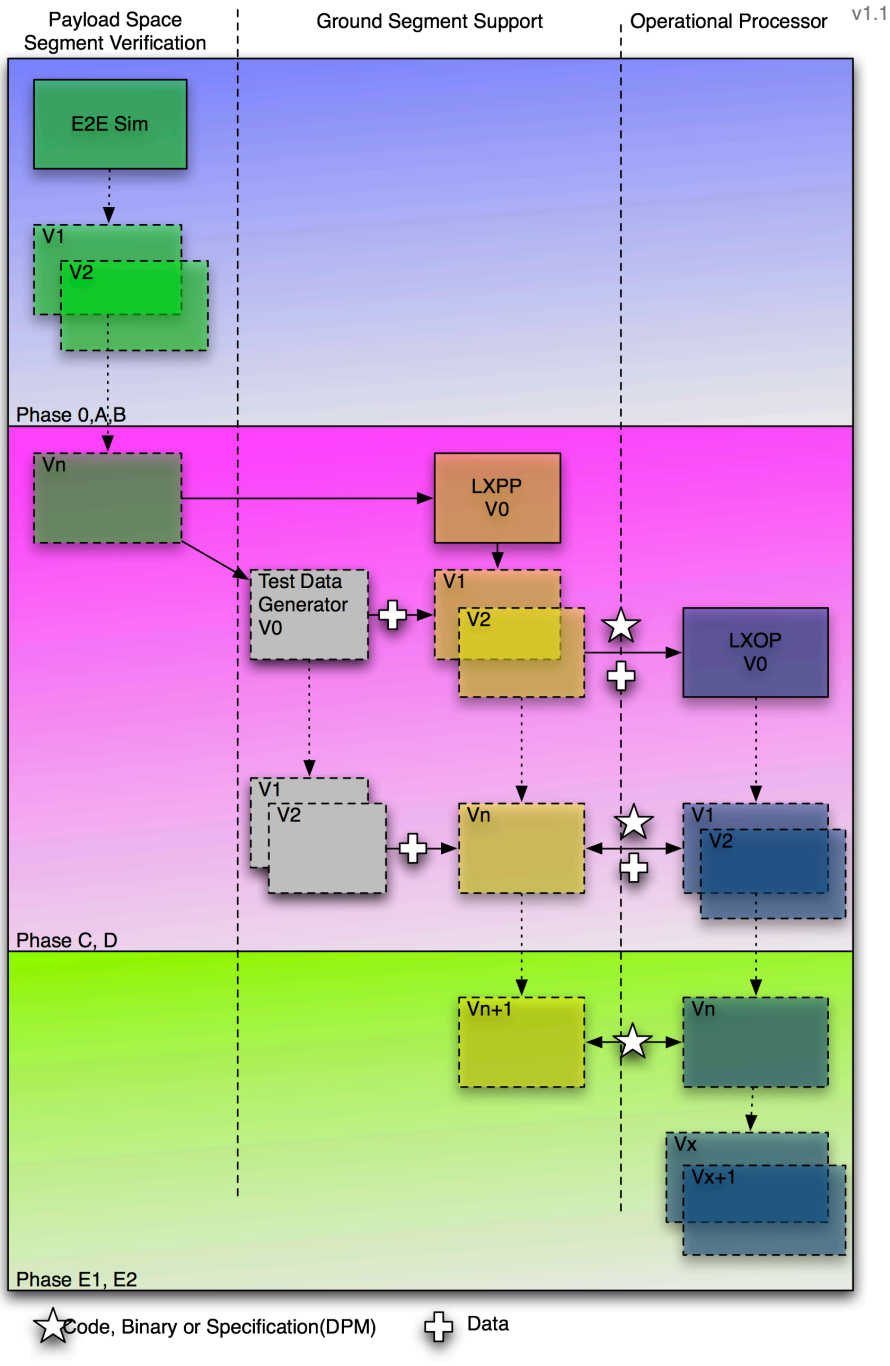

Fig. 1 Typical lifecycle of E2E Performance Simulator and L1PP

1.1 Data Definition

The following data types and nomenclature are defined within the scope of this activity and used within this document:

Observation data (OBS)	Instrument Space Packet (ISP) as generated by the Instrument and containing the measurements both in normal and calibration modes.
Ancillary data (ANC)	Space Packet as generated by any on-board source and needed for ground processing (e.g navigation, HKTM, temperature, AOCS, etc)
Raw data (RAW)	Concatenation of ISP and Ancillary Source Space Packets as are transmitted on the space to ground RF link and would be produced by the acquisition system in the Ground Station.
Level 0 product	Level 0 data files in the same format at the actual GS (Ground segment header + concatenation of Space Packets)
Level 1 product	Level 1 data files in the same format at the actual GS and as generated by L1PP
Level 2 product	Level 2 data files in the same format at the actual GS and as generated by L2PP
Auxiliary data (AUX)	Other data (static or dynamic) in format of files formatted as in the real GS to be used for configuration of the processor or as input to the processors (e.g. Restituted or Reconstituted Orbit File, Instrument Characterisation, Meteo data, Offset tables, etc). Some auxiliary data can originate from offline calibration activities.
Calibration Products (CAL)	Data files (products) generated during the processing of instrument data and used in the Ground Segment or in the L1 and higher level processing. They can be either dynamic (CAL) or static (CAL/AUX) (see nomenclature note in section 3.3.1).
Breakpoint (BRK)	Data files optionally produced by L1 and L2 Processing modules containing any intermediate result useful for diagnostic, debug and troubleshooting.

1.2 Acronyms

OBS
ANC
RAW
AUX
CAL
BRK
ISP
HKTM
AOCS
L1PP
L2PP
L1OP
L2OP
L0P
TOA
CCDBs

2 DOCUMENTS

2.1 Applicable documents

The documents applicable to the required -<MISSION-X> activities and deliverables are formally defined in the contract. For ease of reference the contractual appendices/applicable documents are repeated herewith. In case of conflicting, incomplete, missing or ambiguous requirements the contractor shall bring these to the attention of the customer for formal resolution.

AD	Title	Reference	Issue
AD01	Statement Of Work for the <MISSION-X> (SOW)		
AD02	<MISSION-X> System Requirement Document (SRD)		
AD03	Tailoring of ECSS Standard for <MISSION-X>		
AD04	2.1.1.1.1.1.1.1 <MISSION-X> Document Requirements List (DRL)		
AD05	Earth Observation File Format Standard	PE-TN-ESA-GS-0001	3.0
AD06	Handbook for EO XML and Binary Schemas	PE-TN-ESA-GS-0121	1.7.1
AD07	OpenSF Documentation at : http://opensf.esa.int/opensfwiki/index.php/Documentation		3.5
AD08	ESA generic E2E simulator Interface Control Document	PE-ID-ESA-GS-0464	1.2
[S2GICD]	Space to Ground ICD		
[L1IODS]	Level 1 Input/Output Data Specification		
[L2IODS]	Level 2 Input/Output Data Specification		
[L1ATBD]	Level 1 Algorithm Theoretical Baseline Definition		
[L2ATBD]	Level 2 Algorithm Theoretical Baseline Definition		

2.2 Normative documents

The following ECSS standards apply to the /<MISSION-X> E2E development with tailoring for deliverable documentation as described in the present document.

ND	Title	Reference	Published
ND-28 …	Space Engineering-Software	ECSS-E-ST-40C	6 March 2009
ND-65 …	Space Product Assurance	ECSS-Q-ST-80C	6 March 2009

2.3 Reference documents

RD	Title	Reference	Issue
RD-01	Earth Observation Mission Software CFI 4.11 UM	http://eop-cfi.esa.int	4.11

3 CONTEXT AND PURPOSE OF THE END-TO-END PERFORMANCE SIMULATOR AND LEVEL 1 PROCESSORS

3.1 The E2E performance Simulator

The E2E Performance Simulator is a complete *end-to-end* chain of software modules representing both the Space Segment and the Ground Segment of the mission and **generically** built as shown in Fig. 2

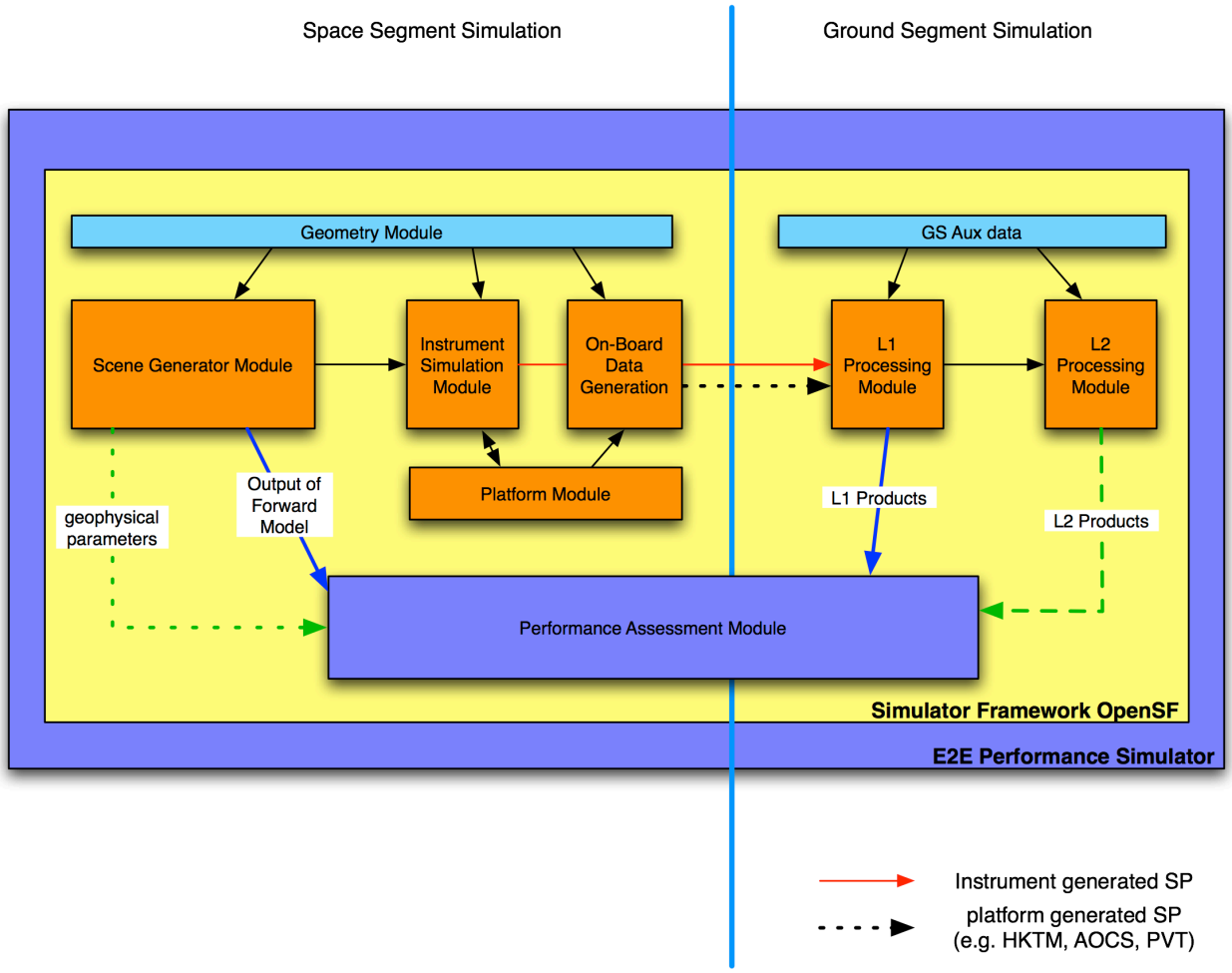

Fig. 2 E2E Performance Simulator

This chain allows simulating the complete process and flow from a simulated scene (the *truth*) to the L1 (and later L2) computed quantities, to introduce noise and errors, different instrument modelling as well as different L1 algorithms and ultimately to assess and characterise the performance of the whole chain as function of instrument design, L1 algorithm, noise and errors by comparing the simulated truth with the data as retrieved by the simulated ground processing.

In the early phases of a mission the E2E Performance Simulator supports the definition and the verification of the Space Segment requirements; in later phases is used as an offline Test Data Generator for the Ground Segment and as breadboard for the ground processing.

In order to ensure that the E2E is fully representative it is mandatory the there is no direct interface or data sharing between the Space segment simulation and the ground segment simulation and that any data exchange is performed via simulated TM files and static AUX data.

The E2E performance simulator will be made available to various scientific actors supporting <MISSION-X>. Any contribution from this external use that would allow further improvement of the E2E performance simulator will be repatriated.

3.2 The Space Segment Simulation

3.2.1 *The Geometry Module*

The Geometry Module (GM) computes all environmental orbit and attitude information related to the observation geometry, including e.g. Orbit Propagation (PVT), Attitude Determination (Quaternions), Field Of View and Coverage areas and provides them to the other modules as needed. It shall be based on the Earth Observation Mission Software CFI library [RD 1].
The GM implements the orbit propagation either using an internal model or by ingestion of externally generated Orbit and Attitude data (e.g. predicted, restituted or externally simulated) providing an abstraction layer to the actual source of data respect to the rest of the module.

~~3.2.1~~3.2.2 *The Scene Generator*

The *Scene Generator* performs 2 functions:

1. Represents the geophysical model (truth) of the quantity to be observed e.g. temperature, sea roughness, dielectric constant, wind speed, altitude, salinity, CO2 concentration, aerosol size, etc

2. Implements the forward model: e.g. to generate the stimuli TOA to the instrument at any one time (for example radiance) or to generate (for active instruments) the relevant backscattering matrices.

These functions make use of a number of auxiliary geophysical information and use the GMD to produce the correct complete set of time based instrument scenes, which will be the input to the ISM. This process includes an appropriate modelling of the atmosphere. When user defined errors can be introduced (e.g. in the atmospheric modelling part) these shall be computed as and included in the scene generator.

The figure below shows the Geophysical Target and disturbances modelled as part of the Scene Generator.

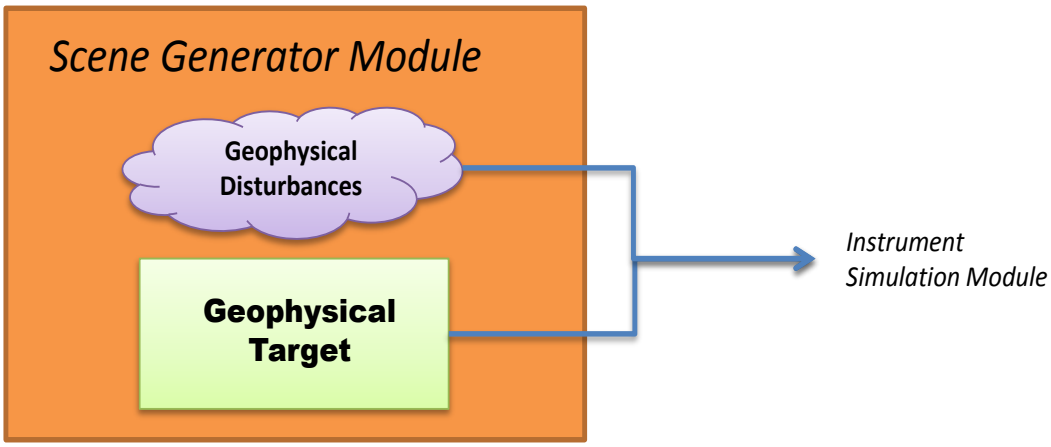

Fig. 3 Scene generator

The Geophysical Disturbances represent the effects observed by the instrument affecting the final measurements. E.g. active instrument as Synthetic Aperture Radar can be affected by Ionosphere while targeting the Geophysical ground backscattering; Lidar instrument observing the wind speed can be affected by the Earth motion.

Any geometrical calculation needed e.g. sun/star position, satellite position, line of sight, visibility needed, for example, to limit the spatial range or directions in which the scene have to be generated are computed by relying on functionalities provided via the common Geometry Module.

~~3.2.2~~3.2.3 *The Instrument Simulator*

The *Instrument Simulator* implements the transfer function represented by the instrument based on the input scene generated by the scene generator, it implements an appropriate modelling of the instrument and it outputs the measurement and its ancillary data as they are generated on board.

Any user-defined errors (e.g. Gaussian measurement noise, biases, drifts, vibrations, harmonic oscillation, thermo elasticity, mis-pointing, etc.) are implemented to produce the affected on-board generated data. The instrument modelling makes use of constructive or engineering values, which need to be used also during the ground processing; these data is contained in AUX files.

Any geometrical calculation needed e.g. sun/star position, satellite position, instrument pointing, line of sight, occultation, eclipses, visibility needed, for example to select the visible stimuli or to compute the impact of sun illumination on detectors, thermal variation impacting or deforming the instrument geometry, is achieved by relying on functionalities provided via the common Geometry Module

In analogy to a passive instrument where the scene information consists of TOA stimuli, an active instrument receives also as input the Scene information which are however not direct stimuli but represent the interaction between the active part and the target allowing the instrument simulatort to compute the response. The information flow of an active instrument simulator is presented in Fig. 4

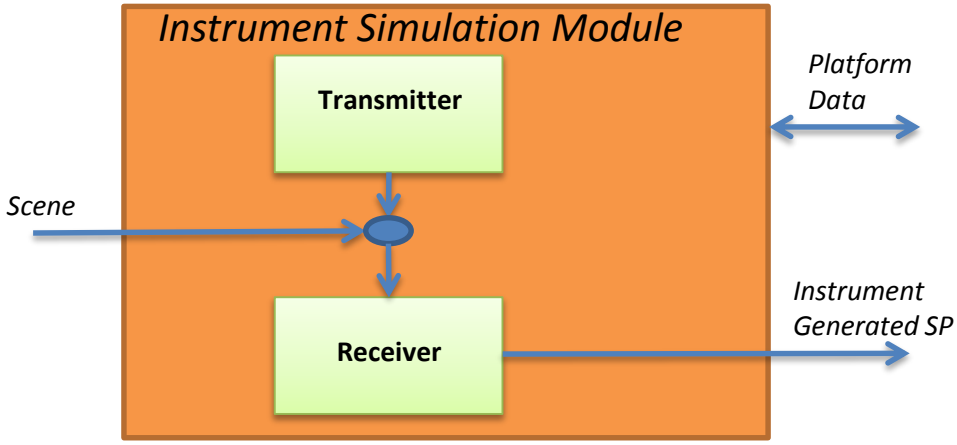

Fig. 4 ISM (example for an active instrument)

In this case (e.g. a SAR) the transmitted signal is convoluted with the target simulated by the Scene generator and the geophysical disturbances are applied. The modified signal is then converted in the receiver to generate the instrument packets.

~~3.2.3~~3.2.4 *The Platform and On-Board data generation*

The *Platform and On-Board data generation* function implements the simulation of any platform function needed directly by the instrument model or needed in order to generate the data in format compliant to the space to ground interface Space Source Packet data (i.e. RAW) e.g. by simulating GPS, AOCS, temperatures, timing and data formatting functions.

This function will also generate any HKTM source packet (ANC) that is produced on-board and that is needed on-ground to perform the processing when the corresponding parameter has not been included directly in the instrument generated telemetry.

Any geometrical calculation needed e.g. sun/star position, satellite position, attitude, etc needed, for example to provide inputs to the instrument model or to generate ancillary (ANC) HKTM, is done by relying on functionalities provided via the common Geometry Module.

3.3 The Ground Segment Simulation

For reference a view of the dataflow within a generic Earth Observation ground segment is shown here in Fig. 5.

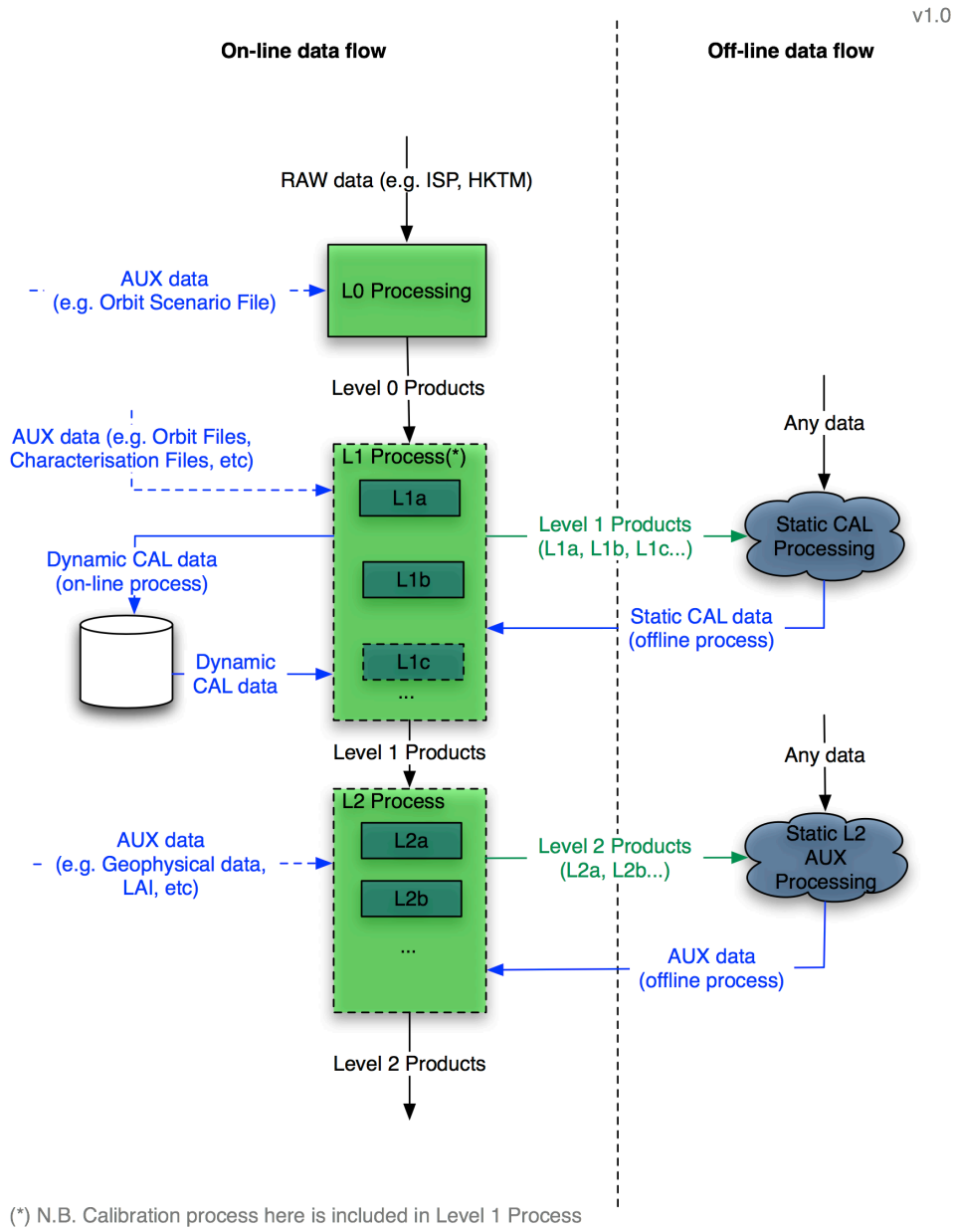

Fig. 5 Generic view of dataflow in an Earth Observation data processing Ground Segment

3.3.1 *The Level 1 Processor Prototype*

Within this context the *L1 Processor Prototype* (L1PP) processes Level 0 data into Level 1 and Calibration data (including therefore also the dynamic calibration function). In doing so it ingest

Level-0, Auxiliary data and Calibration data. The *generic* functionality of Level 1 processing is indicated in Fig 6 here below.

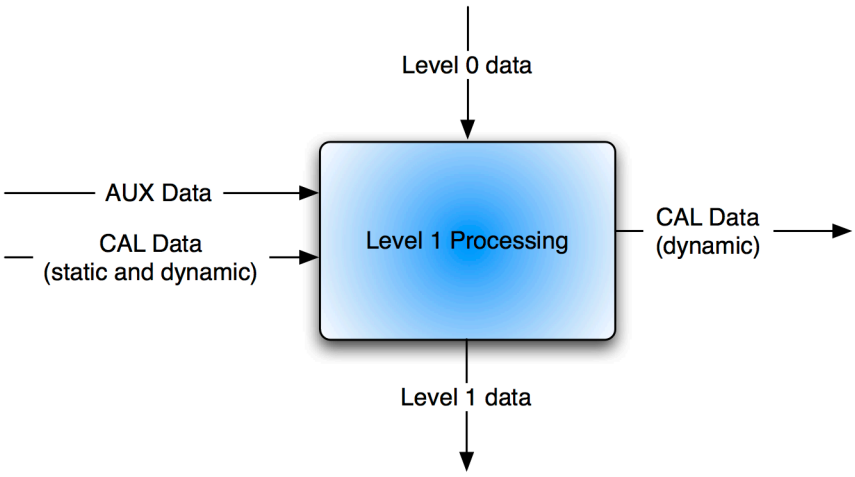

Fig. 6 Generic Level 1 Processing function

Nomenclature Note:

- *dynamic CAL* data are the ones automatically produced by the L1PP during the processing of data from nominal or calibration modes of the instrument and used automatically in the processing chain (either internally or externally).
- *static CAL* data are data produced by the L1PP processor (also via dedicated CAL processors) and which are not automatically used in the processing chain. Use of static CAL data in the processing chain is implemented only following human review/intervention/authorisation operation (e.g. a permanent update of a table of sensor gain parameters following some ad-hoc observation of a calibration target). From the point of view of data flow the static CAL data are like AUX data or can be used as such.

NB: It is common practice that the instrument characterisation quantities (e.g. gains, conversion factors, offsets, mis-pointing, biases, etc) are described in so called CCDB files. These files belongs to the AUX file category and treated as such with respect to the data flow and selection rules (e.g. versioning and validity) i.e. there is no special separated handling.

L1PP is to be developed with the following objectives:

a) to serve as an element in the chain of the E2E Performance Simulator
b) to serve as the baseline and reference for the development of the L1 Operational processor (e.g. production of DPMs) and to support commissioning standalone.

c) Optionally to be transformed into an L1 Operational Processor module to be integrated into an Operational Ground Segment.

While the L1PP is to be developed in the E2E Performance Simulator first and then to evolve as the algorithm baseline for the Ground Segment, there is also the need to support Ground Segment development by developing an early L1PP *mock-up* with I/F stubs (compatible with the expected Ground Segment) prior to inclusion of actual algorithms. Subsequently these components must converge and the same software module is to be usable for both purposes.

Maintaining the same L1PP interfaces allows first the direct re-use of the L1PP module part of the E2E Performance Simulator and later the repatriation of any improvement in the L1PP standalone into the E2E Performance Simulator. This will ensure coherency between Space Segment Performance assessment and Ground Segment ones.

The L1PP detailed processing models will be used as the specification of the algorithms of the operational processors required for the overall mission. Therefore the L1PP will be developed strictly taking into account the operational data flow concepts and formats.

The L1PP will be then used for the following purposes:

a) Performance simulation on simulated data
b) Instrument and algorithm performance assessment on data from AIV/AIT on-ground pre-launch measurements
c) Algorithm's evolution and improvement
d) Instrument calibration using data from AIV/AIT on-ground pre-launch calibration
e) Instrument and algorithm performance assessment using in-flight data (in particular during commissioning phase);
f) Monitoring (e.g. instrument performance aspects).
g) Analyses.

The L1PP will be made available to various scientific actors supporting <MISSION-X>. Any contribution from this external use that would allow further improvement of the L1PP will be repatriated.

3.3.2 *The Level 2 Processor Prototype*

Within this context the *L2 Processor Prototype* (L2PP) processes Level 1 data into Level 2 and geophysical parameters to allow performance evaluation at level of geophysical parameters (L2). In doing so it ingests Level-1 and Auxiliary data and output Level-2 products.

NB: due to the fact that the definition of the Level-2 products normally comes later in a mission lifetime the L2PP included in the E2E Performance Simulator might also only provide geophysical data not formatted as a Level-2 Data product.

L2PP is to be developed with the following objectives:

a) to serve as an element in the chain of the E2E Performance Simulator
b) to serve as the baseline and reference for the development of the L2 Operational processor (e.g. production of DPMs) and to support commissioning standalone.
c) optionally to be transformed into an L2 Operational Processor module to be integrated into the Operational Ground Segment.

3.4 The Test Data

A reference test data set (TDS) is needed during the acceptance of the E2E and L1PP modules as well as to be used as reference TDS for the L1OP and ground segment.

The deliverable TDS shall be generated using the E2E Performance Simulator and will include nominal and non-nominal cases (to be agreed with ESA) as well as examples of all possible modes/data types/calibrations of <MISSION-X>. In case the processing performance of the E2E does not allow generation of the required TDS as it would take too long, an approach commonly used is to generate a core TDS using the E2E and then duplicate and recondition using a separate software the data to simulate a longer data set.

The TDS shall comprise the following elements:

a. Infrastructure (openSF) related Items, i.e. Configuration files, scenarios, scripts
b. Output of the simulation chain: generated RAW data (Observation (ISP), Ancillary (ANC)), Auxiliary Data File (AUX), Level 0.

c. Output of the processing chain within the L1PP: L1 Product, Calibration Product corresponding to the input b)
d. Output of the processing chain within the L2PP: L2 Products and auxiliary files (e.g meteo) corresponding to the input c)
e. any auxiliary software tool needed to reproduce the TDS generation.

4 GENERAL AND SOFTWARE REQUIREMENTS

4.1 Architecture and general functions

E2E-ARC-GEN-010
The E2E Performance Simulator shall be composed of the following modules

1) Geometry Module (GM)
2) Scene Generator Module (SGM)
3) Instrument Simulator Module (ISM)
4) Platform and On-Board Data Generation Module (ODGM)
5) L1 Processor prototype Module (L1PP)
6) L2 Processor Prototype Module (L2PP)
7) Performance Assessment Module (PAM)

E2E- ARC -GEN-015
The internal and external E2E data flow shall be representative of the high level data flow related to the -<MISSION-X> within the operational Ground Segment as per Fig 2.

E2E-ARC-GEN-020
Geometry Module (GM)
The geometry module shall implement all functions related to geometry and provides them to the other modules as needed, e.g. Orbit Propagation (PVT), Attitude Determination (Quaternions), Field Of View and Coverage areas, etc. It shall support both stand-alone mode (e.g. internal orbit propagation) and ingestion of externally generated Orbit and Attitude data (e.g. Predicted, Restituted or externally simulated) providing an abstraction layer to the actual source of data respect to the rest of the module.

E2E-ARC-GEN-030
Scene Generator Module (SGM):
The scene generator module shall generate a simulation of the geophysical target based on a user-defined scenario. It shall also generate the stimuli TOA to the Instrument Simulator (ISM) by implementing the forward model from the geophysical target (which represents the reference truth within the E2E Performance Simulator), it shall therefore also include any simulation of the Atmosphere needed.

E2E-ARC-GEN-040

Instrument Simulator Module (ISM):
The instrument simulator module shall implement the simulation of the instrument based on the input stimuli from the SGM, the geometrical conditions (with input from GM) and the simulation of any internal modelling needed to evaluate the mission performance including instrument configuration. The ISM shall include functionality to inject errors in both measured stimuli as well as to simulated instruments characteristics. It shall implement the generation of data corresponding to every calibration mode of the instrument. It shall implement any additional platform simulation needed as input for the modelling (e.g. thermal, electrical, AOCS, propulsion, environmental conditions) and allow application of representative errors. It shall generate instrument output in the format of Instrument Source Packet telemetry.

E2E-ARC-GEN-050
Platform and On-Board Data Generation Module (ODGM):
The Platform and On-Board Data Generation Module(s) shall simulate and produce any platform-generated HKTM Source Packets in the real satellite packet format needed for ground processing e.g. PVT, AOCS, Temperature, etc (the data needed by its functionality may be internally produced or coming from ISM). It shall also perform any eventual processing/modification that the platform might apply to the Instrument generated Source Packet (e.g. time stamping, etc.)

E2E-ARC-GEN-060
L1 Processor Prototype Module (L1PP):
The L1 Processor prototype module shall ingest satellite data (both RAW and Level 0 formats) and implement the level 1 Processing including any calibration function needed i.e. produce both of Calibration data and Level 1 products. It shall ingest any necessary Auxiliary data (e.g. Characterisation data, off-line calibration data, restituted orbit and attitude data, etc) as would be available in actual ground processing.

E2E-ARC-GEN-070
L2 Processor Prototype Module (L2PP):
The L2 Processor prototype module shall ingest Level 1 data and implement the level 2 Processing to generate Level 2 products and provide with it the necessary inputs to the PAM to perform the end-to-end comparison of retrieved geophysical quantities with the simulated one. In doing so it shall also ingest any necessary Auxiliary data files (e.g. Characterisation data, off-line calibration data, orbit and attitude data, etc) as would be available in actual ground processing.

E2E-ARC-GEN-080
Performance Assessment Module (PAM):
The performance assessment module shall compare the calculated L1 outputs with the instrument stimuli generated by the Scene Generator module, it shall produce statistics, analysis, error characterisation and verification of error propagation and it shall support the verification of all Space Segment Requirements related to L1 quantities

4.2 Development/software Requirements

4.2.1 *Environment and common libraries*

E2E-ENV-GEN-010
The E2E performance simulator and all its modules including the L1PP and the L2PP shall be developed and execute on an x86 Linux Operating System environment.

E2E-ENV-GEN-020
Linux environment should be based on Open Source free distributions (e.g. OpenSUSE, Fedora, Ubuntu).

E2E-ENV-GEN-030
All development shall use permissive licence open source packages (e.g. BSD,LGPL), compiler, tools unless duly justified.

E2E-ENV-GEN-040
The E2E Performance simulator shall be developed based on the openSF infrastructure [AD07]

E2E-ENV-GEN-050
All modules shall be written in a compiled language C or C++. The compiler used shall ***<Mission Specific>***. This requirements applies to Phase C/D. During Phase 0 and Phase A/B Module might initially be written in other languages as supported by openSF e.g. Phyton, Fortran, Matlab, IDL, Java)

NB. If no specific external software environment is dictated for <MISSION_X>, the recommended compiler at the moment of issuing this documents are: ***gcc 4.7, or llvm 3.6 (clang) or newer***

E2E-ENV-GEN-060
All code shall be written in a portable way across 64 bit Unix platforms (Linux, OSX, Cygwin).

E2E-ENV-GEN-070
The E2E performance simulator, the L1PP and the L2PP shall make use for all orbit, attitude and geometrical calculation of the EO Mission software [RD1] libraries version 4.11 or higher. (http://eop-cfi.esa.int).

E2E-ENV-GEN-080
The L1PP and the L2PP shall support multithreading and parallel processing by using the OpenMP library 3.x or newer

E2E-ENV-GEN-090
All non-binary files shall be based on XML as per [AD-14]

E2E-ENV-GEN-100
GPU support shall be implemented using openCL 1.2

4.2.2 *Other software requirements*

E2E-OTH-GEN-010
All software deliveries shall be full i.e. no patches.

E2E-OTH-GEN-020
Every software delivery shall include an installation kit to automatize the installation including *clean-up* of previous version.

E2E-OTH-GEN-030
It shall be possible to execute every E2E module as standalone i.e. outside the E2E simulator environment.

E2E-OTH-GEN-035
Deliverable shall include all configuration and data items to perform the Verification as per SSVP.

E2E-OTH-GEN-040
The software shall provide means to automatically validate all non-binary input files: e.g. XML inputs shall use of schema as validation tool [ADX].

E2E-OTH-GEN-050
The software shall be delivered with the ESA Community licence Type 3 allowing ESA free distribution/use of the developed software.

4.2.3 *Miscellanea*

E2E-OTH-GEN-060
All deliverables shall be covered by 12 month warranty for corrective maintenance or bug fix.

E2E-OTH-GEN-070
All software shall be kept under strict Configuration using a CM tool (e.g. SVN, GIT)

E2E-OTH-GEN-080
The Contractor shall provide an on-line SPR tracing/ticketing system

5 FUNCTIONAL REQUIREMENTS

The requirements described in this section apply to the overall E2E performance simulator and need to be implemented by the framework or by any of the modules/tools (e.g. compare functionality is not implemented by the openSF framework but rather by a dedicated tool/module)

5.1 General Functional Requirements

E2E-FUN-GEN-010

The E2E shall process:

- Observation data (RAW);
- Ancillary (ANC) data;
- Real or simulated level 0 data;
- Real or simulated level 1 data;
- Auxiliary (AUX) data

into

- Level 0 data;
- Level 1 data;
- Level 2 data;
- L1 and L2 Performance assessment and compliance reports;
- Calibration data (CAL)
- Breakpoints (BRK)

E2E-FUN-GEN-020

The E2E shall include functionality to allow:

- Controlling and monitoring the E2E operation
- Managing its related data (input, output, databases).

E2E-FUN-GEN-030

The E2E shall include functionality to allow:

- Computing the geometric, and other <MISSION-X> specific performance indicators;
- Optimising the instrument settings as function of the level 1 processing results;
- Assessing of the data quality;
- Assessing of the overall <MISSION-X> performance;
- Statistical analysis of the instrument behaviour over configurable range of data and simulation time;

E2E-FUN-GEN-040

The E2E shall allow the use of the E2E in different user selectable configurations. It shall be possible for the users to select independently of the configuration the source of the inputs and the destination of the outputs.

E2E-FUN-GEN-050

The E2E functions shall be able to simulate and in any of the operational conditions encountered by the instrument throughout its life, for example:

- In any season,
- In eclipse or during day-time;
- At Beginning Of Life (BOL) or at End Of Life (EOL).

E2E-FUN-GEN-060

The E2E shall include function for the quality assessment of the calculations performed and of the data produced (format and content)

E2E-FUN-GEN-070

The E2E shall be capable of execute dedicated software components for calculating new calibration data; this execution shall be based both on automatic data trigger and manual invocation.

E2E-FUN-GEN-080

The E2E shall include modules to support functionalities to compare E2E datasets with reference datasets acquired through external means (e.g. on-ground measurements and/or data from other operational satellite instruments) with TBC format.

E2E-FUN-GEN-090

The E2E (modules) shall be able to export and import all data (in particular AUX and CAL) using the operational format used in the actual ground segment.

E2E-FUN-GEN-100

The E2E shall store and load available all the configuration data needed for the operations of its internal modules.

E2E-FUN-GEN-110

Once configured and started the E2E performance simulator shall be able to run unattended without any user intervention.

E2E-FUN-GEN-120

The E2E and all its modules shall be able to handle gracefully any error.

Rationale: Errors shall not lead to a crash of the software.

Note: The way in which errors are handled is left to the detailed design phase. Errors can for example be handled by writing self-explanatory messages to the log file or flag impacted data or gracefully terminate the processing.

E2E-FUN-GEN-130

All the E2E modules shall be able to correctly handle geometric boundary conditions.

Note: Geometric boundary conditions are, for example, terminator crossing, day / night transitions, date/line, etc

E2E-FUN-GEN-140

The E2E and all his modules shall be able to correctly handle date and time boundary conditions.

Note: Date and time boundary conditions are, for example, time zone crossing, daylight saving transitions, leap years and leap seconds.

E2E-FUN-GEN-150

The way to operate and use the E2E and any of its modules shall be independent of the type of data used when multiple type are possible e.g. L1PP Module shall be able to perform all its functions regardless if the input is Level-0 or RAW.

E2E-FUN-GEN-160

The E2E and all his modules shall be able to process / handle all possible <MISSION-X> instrument(s) configuration and settings.

NB This requirement address the general common case where each instrument can be considered in isolation. Missions including multiple synergetic instruments either on-board or on ground should define requirements to ensure the architecture support the synergetic data flows/functionality.

E2E-FUN-GEN-170

The E2E Performance Simulator shall allow a time-based scenario orchestration function to allow batch test data generation, execution of processing and performance assessment reporting.

E2E-FUN-GEN-180
The E2E scenario orchestration function of E2E-FUN-GEN-170 shall allow the definition of list of changes of the instrument mode of operation on a time basis e.g. 10 minutes in mode A, 5 minutes mode B, etc

E2E-FUN-GEN-190
It shall be possible in the E2E Performance Simulator to define, save and load the time-based scenarios.

E2E-FUN-GEN-200
It shall be possible to use the E2E Performance Simulator to generate RAW and Level-0 Test Data Sets to be used in the GS validation.

E2E-FUN-GEN-210
The E2E Performance Simulator shall allow the user to injection errors of applicable type to the space segment simulation including among others: atmospheric modelling, platform behaviour, instrument behaviour including also data stream errors (e.g. gaps).

E2E-FUN-GEN-210
The E2E Performance Simulator shall allow execution automatically simulations with variable amounts of errors or bias within a user configurable range to e.g. support the execution of sensitivity analysis.

E2E-FUN-GEN-220
It shall be possible, in a single operation, to save and load the overall simulation context to reproduce on a separate instance of the E2E simulator exactly the same configuration.

E2E-FUN-GEN-230
Every module shall verify the correct formatting of any input data and be robust to any format error. In case of a format error is detected a meaningful error message shall be issued which shall include at least: filename, position/location of the error, expected value, encountered value.

E2E-FUN-GEN-240
Every module shall allow for different severity category of messages as: DEBUG, INFO, WARNING, ERROR (TBC wrt openSF constraint).

E2E-FUN-GEN-250
It shall be possible to enable or disable the generation of each category of messages.

E2E-FUN-GEN-260
It shall be possible to run different versions of the E2E on the same computer.

E2E-FUN-GEN-270
It shall be possible to execute the E2E simulator from 2 different user accounts and keep all configuration and all data separated.

E2E-OUT-GEN-280
The output data shall include a log of the E2E runs:

- An E2E run identifier;
- The simulation support data;
- Any support data if used;
- The conditions under which the E2E is operating, including a reference to all the input data used in the run and to all the output data generated; a summary of the main features of the run (e.g. E2E configuration, E2E version/release number, mode of operation, functions inhibited, settings, etc.) shall also be included;
- The status of all the E2E functions during the E2E operation;
- The content of the E2E internal variables, as selected by the user;
- All non-nominal events;
- All real-time events;
- Duration of the L1PP, L2PP and PAM computations;
- Duration of the E2E simulation;
- Unique identifier.

5.2 Geometry Module (GMD) Functional Requirements

E2E-FUN-GMD-010
The GMD shall implement all common functions related to geometry and provides them to the other modules. These functions shall include at least:

- Orbit Propagation (PVT)
- Attitude Determination (Quaternions)
- Field Of View
- Line of Sight
- Coverage and Coverage areas
- Time functions
- Atmospheric line of sight modeling
- DEM and geolocation functions
- Celestial target calculation (sun, moon, etc)

- Support for calibration manoeuvres (e.g. special attitude modes)

E2E-FUN-GMD-020
The GMD shall be able to perform its function both in stand-alone mode (e.g. by mean of internal orbit propagation) or in externally driven mode (e.g. by ingestion of externally generated Orbit and Attitude data)

E2E-FUN-GMD-030
The GMD shall make use for its calculation of the EO CFI [RD1]

E2E-FUN-GMD-040
The GMD shall make use for its files (e.g. Orbit, Attitude, Zones, Swath definition, etc.) of a format compliant with EO CFI [RD1]

E2E-FUN-GMD-050
Within the E2E performance simulator the GMD shall consist of a standalone module with persistent data.

E2E-FUN-GMD-060
The GMD shall implement timing functions as well as process and handled in centralised way any discontinuity (e.g. leap seconds)

5.3 Scene Generation Module (SGM) Functional Requirements

E2E-FUN-SGM-010
The scene generator module shall implement and compute the geophysical target/values (the *truth*) based on a user defined scenario and data.

E2E-FUN-SGM-020
The scene generator module shall be able to ingest statically or dynamically all data needed to provide input to the forward model or to define the geophysical values (e.g. weather forecast or analysis data, maps, sun activity data, ice coverage maps, etc.)

E2E-FUN-SGM-030
The scene generator module shall take into account any external factor affecting the forward model or the geophysical target (e.g. sun illumination, AUX data, etc.)

E2E-FUN-SGM-040

The scene generator module shall implement the **forward model** to generate TOA stimuli based on the geophysical target and on observation geometry

E2E-FUN-SGM-050
The scene generator module shall generate the TOA stimuli taking into account the effect of atmosphere.

E2E-FUN-SGM-070
The scene generator module shall allow the user to configure if the atmospheric model is used (i.e. it shall be possible to switch it on-off)

E2E-FUN-SGM-080
The scene generator module shall allow the definition and automatic injection in the simulation of user-defined errors (biases, drifts, statistical errors, noise, time or space dependent) on any of its input data (including the atmospheric model) to simulate the effect that these errors would have on the generated TOA *stimuli.*

E2E-FUN-SGM-090
The scene generator module shall make available to the Performance Assessment Module all the inputs needed to perform comparison with the retrieved data, including at least: geophysical target data, injected errors (if any), BOA and TOA stimuli.

E2E-FUN-SGM-100
The scene generator module shall support the generation of calibration data in the ISM by generating the stimuli corresponding to external astronomical or ground based calibration target (e.g. sun, stars, moon, transponders)

5.4 Instrument Simulator Module (ISM) Functional Requirements

E2E-FUN-ISM-010
The Instrument Simulator Module shall perform the simulation of the <MISSION-X> instrument based on the input stimuli from the SGM, the geometrical conditions (with input from GM) and its internal implementation of the instrument modelling

E2E-FUN-ISM-020
The Instrument Simulator Module shall implement any additional platform simulation needed as input for the modelling (e.g. thermal, electrical, AOCS, propulsion, environmental conditions)

E2E-FUN-ISM-030

The Instrument Simulator Module shall be able to generate fully realistic measurement parameters as would be generated by the instrument in all its modes of operation including in particular every measurement and calibration mode.

E2E-FUN-ISM-035
The data and parameters used to characterize the instrument shall be contained in dedicated AUX files (e.g. Calibration and Characterisation DB files) and not hard coded…(FIX)

E2E-FUN-ISM-040
The output of the Instrument Simulator Module shall be formatted as RAW CCSDS Source Packets telemetry and with all fields and parameters fully representative of the one generated on-board including both scientific and ancillary parameters (e.g. timing, temperature, position, velocity etc).

E2E-FUN-ISM-050
The Instrument Simulator Module (together with the ODGM) shall provide to the (simulated) ground segment all the dynamically generated platform data, required by processing, in the same form, as they would be available in the actual ground segment. This shall apply in the case that the data is included as parameters within the Instrument Source Packets or is formatted as separate ancillary/HKTM source packets generated by the platform.(e.g. GPRS and Star Tracker source packets)

E2E-FUN-ISM-060
The ISM shall allow to define and automatically inject in the simulation, user-defined errors (e.g. bias, drifts, statistical errors, noise, linear, harmonic, time or space dependent) on any of its input data or internal modeling element to simulate the effect that these errors would have on the generated observation data.

E2E-FUN-ISM-070
The ISM shall allow configuring, the modeling of its internal operation as it would be done in the real instrument via TC whenever this affects the results (e.g. change of measurement integration time, delay windows, modification of calibration sequences executed on board as OBCP, etc). This configuration shall be performed via static auxiliary configuration file and shall not require any recompilation.

E2E-FUN-ISM-080
The ISM shall make use of the common services provided by the GMD for any operation requiring access to simulated position, timing, attitude, line of sight, visibility, occultation, manouvres etc.

5.5 Platform and On-Board Data Generation Module (ODGM) Functional Requirements

E2E-FUN-OGM-010
The ODGM shall implement all functions related to the generation of on-board RAW telemetry for both ISM and Platform in its final and complete form as it would appear on the space to ground link [S2GICD].

E2E-FUN-OGM-020
The ODGM shall interface with the ISM to simulate any needed platform parameter (e.g. Temperature, PVT, attitude, voltages, PPS pulse, etc.) needed by the ISM modelling.

E2E-FUN-OGM-030

The ODGM shall interface with the ISM to simulate any needed platform parameter (e.g. Temperature, PVT, attitude, voltages, OBT, GPS time, counters, etc), which needs to be included into the telemetry data generated in the ISM. This can be either be provided to ISM for inclusion or the OGMD can add it to the data generated by the ISM.

E2E-FUN-OGM-040
The ODGM shall support the generation of idle data both at level of instrument as well as of the platform.

E2E-FUN-OGM-050
The ODGM shall implement the generation of any other packet type generated on-board which is needed for the ground processing, e.g. GPS Packets, STR packets, AOCS Packets, HKTM packets.

E2E-FUN-OGM-060
The ODGM shall ensure that the simulated on-board data coming from different sources (instrument, AOCS, etc) is coherent wrt to timing (e.g. coherent timestamps) and to the environmental and geometrical conditions

E2E-FUN-OGM-070
The ISM shall make use of the common services provided by the GMD for any operation requiring access to simulated position, timing, attitude, line of sight, visibility, occultation, sun illumination etc.

E2E-FUN-OGM-070
Any Space packet data generated shall comply to the format as per [S2GICD]

5.6 Level 1 Prototype Processor (L1PP) Functional Requirements

E2E-FUN-L1PP-010
The L1 Processor prototype module shall ingest satellite data (both RAW and Level 0 formats) and implement the level 1 Processing including any calibration function needed and output both of Level 1 products and dynamic Calibration products (see Fig. 3) depending on the input.

E2E-FUN-L1PP-020
The processing of L1PP shall be implemented according to [L1ATBD].

E2E-FUN- L1PP-030

When fed with RAW data (instrument source packets), the L1PP shall implement a function to generate and output the corresponding Level-0 product prior performing L1 processing.

E2E-FUN-L1PP-040
The L1PP processor shall produce Level 1 products and Calibration products in format according to [L1IODS]

E2E-FUN-L1PP-045
The L1PP shall be compliant with the file naming convention of the Level 1 format definition as used in the operational Ground Segment.

E2E-FUN-L1PP-50
All inputs to L1PP (including in particular L0 and Calibration files) shall be marked as either as mandatory or as optional. A missing mandatory input shall result in no processing while a missing optional input shall result in degraded processing as defined in [L1ATBD] and marked as such by means of quality flag.

E2E-FUN-L1PP-060
The L1PP shall be able to directly ingest any necessary AUX data (e.g. Characterisation data, static calibration data, orbit and attitude data, etc) in the same format these would be available in actual ground segment.

E2E-FUN-L1PP-070
The L1PP shall allow the writing of intermediate BRK data (breakpoints) e.g. in between processing steps / internal algorithms, before after calibration etc.

E2E-FUN-L1PP-075
A user-enabled flag shall control generation of BRK within L1PP.

E2E-FUN-L1PP-080
The L1PP shall be a scalable wrt use of multiprocessors/multicore computer by making use a multi-threading architecture.

E2E-FUN-L1PP-085
The L1PP shall be capable of running multiple (independent) instances simultaneously on the same machine.

E2E-FUN-L1PP-087
The L1PP shall be fully re-locatable and make no assumptions on the machine that it is running, the directory it is running in, the directories where input and output files are expected etc.

E2E-FUN-L1PP-090

L1PP shall be able to work in 2 modes:
a) compatible with invocation as per openSF requirements [AD08] (when part of the E2E Perf. simulator)
b) standalone use (user invocation by command line)

E2E-FUN-L1PP-100
In the standalone mode, the L1PP shall be self-orchestrating including the selection of the observation and applicable calibration and auxiliary data to allow stand alone use (i.e. does not need any external job order generation).

E2E-FUN-L1PP-110
In the standalone mode, while executing, the L1PP shall be data-driven i.e. performing the RAW/L0 to L1 processing based on automatically detecting the presence of process-able data in an input directory (i.e. no repeated manual invocation from command line needed)

E2E-FUN-L1PP-120
The L1PP shall include (when running stand-alone) an “abort/suspend” command to gracefully interrupt the processing.

E2E-FUN-L1PP-130
The L1PP shall be able (when running stand-alone) to resume the processing interrupted with “abort/suspend” taking as input the intermediate products.

E2E-FUN-L1PP-135
The L1PP shall not require any user interaction to allow batch processing.

E2E-FUN- L1PP -140
The L1PP shall be able handle changes in the <MISSION-X> operational baseline without requiring recompilation, i.e. it shall not assume a hard-coded sequence of operating modes. Any such sequence shall be implemented if needed as dynamic configuration items.

E2E-FUN-L1PP-145
Limit processing by time range: The L1PP shall have the capability to limit the data processing to a time range that can be specified using run-time configuration.

E2E-FUN-L1PP-147
Limit processing by instrument measurement mode: The L1PP shall have the capability to limit the data processing to a set of one or more measurement mode that can be specified using run-time configuration (e.g. only process Space Packet of specific APID).

E2E-FUN-L1PP-150
The L1PP shall be able perform aggregate/accumulate calculations that span multiple measurements/time intervals e.g. averaging of several measurements on a sliding window or determining a median across multiple measurements.

E2E-FUN-L1PP-160
The L1PP shall be designed to allow easy replacement, additions or removal of algorithms without or with minimal changing of the architecture or structure of the L1PP software, e.g. by use of dynamic libraries

E2E-FUN-L1PP-170
The internal and external L1PP data flow shall be representative of the high level data flow related to the -<MISSION-X> within the operational SG Ground Segment (see Fig. 3).

E2E-FUN-L1PP-172
The L1PP processing shall include any needed correction (e.g. for radiometry, geometry, etc) as specified in [L1ATBD]

E2E-FUN-L1PP-173
The L1PP shall calculate geo-location for all parameters as specified in [L1ATBD] and [L1IODS]

E2E-FUN-L1PP-175
The L1PP shall be able to calculate/estimate the precision of the generated Level 1 parameters.

E2E-FUN-L1PP-178
The L1PP shall compute and output all values needed on-line or off-line (e.g. by the PAM or by an offline Monitoring Facility) to evaluate the instrument performance trend monitoring from L0 and L1 data

E2E-FUN-L1PP-180
The L1PP shall be able to interpret and consider during processing, data quality flags set on-board and included in the instrument measurement data, instrument ancillary data and satellite ancillary data.

E2E-FUN-L1PP-190
The L1PP shall be able to identify, process (where possible) and flag degraded input data including:
- Duplicated packets;

- Corrupted and missing packets, instrument measurement samples and parameters;
- Time and spatial gaps (when applicable)
- Instrument parameters/measurements out of nominal range.

E2E-FUN-L1PP-200
The L1PP shall define and perform automated quality checks and update the corresponding quality flags in the output products.

E2E-FUN-L1PP-210
The L1PP shall flag and report about any degraded output data in the metadata part of the output products.

E2E-FUN-L1PP-220
The L1PP shall be able to generate the L1 and Calibration products even in case of corrupted input files (when this is possible as per [ATBD]), and in such a case it shall flag output as degraded quality.

E2E-FUN-L1PP-230
The L1PP shall generate and annotate in the metadata part of the output L1 products all performance parameters and quality indicators to be monitored during in orbit instrument operations, including the results of consistency checks on input and on output data.

E2E-FUN-L1PP-240
The L1PP software shall rely for all geometrical, orbital or attitude calculations only on internal algorithm and on data available within its input data files i.e. shall not interface with the GMD used in the simulation part of the E2E.

5.7 Level 2 Prototype Processor (L2PP) Functional Requirements

E2E-FUN-L2PP-010
The L2 Processor prototype module shall ingest Level 1 data, perform the level 2 Processing and produces the Level 2 products.

E2E-FUN-L2PP-020
The processing of L2PP shall be implemented according to [L2ATBD].

E2E-FUN-L2PP-040
The L2PP processor shall produce Level 2 products in format according to [L2IODS]

E2E-FUN-L2PP-045
The L2PP shall be compliant with the file naming convention of the Level 2 format definition as used in the operational Ground Segment.

E2E-FUN-L2PP-050
All inputs to L2PP (including in particular L1 and Calibration files) shall be marked as either as mandatory or as optional. A missing mandatory input shall result in no processing while a missing optional input shall result in degraded processing as defined in [L2ATBD] and marked as such by means of quality flag.

E2E-FUN-L2PP-060
The L2PP shall be able to directly ingest any necessary AUX data (e.g. geophysical data, meteo data, orbit and attitude data, etc) in the same format these would be available in actual ground segment.

E2E-FUN-L2PP-070
The L2PP shall allow the writing of intermediate BRK data (breakpoints) e.g. in between processing steps / internal algorithms, etc.

E2E-FUN-L2PP-075
A user-enabled flag shall control generation of BRK within L2PP.

E2E-FUN-L2PP-080
The L2PP shall be a scalable wrt use of multiprocessors/multicore computer by making use a multi-threading architecture.

E2E-FUN-L2PP-085

The L2PP shall be capable of running multiple (independent) instances simultaneously on the same machine.

E2E-FUN-L2PP-087
The L2PP shall be fully re-locatable and make no assumptions on the machine that it is running, the directory it is running in, the directories where input and output files are expected etc.

E2E-FUN-L2PP-090
L2PP shall be able to work in 2 modes:
a) compatible with invocation as per OpenSF requirements [AD08] (when part of the E2E Perf. simulator)
b) standalone use (user invocation by command line)

E2E-FUN-L2PP-100
In the standalone mode, the L2PP shall be self-orchestrating including the selection of the observation and applicable auxiliary data to allow stand alone use (i.e. does not need any external job order generation).

E2E-FUN-L2PP-110
In the standalone mode, while executing, the L2PP shall be data-driven i.e. performing the L1 to L2 processing based on automatically detecting the presence of process-able data in an input directory (i.e. no repeated manual invocation from command line needed)

E2E-FUN-L2PP-120
The L2PP shall include (when running stand-alone) a “abort/suspend” command to gracefully interrupt the processing.

E2E-FUN-L2PP-130
The L2PP shall be able (when running stand-alone) to resume the processing interrupted with “abort/suspend” taking as input the intermediate products.

E2E-FUN-L2PP-135
The L2PP shall not require any user interaction to allow batch processing.

E2E-FUN- L2PP -140
The L2PP shall be able handle changes in the <MISSION-X> operational baseline without requiring recompilation, i.e. it shall not assume a hard-coded sequence of operating modes. Any such sequence shall be implemented if needed as dynamic configuration items.

E2E-FUN-L2PP-145

Limit processing by time range: The L2PP shall have the capability to limit the data processing to a time range that can be specified using run-time configuration.

E2E-FUN-L2PP-147
Limit processing by instrument measurement mode: The L2PP shall have the capability to limit the data processing to a set of one or more measurement mode that can be specified using run-time configuration (e.g. only process L1 data from a specific instrument mode).

E2E-FUN-L2PP-150
The L2PP shall be able perform aggregate/accumulate calculations that span multiple measurements/time intervals e.g. averaging of several measurements on a sliding window or determining a median across multiple measurements

E2E-FUN-L2PP-160
The L2PP shall be designed to allow easy replacement, additions or removal of algorithms without or with minimal changing of the architecture or structure of the L2PP software, e.g. by use of dynamic libraries

E2E-FUN-L2PP-170
The internal and external L2PP data flow shall be representative of the high level data flow related to the -<MISSION-X> within the operational SG Ground Segment.

E2E-FUN-L2PP-172
The L2PP processing shall include any needed correction as specified in [L2ATBD]

E2E-FUN-L2PP-175
The L2PP shall be able to calculate/estimate the precision of the generated level 2 parameters.

E2E-FUN-L2PP-178
The L2PP shall compute and output all values needed (e.g. by the PAM or by an offline Monitoring Facility) to evaluate the geophysical mission performance.

E2E-FUN-L2PP-180
The L2PP shall be able to interpret (within the L1 Product) and consider during processing, data quality flags set on-board and included in the instrument measurement data, instrument ancillary data and satellite ancillary data and propagated.

E2E-FUN-L2PP-190

The L2PP shall be able to identify, process (where possible) and flag degraded input data including:

- Time and spatial gaps (when applicable)
- L1 values out of nominal range or unrealistic from geophysical point of view.

E2E-FUN-L2PP-200
The L2PP shall shall define and perform automated quality checks and update the corresponding quality flags in the output products.

E2E-FUN-L2PP-210
The L2PP shall flag and report about any degraded output data in the metadata part of the output products.

E2E-FUN-L2PP-220
The L2PP shall be able to generate the L2 products even in case of corrupted input files (when this is possible as per [ATBD]), and in such a case it shall flag output as degraded quality.

E2E-FUN-L2PP-230
The L2PP shall generate and annotate in the metadata part of the output L2 products all performance parameters and quality indicators to be monitored during in orbit instrument operations, including the results of consistency checks on input and on output data.

E2E-FUN-L2PP-240
The L2PP software shall rely for its processing only on internal algorithm and only on data available within its input data files i.e. shall not interface with the SGM used in the simulation part of the E2E.

5.8 Performance Assessment Module Functional Requirements

E2E-FUN-PAM-010
The PAM shall assess the instrument and L1PP performance by comparing the calculated L1PP outputs with the instrument Stimuli generated by the Scene generator module

E2E-FUN-PAM-020
The PAM shall assess the end-to-end mission performance by compare the calculated L2PP outputs with Geophysical model used as input to the Scene generator module

E2E-FUN-PAM-030

The PAM shall allow the characterisation of the end-to-end chain behaviour and assessment of <MISSION-X> sensitivity (e.g. different AUX/CCDBs files) to different geophysical input scenarios

E2E-FUN-PAM-040
The PAM shall allow the characterisation of the end-to-end chain behaviour and assessment of <MISSION-X> sensitivity to different instrument configurations and all operating modes.

E2E-FUN-PAM-050
The PAM shall allow characterisation of the end-to-end chain behaviour with respect to errors and performance with respect to errors (e.g. sensitivity of retrieved L1 or L2 to instrument errors or to error in the needed AUX data)

E2E-FUN-PAM-060
The PAM shall compute the necessary performance quantifiers to demonstrate compliance to the <MISSION-X> space segment Requirement Specifications [XXX] including both sensing (e.g. radiometric) and spatial (e.g. geometrical) domains.

E2E-FUN-PAM-070
The PAM shall implement the generation of any *static/off-line* CAL product (used as AUX in input to the L1PP). The format of these files shall be fully compliant to the one used in the Ground Segment.

E2E-FUN-PAM-080
The PAM shall produce statistics and accumulated results in support to requirement verification

E2E-FUN-PAM-090
deleted

E2E-FUN-PAM-100
The PAM shall perform consistency check of all its inputs both internal and across results

E2E-FUN-PAM-110
The PAM modules generating static/off-line CAL and AUX product shall be able to operate in standalone mode, i.e. independently form the other modules making up the Performance Assessment Module and triggered both automatically and manually.

E2E-FUN-PAM-120
Seasonal and long term dependencies shall be reflected in the calibration data sets (CAL/AUX), which are generated by the PAM as input for the L1PP.

E2E-FUN-PAM-130
The PAM shall provide tools for the optimisation of detection chain settings as function of characterisations and calibrations, according to the design and algorithms provided by the instrument supplier.

E2E-FUN-PAM-140
The PAM shall be able to support both on-ground (e.g. ingestion of data produced during AIV and support of its modes) and in-flight activities.

E2E-FUN-PAM-150
The PAM shall include tools to support
- Modification of instrument parameters (e.g. AUX files);
- Modification of calibration algorithm parameters;

E2E-FUN-PAM-160
The PAM shall be able to compute:
- TBD parameters

E2E-FUN-PAM-170
The PAM shall be able to produce comparison output in graphical form (line, histogram, etc) in .png and pdf format.

E2E-FUN-PAM-180
The PAM shall be able to produce summary reports in user-friendly format (e.g. PDF, web page, XML + Stylesheet).

E2E-FUN-PAM-190
The PAM shall be able to produce its output and performance assessment report in less than 2 minutes after an E2E simulation for corresponding to 1 day of observations has completed.

E2E-FUN-PAM-200
It shall be possible for the user to superimpose on the plots from E2E-HMI-GEN-050 lines representing the required performance, in order to allow a direct comparison between them.

E2E-FUN-PAM-210
It shall be possible for the user to zoom in and out on the plots.

E2E-FUN-PAM-220

It shall be possible for the user to superimpose the measured performance parameters of two different evaluation periods (neither necessarily consecutive nor equal length), in order to allow a direct comparison between them.

5.9 Support functions requirements

E2E-FUN-FCT-010

The E2E Performance Simulator shall include “Support Functions” to complement and extend the native capabilities of openSF.

E2E-FUN-FCT-020

The Support functions shall allow the User to control and monitor of the E2E:

- Selection of the release/version number to be used in the E2E run;
- Initialisation and definition of the E2E functional configuration and internal settings;
- Management of any interface external to E2E;
- Management of human-computer interface;
- Monitoring of the E2E operations;
- Detection and flagging of run-time errors;
- Logging of information related to the simulation run;

E2E-FUN-FCT-030

The Support functions shall allow user management of E2E data (e.g. input data, output data, databases), i.e. generating, preparing, viewing, modifying, merging, maintaining, versioning, deleting, archiving, monitoring and retrieving all data required in the initialisation, parameterisation and operation of the E2E.

E2E-FUN-FCT-040

The support functions shall provide tools to generate and manage the following:

- Initialisation of parameter data for the Scene Generation (scenario);
- Initialisation of parameter data for the Instrument Data Simulator;
- Initialisation of parameter data for the Platform and On-Board Data Generation Module;
- Initialisation of parameter data for the L1PP;
- Initialisation of parameter data for the L2PP;
- Initialisation of parameter data for the PAM;

E2E-FUN-FCT-050

The support functions shall provide tools to relate the outputs of any E2E run to the data sets that were used as inputs (e.g. using file identifiers with run number, date of run, unique measurement identifiers), so that the conditions that generated the outputs can be easily traced.

E2E-FUN-FCT-060

The support functions shall provide the user with a real-time message that when out-of-limit conditions or run-time errors have occurred during the E2E run. Different levels of error identification shall be provided by the E2E to ensure rapid identification of non-valid user inputs and non-nominal E2E operation.

6 OPERATIONAL REQUIREMENTS

This section specifies the operational requirements of the E2E.

6.1 General operational requirements

E2E-OPE-GEN-010
The E2E shall be capable of simulating unattended a scenarios of at least 7 days.

E2E-OPE-GEN-020
The user shall include the provision of removing or by-passing the execution of TBD E2E functions during operation, e.g. in order to speed up the preparation and conduct of E2E runs so that rapid (although probably less accurate and less complete) results can be obtained.

E2E-OPE-GEN-030
Each simulation initialisation, as defined by the combination of all the user inputs, shall be stored in configuration files.

E2E-OPE-GEN-040
The parameters specifying the user control over the E2E functions and operation shall provide a complete user control over the selection of the E2E functions and over the initialisation, execution and termination of the E2E operation. It shall include as a minimum the following control parameters and data (to be complemented by the contractor as the need arises):

- Flags that determine the system to be analysed: spacecraft identifier, instrument version;
- User inputs that determine which functional configuration of the E2E, which E2E version/release number, which external interfaces, the user wants to use during E2E operation;
- User inputs that determine which elementary functions of the L1PP the user wants to include or exclude during the E2E operation;
- User inputs that determine, which elementary functions of the Performance Assessment Module the user want to include or exclude during E2E operation;
- User inputs that determine, which elementary functions of the support functions the user wants to include or exclude during the E2E operation;
- For use with the Instrument Data Simulation, flags that determine the nature and extent of the E2E run shall be defined:
  - Which channel;
  - The number of data;
  - Orbit: full or subset;
  - Coverage and location;

- The source observation data used;
- Unique identifier per measurement;
- Other TBD flags as required;

- Parameters that specify the computation of the level 1b data quality (e.g. number of measurements for absolute and relative error computations);
- Flags that control the extent and content of the support output data i.e. which E2E variables, function status, parameters, etc., are to be output by the E2E;
- Parameters defining the conditions under which the E2E shall terminate its operation (e.g. time, number of samples, user interrupt, etc.).

E2E-OPE-GEN-050
Defaults values for all user inputs shall be provided by the E2E.

E2E-OPE-GEN-060
The user shall have the possibility to define and set tags for the environmental conditions of the simulated scenario and corresponding data e.g. season of the year, time of day, cloud or meteo conditions. Each source data and scenario shall therefore be associated, within the E2E, with these tags identifying these conditions allowing the User an easy selection of the relevant set of scenario/source observation data.

E2E-OPE-GEN-070
It shall be possible to load a configuration file as defined in E2E-OPE-GEN-065 to initialise the simulation.

E2E-OPE-GEN-080
The E2E shall operate without loss of performance in case of missing samples / data in the datasets.

E2E-OPE-GEN-090
The E2E shall continue to operate in the presence of gaps/missing data (e.g. due to simulated loss in the data link).

E2E-OPE-GEN-100
The E2E shall be able to synchronise its simulation time with an external interface, e.g. an Network Time Protocol (NTP) server or to run on its own simulation time.

E2E-OPE-GEN-110
The E2E shall possess an alert functionality performed at each simulated time or scene for TBD values e.g.:

- Signal to Noise Ratio (SNR);
- Radiometric correction;
- TBD calibration (e.g. coverage, shift, squeeze/stretch);

This functionality shall raise an alert when exceeding threshold or set values.

7 PERFORMANCE REQUIREMENTS

E2E-PER-GEN-005
The E2E simulator and its modules shall be able to satisfy their performance requirements on a x86 computer with 8 cores and 16 GB RAM (SpecFP2000 of .2000 (TBC))

NB The performance requirement above needs to be re-evaluated at the time the activity is started.

E2E-PER-GEN-010
The E2E simulator shall be able to generate simulated data (RAW) corresponding to 1 hour of observation in less than 1 hour i.e. in real time (TBC)

E2E-PER-GEN-020
The L1PP shall be able to convert 1 hour of simulated data (RAW) into Level 0 data, in less than 5 minutes.

E2E-PER-GEN-030
The L1PP shall be able to completely process 1 hour of simulated data (RAW) of any instrument operating mode, to Level 1 in less than 15 minutes i.e. 4 times faster than real time

E2E-PER-GEN-040
The L1PP shall be able to process Level 0 data (corresponding to 1 hour of observation) of any instrument operating mode, in less than 15 minutes i.e. 4 times faster than real time

E2E-PER-GEN-050
The L2PP shall be able to process Level 1 data (corresponding to 1 hour of observation) in less than 30 minutes i.e. 2 times faster than real time

E2E-PER-GEN-060
The PAM shall be able to perform all its processing and produce the performance assessment reports and plots for 1 hour of simulated observation in less 10 minutes

8 INTERFACE REQUIREMENTS

The following requirements specify the external interfaces between the E2E and the actual Ground Segment.

8.1 General Interfaces Requirements

E2E-INT-GEN-010

The E2E Simulator and any of its module shall be able to ingest the relevant payload, platform, auxiliary and calibration data files in the Ground Segment format and as defined in the [L1IODS] and [L2IODS] (e.g. L0 science files, L0 ancillary/HKTM files, Instrument characterisation AUX files, Orbit Files, Level 1 Files, CAL files, etc)

E2E-INT-GEN-020

The E2E Simulator and any of its module shall generate any output data file in the Ground Segment format and as defined in the [L1IODS] and [L2IODS], e.g. L0 files, CAL files, L1 Files, L2 Files.

E2E-INT-GEN-030

The design of the E2E simulator shall incorporate flexibility to minimise the work to adapt its input data format to changes in the input data space packet definition within any RAW or Level 0 Data files (e.g. avoid hard-coding packet/parameters structure).

9 VERIFICATION, VALIDATION AND SYSTEM INTEGRATION

E2E-VVP-GEN-010

The E2E shall follow the verification and validation processes as defined by the ECSS standard ECSS-E-ST-10-02C.

9.1 Level 1 Prototype Processor (L1PP) Verification and Validation

E2E-VVP-L1P-010

The L1PP verification shall be performed against the level 1 related requirements that are specified in the present document.

E2E-VVP- L1P -020

The L1PP validation shall be performed against the level 1 related requirement that are specified in [L1ATBD]

E2E-VVP-L1P-030
The validation of the of the L1PP shall be performed using at least the following types of data:
- Instrument simulator data;
- data obtained during ground AIT/AIV activities or calibration campaign of the space segment;

9.2 Level 2 Prototype Processor (L2PP) Verification and Validation

E2E-VVP-L2P-010
The L2PP verification shall be performed against the level 1 related requirements that are specified in the present document.

E2E-VVP-L2P-020
The L2PP validation shall be performed against the level 1 related requirement that are specified in [L2ATBD]

E2E-VVP-L2P-030
The validation of the of the L2PP shall be performed using at least the following types of data:
- Instrument simulator data;
- data obtained from the Level 1 Operational Processor (TBC);

10 HUMAN-MACHINE INTERFACE (HMI) REQUIREMENTS

E2E-HMI-GEN-010
It shall be possible to perform all operation of the E2E simulator by mean of an HMI.

E2E-HMI-GEN-020
The E2E HMI for each instrument shall be the same for as for the other instruments on <MISSION-X>, as far as possible given the specificities of the instruments.

E2E-HMI-GEN-030
The E2E HMI shall:

- Manage (i.e. create, modify, view, delete, store, retrieve) all E2E input/output data;
- Display on the screen relevant information on E2E processes;
- Allow the user to monitor in real-time the operation of the E2E;
- Allow the user to control in real-time the operation of the E2E;

in accordance with the detailed requirements specified below.

E2E-HMI-GEN-040
The E2E HMI shall allow the user to manage and display all the E2E output data and the Performance Assessment Module outputs.

E2E-HMI-GEN-050
The E2E HMI shall provide the user with the real-time display of warning and error messages. The message shall identify the nature of the error and shall be color coded (e.g. warning orange, error red, informative blue)

E2E-HMI-GEN-060
The E2E HMI shall automatically display all run-time errors or TBD out-of-limit conditions.

E2E-HMI-GEN-070
The HMI shall allow the user to browse and search the above history files, for the purpose of the user creating ad-hoc reports and displays on either specific periods of measurements or specific locations, as specified above.

E2E-HMI-GEN-080
The HMI shall be readable by a distance of 50 cm.

E2E-HMI-GEN-090

It shall be possible to use the HMI locally or remotely on a multiple screen configuration

E2E-HMI-GEN-100
It shall be possible to place separate HMI windows on separate screens and to move them from one to the other with the mouse (e.g. log window, scenario window, erro window, execution window, etc)

E2E-HMI-GEN-110
The HMI shall include progress bar/status indicating the completion status of the simulation/processing as well as the remaining estimated time.

11 REFERENCE TEST DATA SET REQUIREMENTS

E2E-TDS-GEN-010
A reference test data set, generated with the E2E Performance Simulator, shall be delivered (TDS).

E2E-TDS-GEN-020
The TDS shall include nominal as well as non nominal cases

E2E-TDS-GEN-030
The TDS shall include examples of all possible modes/data types/calibrations of <MISSION-X>.

E2E-TDS-GEN-040
The TDS shall comprise:
1) openSF Configuration and scenario
2) Output of the simulation chain: generated RAW data (Observation (ISP), Ancillary (ANC)), Auxiliary Data File (AUX), Level 0.
3) Output of the processing chain within the L1PP: L1 Products, Calibration Products.
4) Output of the processing chain within the L2PP: L2 Products.

12 INPUT TO THE SOW

12.1 Deliverables

12.1.1 *Software and data*

The following software deliverables shall be provided:

D-SW-01 E2E Performance simulator executable form (including L1PP and L2PP)
D-SW-02 E2E Performance Simulator Source Code
D-SW-03 L1PP (standalone) in executable and source code
D-SW-04 L2PP (standalone) in executable and source code

D-SW-05 Test Data Set defined according to a 48 h mission scenario to be agreed with ESA.

NB. Each delivery of the E2E (D-SW-01) shall include also a stand alone installable L1PP and L2PP Module (D-SW-03/04)

Any source code shall include the necessary script and build tools (makefiles, etc) to generate the running executables.

These shall be provided to the Agency without any restrictions and IPR for use, re-use, modification, adaptation or redistribution.

12.1.2 *Documentation*

The following documentation shall be provided by the contractor, without any restrictions on (re)distribution. It consists of a tailored set of the ECSS documentation plus documentation which is specific to Processors development.

- Software Development Plan (SDP) (including Configuration and Product Assurance Plan aspects)
- Software Design Document (SDD) (at level of architectural design and overall processing logic and dataflow.)
- Software User Manual (SUM)
- Software Verification Plan (SVerP)
- Software Verification Report (SVR) (as needed following Test Execution)
- L1 Algorithm Theoretical Basis Document (ATBD);

- L2 Algorithm Theoretical Basis Document (ATBD);
- L1 Detailed Processing Model (DPM) (at level of detailed design of the numerical implementation of algorithm and orchestration including e.g. pseudo-code and details of all functions I/O, data software types, internal branching, error handling, etc)
- L2 Detailed Processing Model (DPM) (at level of detailed design of the numerical implementation of algorithm and orchestration including e.g. pseudo-code and details of all functions I/O, data software types, internal branching, error handling, etc)
- Input / Output Data Specification (IODS L1) in accordance with the L1PP level 1 format definition description and the calibration and characterisation database.
- Input / Output Data Specification (IODS L2) in accordance with the L2PP level 2 format definition description and the AUX data definition.
- Test Data Set Description Document (TDSD)

Any call in the E2E source code to COTS and third party libraries, including the EO mission CFI library, shall be documented in the ATBD and DPM with associated inputs and configuration parameters.

Formal deliveries shall include documentation, software, installation packages and all associated datasets

12.1.3 *Delivery Plan*

12.1.3.1 E2E

- As a minimum five deliveries of the E2E Performance Simulator shall be provided:
- A preliminary version for the E2E PDR including full infrastructure, representative data flow and orchestration and stub for its components and preliminary formats;
- A version for Instrument Engineering Qualification Model EM/oQM performance verification and calibration, to be delivered at the start of the first performance measurement campaign; including preliminary PAM.
- A version for Instrument Protoflight Model (PFM) / FM2 performance verification and calibration, to be delivered at the start of the PFM / FM2 performance measurement campaign which is fully representative format of all I/O data: L0, ISP, L1 Product, L2 product and
- A version to support ground segment test data generation (fully representative simulation and formats)
- A version to support ground segment evolution of L1PP (fully representative processing at L1)

- A version to support ground segment evolution of L2PP (fully representative processing at L2)

12.1.3.2 L1PP

As a minimum, and in addition to the three deliveries as part of the E2E Performance simulator above, an additional three formal (separate) deliveries of the L1 Processor Prototype shall be provided:

- A pre-launch version, to be delivered at launch – 12 months;
- A -launch version, to be delivered at launch – 1 months (TBC);
- A post-launch version, to be delivered before the end of the in-orbit commissioning phase

The Contractor shall also provide the cost of additional (optional) L1PP deliveries should that be requested by ESA.

12.1.3.3 L2PP

As a minimum, and in addition to the three deliveries as part of the E2E Performance simulator above, an additional three formal (separate) deliveries of the L2 Processor Prototype shall be provided:

- A pre-launch version, to be delivered at launch – 6 months;
- A -launch version, to be delivered at launch – 1 months (TBC);
- A post-launch version, to be delivered before the end of the in-orbit commissioning phase + 1 month

The Contractor shall also provide the cost of additional (optional) L2PP deliveries should that be requested by ESA.

12.1.3.4 TDS

TDS delivery number shall coincide with L1PP deliveries (3 + 3), however it shall also be possible to have (in agreement with ESA) TDS deliveries at separate times (e.g. to cope with delay in L1PP development)

12.2 Maintenance and Support

12.2.1 *Support task for commissioning*

The Contractor shall provide TBD manpower support to ESA during the execution of the commissioning. This support includes use of the E2E and of the L1PP and L2PP on simulated and real data and contributions to analysis of discrepancies.

12.2.2 *Support task for cross validation*

The Contractor shall provide TBD manpower support to ESA for the execution of a cross validation campaign between L1PP/L2PP and the corresponding Operational processor. This support includes definition of appropriate test scenarios, generation of reference test data, and contributions to analysis of discrepancies.

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