EXECUTIVE SUMMARY

SS-E2ES

Prepared by:	SS-E2ES Teams at: GMV
Approved by:	Fernando Alemán
Authorized by:	Fernando Alemán

Code:	ES-001-SSE2ES-ES
Version:	1.0
Date:	07/12/2015
Internal code:	GMV 23785/15 V1/15

GMV
Isaac Newton, 11; PTM Tres Cantos; Madrid 28760
Tel. +34 918072100; Fax. +34 918072199
www.gmv.com

DOCUMENT STATUS SHEET

Version	Date	Pages	Changes
1.0	07/12/2015	20	First version

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1. INTRODUCTION

1.1. PURPOSE

This document is the Executive Summary of the SS-E2ES project, performed under ESA/ESTEC contract 4000112221/14/NL/MV. This project is carried out by a consortium led by GMV and including the different members:

- **GMV**, responsible for management, system-level activities and active optical instruments.
- **Airbus D&S**, providing support in the tasks related to mission categorization and mission selection for the application and evaluation of the reference architecture.
- **UCL-MSSL** (Mullard Space Science Laboratory at the University College of London), providing the necessary expertise on all aspects related to Astrophysics missions.
- **Università La Sapienza di Roma** (Radio Science Laboratory), providing the necessary expertise on instruments for Geodesy and Geophysics
- **Professor Yves Langevin**, acting as external GMV consultant, providing support on the most "classical" instruments for remote sensing of planetary bodies, like imagers and spectrometers in a wide range of the spectrum (from UV to IR).

The output of the SS-E2ES Project consists of the following Technical Notes:

- TN-001-SSE2ES-MC - SS-E2ES - SS Missions and Elements Categorization
- TN-002-SSE2ES-RB – SS-E2ES - Missions Commonalities
- TN-003-SSE2ES-RA - SS-E2ES - Requirements and Reference Architecture
- TN-004-SSE2ES-TS - SS-E2ES - Generic Building Blocks Technical Specification
- TN-005-SSE2ES-EC - SS E2ES - RA evaluation method and missions selection
- TN-006-SSE2ES-AA - SS-E2ES - AIDA-SHIELD E2ES Architecture Design
- TN-006-SSE2ES-EA - SS-E2ES - EUCLID E2ES Architecture Design
- TN-007-SSE2ES-AR - SS-E2ES - Reference Architecture Roadmap

A compilation of the above Technical Notes is also available in the form of a Final Report.

1.2. ABSTRACT

In the context of Earth Observation missions the development of end-to-end simulators (E2ES) has proven to be a useful tool to assess the mission performance and support the consolidation of the technical requirements and conceptual design, as well as to allow end-users assessing the fulfillment of requirements by the mission. For Space Science missions the development of performance simulators is not as extended, and it is usually done externally to the Agency, directly by the scientific community, and mostly for independent instrument chains.

The SS-E2ES activity was initiated in the believe that there could be a use for end-to-end mission performance simulators in the area of Space Science missions, and foreseeing that the framework, architecture and models defined for Earth Observation mission could be reused to a large extent, making the definition and development of end-to-end simulators for space mission affordable even as internal independent engineering and validation tools. Moreover, the availability of generic simulator architectures and a library of building blocks to enable the development of simulation scenarios without too much effort could prove of great use.

Thus, the SS-E2ES activity builds upon the experience of the ARCHEO project [RD.1], in which a Reference Architecture for Earth Observation end-to-end mission simulators was defined, and it is aimed at assessing the use of end-to-end mission performance simulator for Space Science missions, analyzing which category of missions could benefit from the use of end-to-end simulators concept, identifying what could be learnt and reused from the area of Earth Observation missions and defining generic user requirements, a reference architecture and building blocks.

The rationale behind this generic reference architecture is promoting reuse in the development of mission performance simulators by:

- Categorising past, current and planned ESA space science missions to identify the main elements affecting mission performance and having an impact over the simulator architecture.
- Identifying the architecture elements required to model the mission and proposing a generic reference architecture that could be adapted for the different mission particularities.
- Describing the architecture elements, in particular those that can be generalized for the various mission categories.
- Evaluating the reference by comparing the development of an E2ES using this new concept versus *ad-hoc* simulator development.
- Defining a roadmap to reach an operational concept for the development of E2ES based on the presented reference architecture.

2. REFERENCES

2.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Table 2-1 Applicable documents

Ref.	Title	Code	Version	Date
[AD.1]	E2E mission performance Simulators for Space Science missions (SS-E2ES), Statement of Work	TEC-SWM/13-658/RF	1.0	20/12/2013

2.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X]:

Table 2-2 Reference documents

Ref.	Title	Code	Version	Date
[RD.1]	ARCHEO Final Report	ARCHEO-E2E-FR-008	1.1	27/02/2013

2.3. PROJECT DOCUMENTS

The following documents are produced in the frame of this activity. They are referenced in this document in the form [PD.X]:

Table 2-3 Project documents

Ref.	Title	Code	Version	Date
[PD.1]	SS-E2ES - SS Missions and Elements Categorization	TN-001-SSE2ES-MC	1.2	22/07/2015
[PD.2]	SS-E2ES - Missions Commonalities	TN-002-SSE2ES-RB	1.2	22/07/2015
[PD.3]	SS-E2ES - Requirements and Reference Architecture	TN-003-SSE2ES-RA	1.4	07/12/2015
[PD.4]	SS-E2ES - Generic Building Blocks Technical Specification	TN-004-SSE2ES-TS	1.3	07/12/2015
[PD.5]	SS E2ES - RA evaluation method and missions selection	TN-005-SSE2ES-EC	1.1	07/12/2015
[PD.6]	SS-E2ES - AIDA-SHIELD E2ES Architecture Design	TN-006-SSE2ES-AA	1.1	07/12/2015
[PD.7]	SS-E2ES - EUCLID E2ES Architecture Design	TN-006-SSE2ES-EA	1.1	07/12/2015
[PD.8]	SS-E2ES - Reference Architecture Roadmap	TN-007-SSE2ES-AR	1.0	07/12/2015

3. ACRONYMS

BB	Building Block
E2E	End-to-End
E2ES	End-to-End Simulator
EO	Earth Observation
RA	Reference Architecture
SS	Space Science

4. RATIONALE FOR A REFERENCE ARCHITECTURE

While in EO domain the use of E2ES to assess mission performances is very common and well established through several years of successful applications, i.e. Earth Explorer and Copernicus programs, in SS the appeal of such tools is much more limited and their use is not typical at all. It is then worth to globally consider similarities and differences between EO and SS missions design practices, to have a clear indication on the reason why E2ES would have to be (eventually) used also for missions looking beyond our planet.

4.1. DIFFERENCES AND COMMONALITIES BETWEEN THE DESIGN OF SPACE SCIENCE AND EARTH OBSERVATION MISSIONS

A first factor to be considered is of course the difference in the frequency of missions launched between Earth Observation and Space Science. The high number of missions designed to observe our planet entails that different spacecraft could cover the same goals and/or use the same instrument of their predecessors: this pushes the need for a common approach for mission design as well as the interest to reuse what it has already been proved to be successful. Instead in Space Science the variety of targets generally causes the profusion of unique and dedicated mission design processes, while the high mission costs cut down the number of launched missions with respect to EO, reducing then the E2ES employment for missions' performances assessment and comparison.

Another important aspect to be surely taken into account is that in Earth Observation, ESA is responsible for the instrument data processing: this stimulates the dissemination of ESA driven practices, with the consequent diffusion of Agency defined standards aiming at both mission design procedures harmonization and common design modules reusability. On the other hand in Space Science the instrument data processing responsible is usually represented by the scientific team, who does not necessarily deal with more than one mission and does not then need to reuse the mission and instrument design analyses. Moreover, even if these teams could be in principle available to partially or fully disseminate their studies, it is less frequent to incur in the employment of standard and common framework for missions' simulation.

Nevertheless in the last years a common aspect between Earth Observation and Space Science missions rose up in ESA practices and it should be particularly considered within the context of the current study: the use of competition for missions' selection. This kind of approach, employed for example by the Earth Explorer or by the Cosmic Vision programs, relies on the possibility of a straight comparison of missions' performances, which are usually based on E2E simulation results analysis through a "Mission Assessment Report". Therefore this is a clearly common feature among EO and SS missions' design where the E2ES play a major role.

4.2. ADDED VALUE OF E2ES FOR SPACE SCIENCE MISSIONS

It is then important to raise a critical question: would an E2ES be an added value for evaluating the performance of Space Science missions? The design of Space Science missions makes use of a different approach with respect to Earth Observation practices, an approach which demonstrated to be successful for many years and through many very complex missions. Introducing then the use of E2ES in this community will surely face a comprehensible reluctance and could lead to the typical programmatic complications entailed in any *modus operandi* modification.

Nevertheless for some Space Science missions it is more difficult to develop a clear mission plan and little funding is available in early design phases: therefore the availability of standard simulator architectures and a library of building blocks to enable the development of simulation scenarios without too much effort, would be highly appreciated.

It seems therefore that the main added value of E2ES use in Space Science would be the partial or global reusability of some of the simulator modules and possibly of the simulator architecture. Due to the big variety of targets, objectives, instruments and architecture of Space Science missions, it is very unlikely to find a solution valid for all analyzed aspects and for all the considered missions.

5. MISSION AND INSTRUMENT SURVEY AND CATEGORISATION

A detailed review of past, current and planned Space Science missions and instruments has been performed to analyze the implications on the definition of the reference architecture, such as the possibility of using common blocks or defining independent processing chains.

A preliminary categorization of Space Science missions arises naturally from its target objects assortment and has therefore been historically used to delineate the SS missions' taxonomy. The first step has consisted in distinguishing between missions looking at object inside or outside the Solar System; then, among the missions dedicated to study the Solar System bodies other than Earth, another division has been set between studies dedicated to the Sun or investigations targeting bodies in orbit around our star (planets, natural satellites, asteroids and comets). Therefore this first classification is built around the mission target objects, which are usually classified in three main classes:

- Astrophysics missions: all missions targeting objects outside the Solar System
- Solar Science missions: all missions dedicated to study the Sun
- Planetary Science missions: all missions having as target all the Solar System objects but the Sun and the Earth: planets, natural satellites, comets and asteroids.

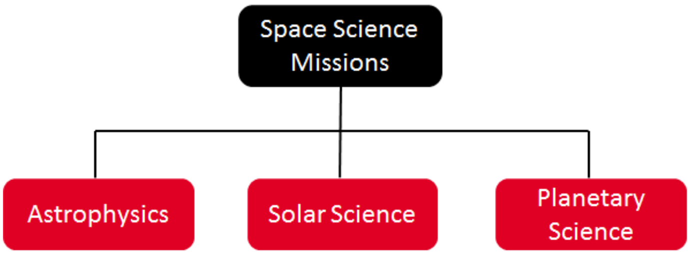

Figure 5-1: Preliminary classification of space science missions

The missions have then been analysed under different aspects and criteria:

- Mission configuration, where the following categorizations have then to be taken into account: spacecraft orbit, number of platforms and number of instruments
- Scientific data retrieval, where three elements are considered critical in mission categorization: the acquisition technique, the science requirements and the performances achievements strategy
- Instruments categorization, which took into consideration both mission objectives and instrument acquisition technique

The results of this large survey have been presented in statistical representations, such as the orbit selection for solar science missions in Figure 5-3 or the instruments usage in planetary missions in Figure 5-2, that allowed properly weighting the impact of each category on the overall analysis.

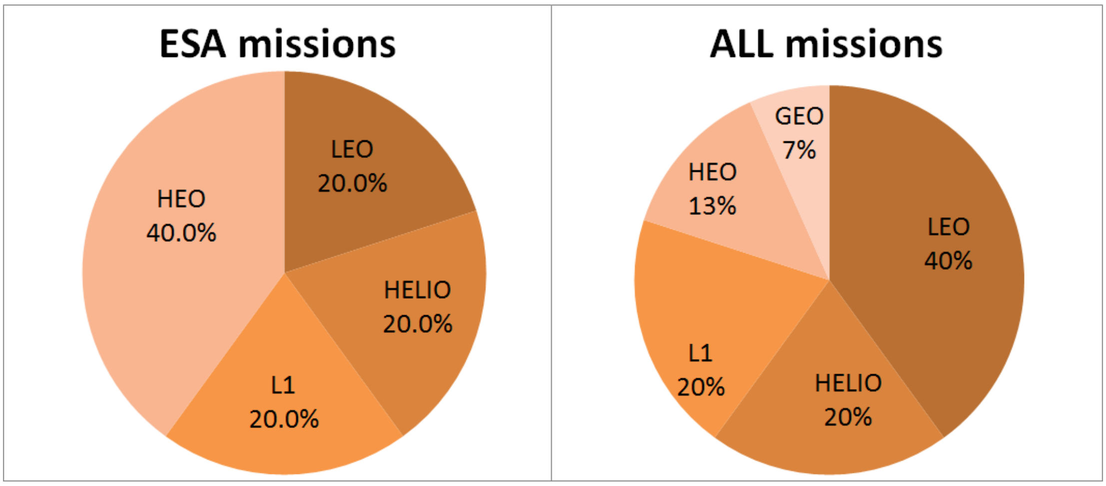

Figure 5-2: Survey of 15 solar science missions orbits

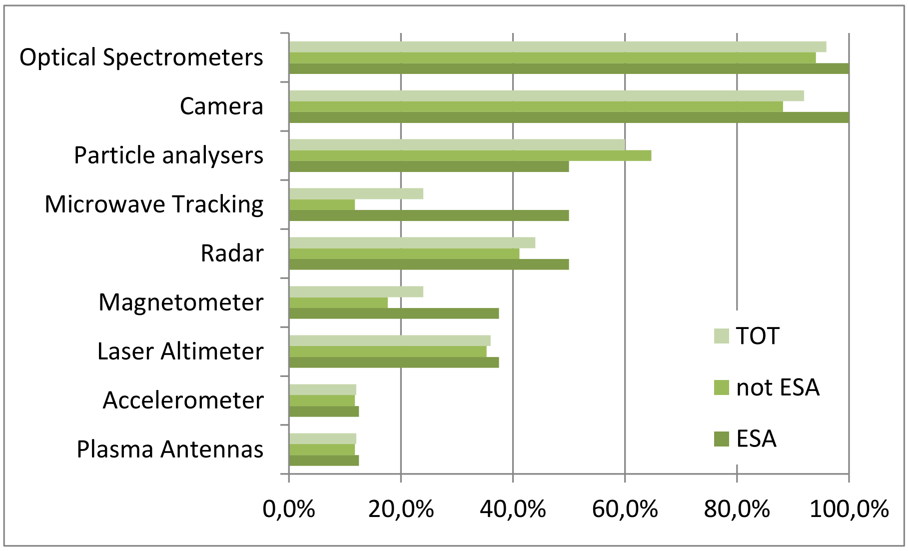

Figure 5-3: Survey of 25 planetary science missions instruments usage

After a careful analysis of the survey results, and based on the team's experience, a final categorization of Space Science missions has been proposed, always from the point of view of what makes sense from the point of view of simulation:

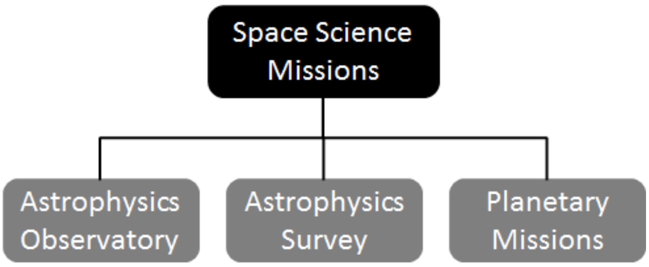

Figure 5-4: Final classification of space science missions

The Astrophysics Survey category includes both Photometry and survey missions, since they revealed to share the same simulation reference architecture. The Planetary Missions category includes both missions orbiting around a central body and missions performing science exploration through one or several fly-bys, but they are treated as a single category and will be differentiate according to their on-board experiments.

In addition to the categorization of missions, a categorization of instruments has also been performed. Similar to what was done when classifying the missions, only those criteria that would impact the definition of the simulator reference architecture were taken into consideration for the classification.

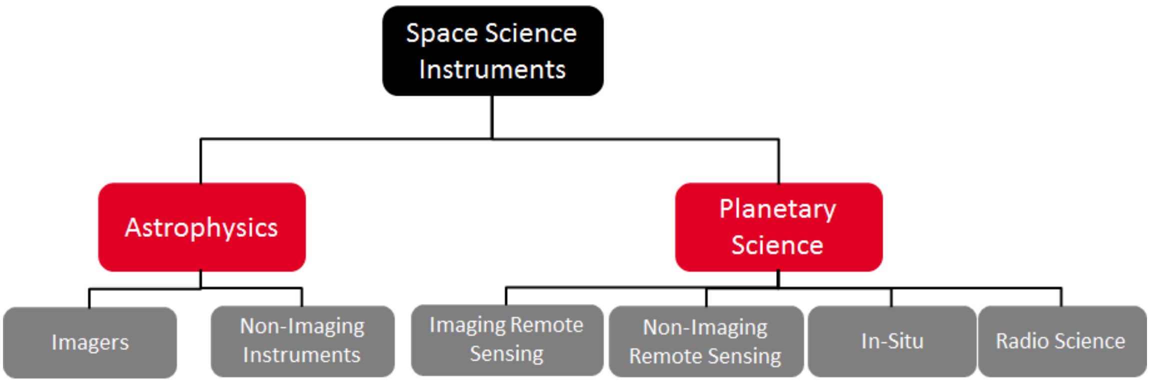

Figure 5-5: Final categorization of space science instruments

6. REFERENCE ARCHITECTURE FOR SS E2E SIMULATORS

Regarding the definition of the high-level reference architecture, one of the premises has been to keep it as simple as possible, defining very few variations with respect to the nominal solution, if possible. This allows having more coherence between the different simulators that will be implemented based on the architecture, being their reuse for other missions favored, even if they are quite different.

Thus, the approach has been to define very few high-level architectures, depending on the type of mission (astrophysics observer, planetary science orbiter…). Then, the type of instrument has impact on the second layer, when analyzing the building blocks and internal architecture of the different high-level modules.

The main premises of the reference architecture are:

- The reference architecture defines a series of high-level modules and the interfaces among them that are common to all type of missions and instruments.
- Although the reference architecture is generic, it is flexible to be adapted for the different mission particularities and needs.
- Depending on the type of instrument to be simulated each of the high-level modules will have an internal architecture broken down in building blocks.
- Different implementations of the same building blocks account for mission parameters, evolution of algorithms throughout the different mission phases, etc.
- Some of the high-level modules and lower-level building blocks will be generic across missions and instruments categories.High-Level Elements of the Reference Architecture.

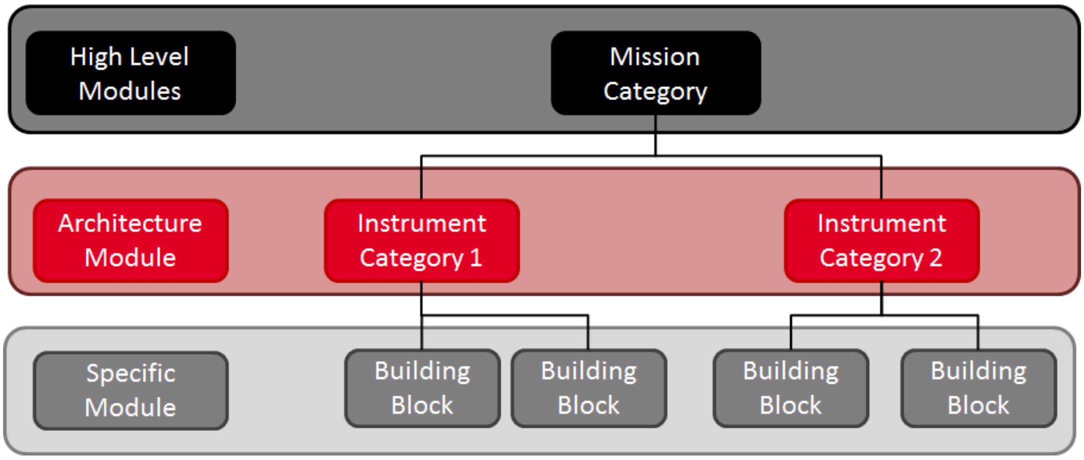

Figure 6-1: The Reference Architecture Concept

Including the high-level modules and the lower-level building blocks, the E2ES can be decomposed in three main elements:

- the **Modules** (or Building Blocks), that are software objects that implement the chosen models;
- the **Data**, that are the input/output information for the models and are exchanged among the different Modules;
- the **Configuration**, which has to be defined by the user depending on the simulation to be run, that can be divided in:
  - Configuration parameters, that are used to configure the Modules in order to process the data under the desired conditions (i.e. instrument characteristics, data sampling, etc.);
  - Activation flags, which are used to enable/disable the execution of a subset of models or to select the algorithm to be adopted when the E2ES is run. These activation flags can also be used to select a particular implementation of the building block when it is shared by different types of instruments.

6.1. HIGH-LEVEL ELEMENTS OF THE REFERENCE ARCHITECTURE

From the categorization of missions and analysis of commonalities, and also taking into account the experience of the project team in the design and implementation of E2E simulators, the simulation elements that are candidate to build the higher level modules of the reference architecture have been identified, resulting in a total of seven high-level modules. Table 6-1 summarises the purpose of each module and its main interfaces.

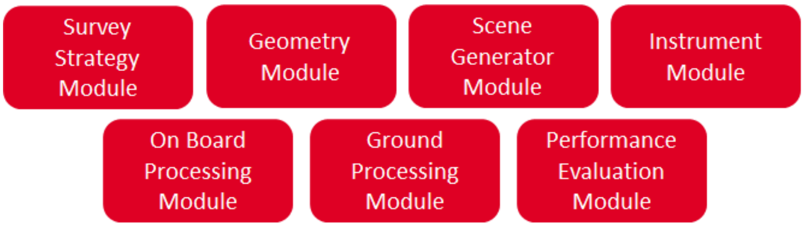

Figure 6-2: High-Level Modules in the Reference Architecture

Module	Purpose	Configuration	Inputs	Outputs
Survey Strategy	Provides the observation strategy through the attitude pointing and the instrument scheduling definition	-Survey strategy configuration	N/A	-Survey strategy pointing -Instrument Scheduling
Geometry	Simulates SC orbit & attitude & observation geometry of each instrument	-Orbit & AOCS configuration	-Survey strategy pointing	-Geometry data -Propagated orbit/attitude
Scene Generator	Simulates scene to be observed and environmental effects needed for generation of stimuli to enter instrument model.	-Scene configuration	-Geometry data	-Stimuli
Instrument	Simulates sensor behavior, having different outputs depending on type of instrument.	-Instrument configuration	-Stimuli -Instrument Scheduling	-Raw data
On Board Processing	Performs the on board data processing to obtain the data to be sent to Earth ground stations	-Data Processing configuration	-Raw data -Propagated orbit/attitude	-On board products
Ground Retrieval	Performs retrieval of physical parameters objective of the mission/instrument (level-2)	-Retrieval configuration	-On board products	-Retrieval products
Performance Evaluation	Performs analysis of simulator outputs to evaluate mission performances. It could be run at different points of the simulation chain.	-Orbit & AOCS configuration -Scene configuration	-Stimuli -Raw data -On board products -Retrieval products	-Performance reports

Table 6-1 High-level modules in the Reference Architecture

6.2. REFERENCE ARCHITECTURE FOR SPACE SCIENCE MISSIONS

The data flows between the high-level modules and even their order of execution could vary depending on the type of mission and instrument being simulated, however it is possible to define a typical generic data flow, presented in Figure 6-3, that is considered as the main Reference Architecture and can be adapted to the different mission and instrument particularities.

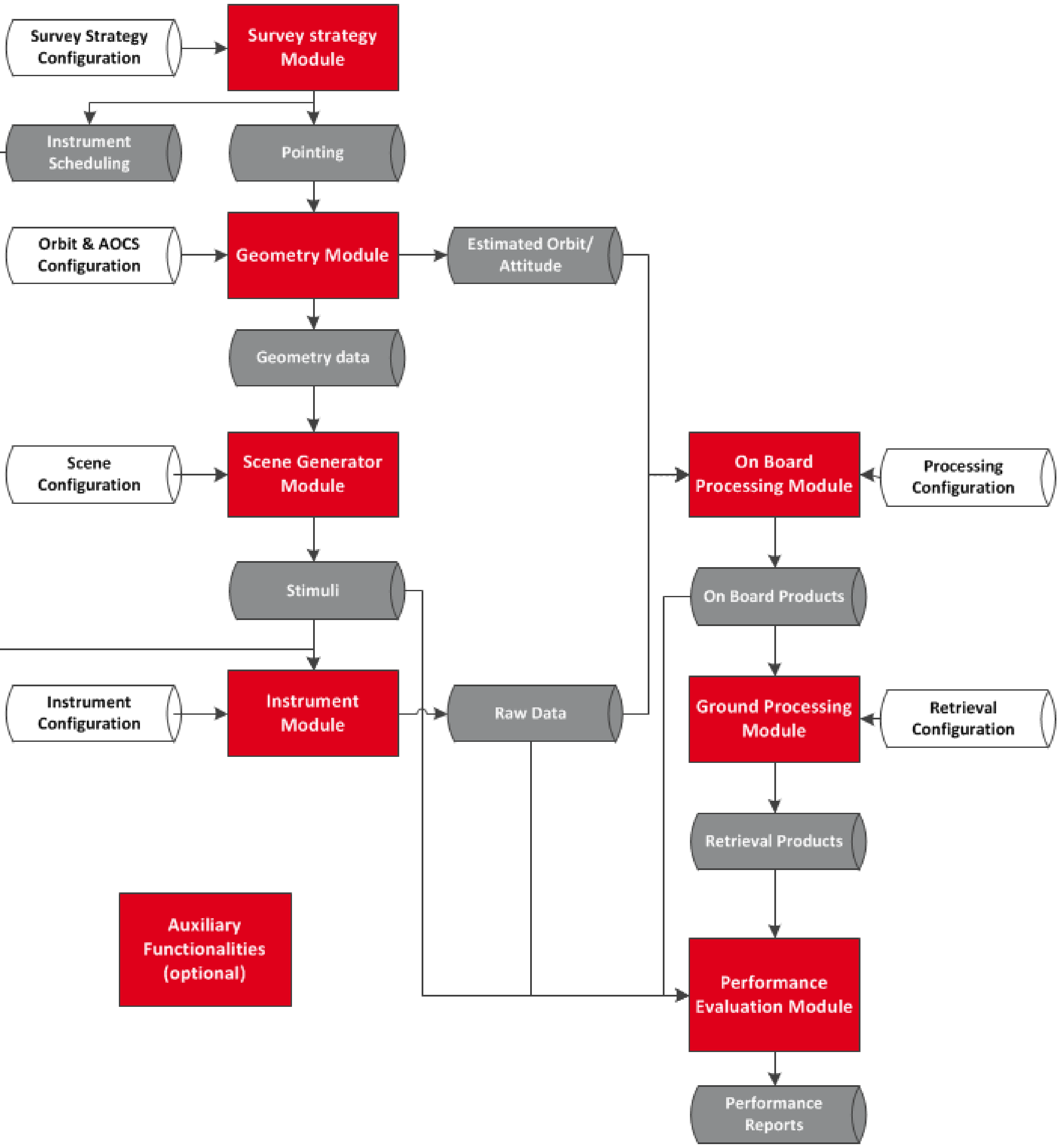

Figure 6-3: Generic reference architecture for space science missions

The Reference Architecture, as proposed, is flexible enough to accommodate particularities of certain missions, for example missions with multiple instruments, in which synergies between different instruments can be exploited, in order to fulfil additional and more ambitious scientific achievements, that would not be possible to obtain with the processing of each dataset alone. An example is the synergy between radio science and laser altimeter data, allowing retrieving information about the crustal thickness of a celestial body, by combining gravity and topography data. More in general, several instruments can contribute to constrain the models of the internal structure of celestial bodies, from magnetometers to cameras. This means that the achievement of the mission scientific requirements requires additional Ground Processing Modules that take as input the retrieval products coming from different instrument chains, as shown in Figure 6-4.

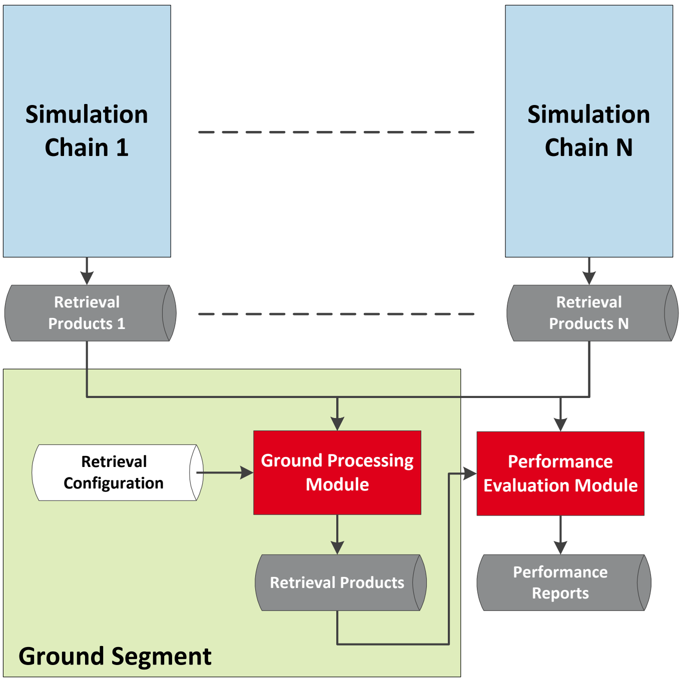

Figure 6-4: Flow diagram for the high level architecture of multiple instruments

Finally, the Reference Architecture proposed in Figure 6-3 has been studied and adapted for each of the mission categories identified in the survey phase. The specific details can be found in the project documentation.

6.3. BUILDING BLOCKS

Following the Reference Architecture concept, each of the different high-level modules has been broken down in a series of building blocks. The granularity of the building blocks has been determined after the identification of the elements to be modelled and a thorough analysis of commonalities. Once the preferred option (or options) for the definition and implementation of a building block has been identified, the building block itself has been defined. To ensure the adequate level of detail in the definition of the building blocks, a custom template – shown in Figure 6-5 - has been developed.

<table>
<tr><th colspan="6">Building Block Description</th></tr>
<tr><td colspan="6">General Information</td></tr>
<tr><td colspan="2">Building Block Name:</td><td colspan="2">Write the Building Block name here</td><td>Version:</td><td>Version</td></tr>
<tr><td colspan="6">Instrument Type: (tick all that apply with ☑)</td></tr>
<tr><td colspan="6">☐ Generic ☐ Astrophysics Imagers
☐ Planetary Remote Sensing ☐ Astrophysics Optical Spectrometers
☐ Planetary Radio Science ☐ Astrophysics X-Ray Spectrometers
☐ Planetary In-Situ Instrument ☐ Astrophysics Non-Imaging Photometers</td></tr>
<tr><td colspan="6">Module: (tick applicable module with ☑)
☐ Survey Strategy Module ☐ Geometry Module ☐ Scene Generator Module
☐ Instrument Module ☐ On-Board Processing Module ☐ Ground Processing Module
☐ Performance Evaluation Module</td></tr>
<tr><td colspan="6">Higher-level Building Blocks:
If applicable, list the higher-level building blocks up to the Module-level.</td></tr>
<tr><td colspan="6">Functional Description:
Include a short functional description of the building block.</td></tr>
<tr><td colspan="6">Scope of Application and Limitations:
Include details of under which conditions is the building block valid (e.g. type of scene, type of instrument, etc.).</td></tr>
<tr><td colspan="6">Configuration Parameters</td></tr>
<tr><td colspan="6">Mission (include mission-related parameters that impact the Building Block)</td></tr>
<tr><td>Name</td><td>Units/Format</td><td colspan="3">Description</td><td>Local/Global</td></tr>
<tr><td>Name</td><td>[Units]/Format</td><td colspan="3">Description (including range & default)</td><td></td></tr>
</table>

Figure 6-5: Partial template for the definition of Building Blocks

7. EVALUATION OF THE REFERENCE ARCHITECTURE

Once the Reference Architecture is defined and the building blocks identified and described by means of a standard template, the next logical step is to evaluate the Reference Architecture. It is important to understand the advantages of the Reference Architecture approach with respect to the current approach of developing E2E simulators for instruments in Science missions. Thus, the goals of this evaluation are:

- First of all, as the development of E2E simulators in Space Science missions during the early stages of study (phases 0, A, B1) is not a common practise in ESA missions, it shall be evaluated the convenience of having such development available in early phases.
- Quantify the benefits expected from the use of the reference architecture.
- Detection of problems that may arise due to the use of the reference architecture.
- Clarify and prioritize requirements for the adoption of the reference architecture.
- Determine the adequacy of the generic building blocks being identified for their use in a specific E2E simulator for a Space Science mission.

This evaluation has been performed by analyzing the process of designing and developing an E2E simulator for two specific Science missions (one Planetary and one Astrophysics mission) by applying the Reference Architecture. The steps followed for the valuation process were:

- Detailed mission description.
- Derivation of requirements for an E2ES.
- Definition of the E2ES architecture based on the SS-E2ES Reference Architecture concept, both at high-level and going down to the level of the building blocks involved in each of the modules.
- Assessment of the usefulness of the Reference Architecture documentation in designing the architecture of the E2ES.
- Assessment of the potential of reuse of the generic building blocks for the mission-specific E2ES.
- Evaluation of the Reference Architecture against a set of pre-defined evaluation criteria.

The two missions for which the evaluation has been performed are:

- **Mission 1 (planetary):** it was agreed with ESA to define as reference mission a hybrid asteroid impact mission, merging the concepts of AIDA (ESA mission) and NEOSHIELD (German mission, in which ADS-GER has the leading role). This hypothetic mission is called **AIDA-SHIELD**.
- **Mission 2 (astrophysics):** the mission selected is **EUCLID**, ESA's mission to map the geometry of the dark Universe. This evaluation has been performed by UCL-MSSL, thus providing the point of view of a scientific institution.

7.1. CONCLUSIONS OF THE EVALUATION PROCESS

7.1.1. RA CONCEPT EVALUATION FOR EUCLID

These are the main conclusions of the applicability of the Reference Architecture for EUCLID E2E Simulator:

- The Reference Architecture documentation has proven useful in designing the architecture of an E2ES for EUCLID from scratch. The particularities of the mission and payload have been captured in an architecture that follows the guidelines of the Reference Architecture.
- With respect to the use of an integrated E2E Simulator in early phases of the mission, the potential users are as follows:
  - Scientists and engineers conceiving and developing a mission concept in the science institutes
  - Scientists and engineers developing a mission concept in the agency
  - Engineers working on a mission study in the prime contractor

  It is unlikely that an E2ES would be used in very early phase science mission definition as this is executed by scientists working outside a formal mission structure, which would not exist at that point in the programme. Therefore, development and use of the E2ES for the mission would have to be supported by suitable funding since it will not be so developed by senior scientists – it would need junior scientist support. However, if such an E2ES existed it could be available to the list of potential users listed above, which would not be the case for a piecemeal simulator.

- With respect to the reuse of generic building blocks, in all the modules there is a high potential of reusing these pieces of SW that may be available from a repository. However, care needs to be taken in using these figures as the elements that are not generic are the most difficult to implement, e.g. the detailed instrument elements and the data processing performance evaluation.

7.1.2. RA CONCEPT EVALUATION FOR AIDA-SHIELD

These are the main conclusions of the applicability of the Reference Architecture for AIDA-SHIELD E2E Simulator:

- There is no doubt on the adequacy of the overall architecture though it is not obvious/trivial where to split for subcontracting separate modules. The actual design is "designed around" existing core modules with high heritage and validation.
- With respect to the applicability of an E2E Simulator in phases A of Space Science missions, ADS-GER position is that the most important goals and tasks of that phase are to demonstrate mission feasibility not only in terms of achieving mission requirements but also critical technology. In a phase A the focus is often on selected aspects, not on the overall mission. Modelling occurs on these aspects, whereas the synthesis of then demonstrated feasible elements to a successful mission becomes "obvious" and is no more explicitly implemented. This means that the integrated E2E Simulator may result not completely necessary.
- The potential reuse of existing and validated precursor simulator elements (modules and BBs) has been a driver for the overall architecture. The actual use has been substantially driven by availability and already existing experiences of
  - in-house AOCS toolboxes
  - in-house instrument simulators
  - in-house image processing toolboxes
  - commercial toolboxes, e.g. MATLAB Image Processing Toolbox
  - commercial/community scene generators (like PANGU)
  - space toolboxes, typically from ESA, JPL/NASA, or international de-facto standards (often various alternatives exist)
- One remarkable aspect regarding this Reference Architecture would be to provide a vocabulary for discussions and definitions. Typically such definitions become covered in ECSS standards.

8. REFERENCE ARCHITECTURE ROADMAP

Once the SS-E2ES project is closed and all its related documents are available, a roadmap to reach a usable E2E Reference Architecture for future Space Science missions can be defined. It would consist of the following activities, ordered sequentially in time:

- First of all, ESA shall take a final decision about the convenience of developing E2E simulators in phases A of Space Science missions, and, if so, the final scope of such simulators. For the roadmap definition it has been assumed that similar E2E simulators to those implemented for EO missions will be required.
- Release one small activity consisting on the investigation of the needs for E2E simulators in the future Space Science missions, including:
  - Applicability of the Reference Architecture.
  - Identification of the generic components that could be needed for those missions
  - Analysis of the modules that can be completely reused from Earth Observation missions (i.e., orbits in case of LEO observatories; or instrument models, like optical telescopes).
- For future Space Science missions in which an E2E simulator will be developed, the Reference Architecture documentation resulting from this contract shall become as applicable document in the ITTs of those future E2E simulators. It is up to ESA to determine how mandatory will be to follow the RA and the associated repository of BBs.
- In the meantime, successive activities (or only one, depending on ESA criterion) will be released to accomplish the detailed design and implementation of the modules identified as high priority in [PD.8]. Depending on the budget available for these activities, the scope of each project could be limited, and priorities shall be assigned to the building blocks to be incorporated to the Reference Architecture.
- Continue with the rest of building blocks of the Reference Architecture, those considered with lower priority.

When all these activities are accomplished, the Reference Architecture can be considered as operational and mandatory reference for the development of the E2E Simulators for Space Science missions. The simulator framework will guide the user in the process of defining the specific simulator design and it will provide useful templates and models to feed that design from the very early steps of the E2E Simulator activity.

A preliminary estimation of the cost associated to the detailed design and implementation of the modules identified as higher priority has been performed.

9. SUMMARY AND CONCLUSIONS

The following summary and conclusions of the SS-E2ES activity can be extracted:

- After a detailed analysis of the most relevant existing and foreseen Space Science missions, categorizations of the missions and instruments have been generated.
- A common Reference Architecture, with the same set of high level modules (Survey Strategy Geometry, Scene Generator, Instrument, On Board Processing, Ground Retrieval, Performance Evaluation) has been defined for all these mission and instrument categories, with only small deviations identified in each case.
- Within the mentioned high level modules it has been possible to identify generic building blocks that can be reusable for the same category of instruments/missions, or even across different categories. These Building Blocks, for Geometry Module or for the category of Planetary Imaging instruments can be shared also with the Earth Observation available libraries.
- Two different missions have been selected for evaluating the application of the Reference Architecture: EUCLID and the hybrid asteroid impact mission called AIDA-SHIELD, a mixture between EOSHIELD and AIDA missions.
- The conclusion obtained from the evaluation of an E2E simulator for both missions is that the Reference Architecture is applicable and that the identified generic Building Blocks can be used for the development of such simulator. Anyway, more details on the specification of the Building Blocks are needed.
- A roadmap has been established and defined for the development of the modules identified as high priority, providing a ROM cost for their detailed design an implementation (including validation).

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