esac

European Space Astronomy Centre
P.O. Box 78
28691 Villanueva de la Cañada
Madrid
Spain
Tel. (34) 91 813 1100
Fax (34) 91 813 1139
www.esa.int

DOCUMENT

Euclid Science Ground Segment Interfaces Document

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Prepared by **John Hoar**
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1 GENERAL

1.1 Purpose of this document

This Science Ground Segment Interface Document (SGSID) provides a top level description of the architecture and design of the Euclid SGS and the set of technical and programmatic assumptions which will form the basis for the proposal and initial definition phase activities. It complies with the Euclid SGS and data management conditions given in the Euclid Science Management Plan, which is endorsed by the SPC.

The release of this AO for the Euclid Payload and Science Ground Segment Components is taking place at an unprecedented early stage during the mission development because of the programmatic decision to involve the community in the payload and SGS development as early as possible. Therefore the proposal and definition phase activities are starting from this document which builds on and replaces the Science Operations Assumptions Document (SOAD) written during the assessment phase.

The SGSID therefore contains the assumptions concerning the Euclid SGS implementation and operation at functional and programmatic levels and it describes the responsibilities, interfaces and high-level assumptions/requirements of the SGS that shall be considered in the design of the EMC SGS.

It ensures that the EMC can make a proposal such that their contribution to the Euclid SGS can be:

- Designed, developed and verified within the technical and programmatic constraints of the Euclid mission,
- Operated to achieve the scientific objectives of the Euclid mission.

This document shall be used by all parties as the baseline for the proposal and for the activities at the start of the definition phase.

1.2 Mission Background

Euclid is a high precision survey mission to map the geometry of the Dark Universe; Euclid is an ESA mission with contributions from the ESA member states and with potential participation from NASA. Euclid was selected by the Science Programme Committee (SPC) to enter the Definition Phase M-class mission for the Cosmic Vision 2015-2025 Plan.

1.3 Interface Responsibilities

1.3.1 ESA Ground Segment Commitments

ESA will contribute the Euclid Mission Operations Centre (MOC), the Ground Station Facilities and the Euclid Science Operations Centre (SOC). ESA will be responsible for the Euclid Legacy Archive and its interface to the public. ESA will be responsible for the development, operation and maintenance of the Euclid Mission Archive, which is the main (shared) data interface to all parties.

1.4 Product Tree

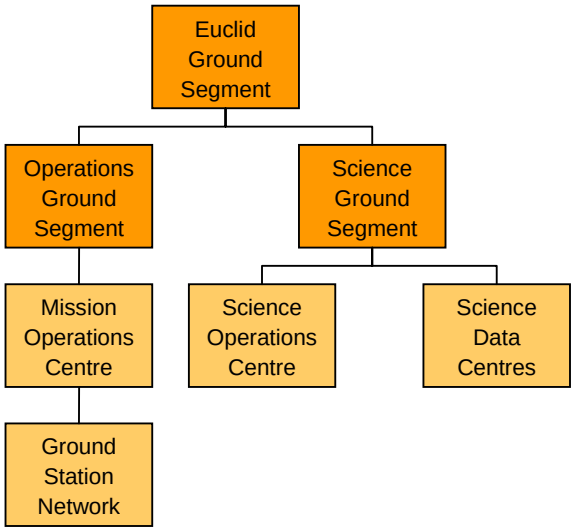

Figure 1: Euclid Ground Segment Product Tree

2 DOCUMENTS

2.1 Applicable Documents

AD1 Euclid Science Management Plan
AD2 Announcement of Opportunity for Euclid Payload and Science Ground Segment components

2.2 Reference Documents

RD1 Euclid Science Operations Assumptions Document,
RD2 Euclid Reference Payload Concept

2.3 Acronyms

AO	Announcement of Opportunity
BAO	Baryon Acoustic Oscillations
CCD	Charge coupled device
CMB	Cosmic Microwave Background
CV	Cosmic Vision
ECL	Euclid Consortium Lead
ECSGSM	Euclid Consortium Science Ground Segment Manager
ELA	Euclid legacy archive
EMA	Euclid mission archive
EMC	Euclid Mission Consortium
ESAC	European Space Astronomy Centre
ESOC	European Space Operations Centre
EST	Euclid Science Team
ESTEC	European Space Research and Technology Centre
FPA	Focal Plane Array
FWHM	Full width at half maximum
ILS	Independent Legacy Scientist
LEOP	Launch and Early Operations Phase
LGPL	Lesser General Public Licence
MLA	Multi-Lateral Agreement
MOC	Mission Operations Centre
NASA	National Aeronautics and Space Administration
NIR	Near infrared
NISP	Euclid's NIR spectroscopy and photometry instrument
OU	Organisation Unit
PS	Project Scientist
PSF	Point spread function
SDC	Science Data Centre
SEL2	2nd Sun-Earth Lagrange point
SGS	Science Ground Segment
SMP	Science Management Plan
SN	Supernova
SOC	Science Operations Centre
SRE	Science and Robotic Exploration
US	United States of America
VIS	Euclid's visual instrument

3 MISSION DESCRIPTION

3.1 Mission and Satellite

Euclid is a high-precision survey mission in the Cosmic Visions Programme of ESA designed to answer fundamental questions on Dark Energy and Dark Matter. Euclid will map the large-scale structure of the universe over the entire extragalactic sky out to redshifts of 2 (about 10 billion years ago), thus covering the period over which dark energy accelerated the universe expansion. The mission is optimized for two primary cosmological probes: Weak gravitational Lensing (WL) and Baryonic Acoustic Oscillations (BAO). The two probes require:

- Determination of the shapes of weak gravitational lensing galaxies over the entire extragalactic sky of 20,000 deg^2.
- Determination of the photometric redshifts of the weak lensing galaxies.
- A spectroscopic redshift survey over the same area of the sky

This is accomplished with a payload which consists of a 1.2m telescope, a visible imaging instrument (VIS, at least 5×10^8 pixels using CCDs) and a near-infrared instrument (NISP, at least 5×10^7 pixels using HgCaTe detectors) with photometric and spectroscopic capabilities. Each instrument has a large field of view and the system is optimized for a sky survey with fast attitude slews to support a step-and-stare tiling mode.

The nominal mission duration is five years. The 3-axis stabilised satellite is launched on a Soyuz ST-2.1B rocket from ESA's spaceport in Kourou. The spacecraft will be placed in a large second Sun-Earth Lagrange point (SEL2) halo orbit. The attitude and orbit control system of Euclid enables an on ground reconstructed absolute measurement accuracy of better than 0.1 arcsec. To achieve the required relative pointing, Euclid will have a fine guidance sensor which is mounted close to the VIS focal plane array.

To facilitate the unprecedented data rate, Euclid will have X and K band transponders to support the telecommanding and the science data transfer to ground, respectively. The K band section supports a downlink data volume of 850 Gbit of compressed science data in 4 hours. Data obtained outside the visibility periods are stored in an on-board mass memory, and later transmitted to ground during the visibility period.

Scientific operations consist of a pre-programmed sequence of manoeuvres to collect ~0.5 deg^2 fields at each step-and-stare pointing. During each pointing, 4 dither frames are collected, and the visible imaging, infrared spectroscopy, and photometry data are collected during the same pointing. The sequence of manoeuvres is known far in advance (more than weeks) and is the result of a pre-defined survey strategy.

3.2 Euclid Ground Segment

The Euclid Ground Segment covers the in-flight operations of the satellite, such that the mission objectives can be met. The Euclid *Operations Ground Segment* consists of the Ground Station Facilities and the Mission Operations Centre (MOC), which operates the spacecraft and creates the telemetry and flight dynamics products.

The Euclid *Science Ground Segment* (SGS) consists of the Euclid SOC provided by ESA and SGS components provided by the EMC. The SGS is responsible for the end-to-end handling of the Euclid data and production of the Euclid mission products.

The SOC acts as the central node for the mission planning; it performs Level 1 data processing and populates the mission archive with the science and housekeeping telemetry after a first quality check. The quality check at the SOC directly feeds back to the mission planning by means of rescheduling of defective observations. The SOC develops, maintains, populates and operates the public archive, which is the vehicle for delivering data products to the general scientific community.

The EMC contributions to the SGS (hereafter referred to as the EMC SGS) consists of Science Data Centres (SDCs) responsible for the science data processing, the generation of the Level 2 and 3 data products, and the development of simulation packages to support the development and testing of the operational pipelines. There will be one or more US provided SDCs. These SDCs will be integrated in the EMC part of the SGS.

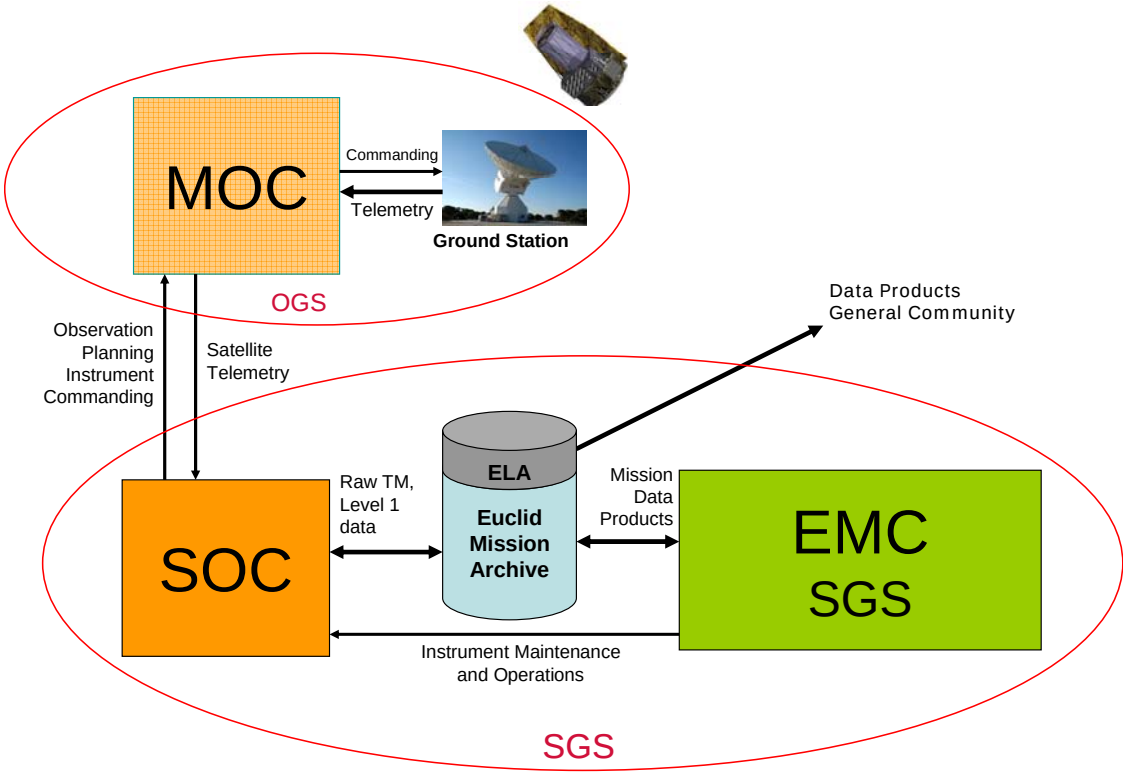

Figure 2: Schematic presentation of the Euclid Ground Segment with its main elements. The elements in the operations ground segment (OGS) and the science ground segment (SGS) have been indicated.

3.3 Euclid Operations Ground Segment

The Euclid Operations Ground Segment consists of the ESA Mission Operations Centre (MOC) and supporting Ground Station facilities.

3.3.1 Euclid Mission Operations Centre

The ESA Euclid Project Manager delegates to ESA's Space Operations Centre (ESOC) the design, development, validation, and operation of the Operations Ground Segment.

ESA is responsible for the readiness of the ground station facilities. MOC is responsible for the availability and operations during the operations phase. Data transfer and supporting infrastructure within the operations ground segment is managed by MOC. The data transfer scheme between the OGS and SGS during routine phase will be defined although given the Euclid data volumes use of the public internet is probably more cost-effective

than dedicated lines. Dedicated links between MOC and the instrument teams' facilities during commissioning and PV phases may be considered. The MOC is in charge of:

- monitoring spacecraft health and safety,
- monitoring instruments safety by ensuring that payload housekeeping data remains within predetermined limits,
- alerting the SGS of all significant anomalies and/or deviations from the nominal behaviour of the spacecraft
- executing predetermined procedures to safeguard the spacecraft and payload, and preserving data integrity
- controlling the spacecraft attitude and maintaining its orbit
- handling telemetry/telecommands for both spacecraft and instruments
- supporting the SGS on all aspects concerning spacecraft operations
- converting SOC requests for pointing and instrument control to spacecraft commands and uplinking them
- daily stripping of the payload data and housekeeping from the telemetry stream, ordering them by (spacecraft) time and making the data available to the SOC
- derivation of the spacecraft pointing history
- archiving the full telemetry data for a period of no less than 10 years.
- receive from Industry the mission information database (MIB)
- maintain the mission information database
- supply to the mission information database to the SOC

3.3.2 Ground Station Facilities

The ESA Deep Space station at Cebreros is baselined as the primary ground station for Euclid operations and is equipped with K(26 GHz) and X band facilities.

3.4 Euclid Science Ground Segment

The Euclid Science Ground Segment consists of the Euclid Science Operations Centre (SOC) and the EMC SGS.

3.4.1 Science Operations Centre

The ESA Project Manager delegates to the Science Operations Department of the Science and Robotic Exploration Directorate based at the European Space Astronomy Centre (ESAC) the design, development, validation, and operation of the SOC. SOC is the only interface to the MOC during routine operations. Within the overall ESA responsibility for the Euclid SGS, the SOC coordinates the overall design, implementation and operation of the Euclid Science Ground Segment with the EMC. It is specifically responsible for:

- Receiving the science data, housekeeping, pointing and other auxiliary data from MOC,

- Deriving the Level 1 products,
- Planning the surveys, based on observing guidelines by the Euclid Science Team,
- Scheduling the spacecraft slews and exposures,
- Monitoring the survey performance and survey rescheduling,
- First-level quality control with Level 1 products,
- Handling instrument operations/maintenance requests from the EMC,
- Requesting MOC action via predefined procedures and sequences of telecommands,
- Provision and operation of the Euclid Legacy Archive,
- Management of the access rights to the Euclid Mission Archive,
- Providing support to the general scientific community.

3.4.2 EMC Science Ground Segment

The contribution of the EMC to the SGS covers the following activities:

- In close collaboration with the SOC, define and maintain the instruments modes of operation to maximise the scientific return of the mission.
- Calibration of the science data including the removal of cosmic ray events, instrumental effects and systematics.
- Preparation of simulated data to support accuracy and performance analysis, optimisation studies and the design, development, and testing of the entire data analysis environment.
- Preparation of data analysis algorithms, which includes galaxy shear analysis, photometric redshift determination, spectroscopic redshift determination, and other slitless spectroscopy analysis. This will include scientific validation of the processing software before launch,
- The design, development, procurement and operation of all aspects of the hardware and software processing environment necessary to fulfil their responsibilities in the reduction of the mission data throughout the simulation, mission operations and the final catalogue production phases. This is considered to include production and scientific validation of the Level 2 and 3 mission data products and population of the EMA with these products,
- The procurement, handling and processing of any additional ground-based astronomical data that may prove necessary for achieving the mission scientific objectives.

4 DATA PRODUCTS AND MANAGEMENT ASSUMPTIONS

4.1 Euclid Databases

4.1.1 Euclid Mission Archive

The Euclid Mission Archive (EMA – a logical, rather than physical entity) will be available to all parties in the SGS for all mission-related analyses. The EMA may be distributed and the EMC and SOC have the responsibility of providing integrity, security and the appropriate level of quality control. The EST will define policies for the data access, which are implemented by the SOC.

The EMC contributes in close co-operation with the SOC to the design, development and operation of the EMA.

4.1.2 Euclid Legacy Archive

As soon as data products have passed quality control and after suitable proprietary period the data will be accessible to the astronomical community through the Euclid Legacy Archive (ELA), which is developed, managed and maintained by SOC.

The ELA is envisaged to be the public subset of a Euclid Mission Archive (EMA) containing all quality controls and intermediate products.

4.1.3 Euclid Mission Data Base

It is assumed that the Euclid mission database will be transferred from industry to MOC and from MOC to SOC before launch. The SOC database will be part of the EMA and maintained by SOC, such that it forms an exact copy of the MOC database. The mission database will be validated by MOC against the spacecraft during System Validation Tests prior to launch. The mission database will be maintained by MOC. During routine operations, the EMC shall provide updates to the instrument section of the mission database via SOC.

4.1.4 External data

To fulfil the Euclid science objectives, the Euclid mission requires complementary datasets obtained via ground-based or space based observations. These datasets include:

- Ground based multi-band photometry of galaxies detected by Euclid covering the entire wide survey area. These data are essential to achieve the required photo-z accuracy.
- A sample of at least 100,000 spectra providing redshifts of galaxies with $dz=0.001(z+1)$ to calibrate the photo-z determination down to AB=24 mag.

- Stellar parameters obtained from Gaia to carry out the astrometry and the absolute photometry calibration

4.2 Data (Processing) Levels

The Euclid data processing system contains “data processing levels” and their associated “data levels”. Data levels consist of all data produced by the corresponding data processing level including intermediate data. The criterion for the definition of a specific data level is that it can be implemented separately from the others and forms a closed and complete part of the data processing chain. Each data level has corresponding quality controls. As described in the SMP, the list of data levels includes:

- External Data. Quality-controlled data from existing missions and ground-based surveys which are used for calibrations, photometric redshift derivations, and simulation validations before and during the mission.
- Level S (Simulation) data. Pre-launch simulations and modelling impacting on calibrations and observing strategies. Massive Monte Carlo simulations are likely to be required post launch to assess systematic effects and derive meaningful uncertainties on the final cosmological parameters.
- Level 1 data. Unpacked and checked telemetry and housekeeping data, and standard processed data with basic detector signatures removed. These signatures include e.g. flat fielding and dark current.
- Level 2 data. Calibrated data and intermediate data products produced during the calibrations. Calibrated data have all instrumental fingerprints removed. Dithered images have been co-added; spectra have been extracted.
- Level 3 data. Science-ready data products, mostly catalogues to achieve the various science goals of the mission.

Additional data levels beyond those listed in the SMP will be discussed between ESA and the EMC during the definition phase; they may, for example, include a post-processing and preparation phase prior to release into the ELA.

EMC SGS will process the Euclid data from Level 1 to higher data levels during all phases of the mission. The EMC has the responsibility of providing integrity, security and the appropriate level of quality control. The Euclid Science Team, via the SOC, authorises data access to the EMA and ELA.

5 IMPLEMENTATION ASSUMPTIONS

In this section the overall function of the Euclid SGS is presented with some consideration of SGS organisation and interface aspects as well as the development and validation/verification of the SGS.

5.1 SGS Function and Structure Assumptions

The following assumptions refer to the Euclid SGS as a whole and apply to the SOC and EMC.

The SGS will develop and validate all algorithms and processing systems required for the scientific processing of the Euclid data and the production of all Euclid products. It also provides the infrastructure required for their processing systems. These processing systems will be operated and maintained until the final Euclid products are produced and validated.

The SGS will support the spacecraft in-orbit commissioning and performance verification phases as required. It will also support instrument operations through the entire routine operations phase. A smooth transition between instrument level tests, system level tests and the operational phases of the mission would be facilitated by maximising the commonality of ground support equipment used through these mission phases.

The SGS produces, validates and documents the intermediate and final Euclid products, according to the schedule and content defined by the PS and EST. The concomitant milestones and schedule for the data reduction activities will be defined by the SGS. The final Euclid products are anticipated to consist of at least Data Levels 1-3 as described in Section 4.2 with accompanying interrogation tools. Access tools and mechanisms will be defined during the definition phase.

The SGS will generate or procure any necessary data sets for test and validation purposes. These could be simulation datasets produced internally or external datasets required to validate the SGS processing systems.

Organisation Units (OUs) and Science Data Centres (SDCs): It is assumed the distribution of work over the so-called OUs and SDCs. In the proposal the feasibility of the structure shall be demonstrated.

Organisation Units will define, specify and validate the processing systems according to their defined role. Section 2.2.3 of the AO describes a potential set of such groups – the proposal shall expand on this list and justify the organisational logic. Science Data Centres will develop and test the processing systems according to the specifications provided by the relevant OUs. They are responsible for the integration and operation of these processing systems into the hardware and infrastructure at the SDC.

One or more Science Data Centres maintains the instrument operational modes and monitor the instrument health until the end of routine operations.

5.2 SGS Interfaces Assumptions

The **Euclid Mission Archive (EMA)** is assumed to be the interface between the SOC and SDCs in the SGS.

The EMA is the primary point of distribution of all Euclid data products within the SGS, which includes the quality data and meta-data. This includes all for example the data levels referred to in Section 4.2 and auxiliary data from MOC

SOC and SDCs use the Euclid Mission Archive to obtain the input data (L1 and higher) and to store the products together with the quality control data.

During routine operations the SOC is the unique point of contact between MOC and the EMC SGS. The SOC receives telemetry and auxiliary data from the MOC, performs the L1 processing, and stores the L1 products and auxiliary data in the EMA. SOC will provide to MOC survey planning and instrument commanding files throughout routine operations phase.

The SOC will receive instrument commanding instructions, instruction database and procedure updates from the instrument operations SDCs which are maintaining and monitoring the health of the instruments. These instructions and updated will be sent to MOC for implementation.

One or more SDCs will procure the external data (either ground or space based) and ingest them in the EMA to make the data available for further processing.

The **Euclid Legacy Archive (ELA)** forms the final scientific archive for the Euclid mission. The SOC will host the ELA and the data and meta-data forming the ELA will be located at the SOC. The data and meta-data underlying the ELA may be replicated elsewhere, although not necessarily with an identical access layer.

5.3 SGS Validation and Verification Assumptions

The overall validation and verification approach and schedule will be described in a top-level test plan. The SGS will be tested and validated before launch in order to demonstrate the ability of the SGS to support the mission. The schedule for this testing will be agreed with ESA. Subsystem and system tests are conducted according to the approved test plans and test reports shall be issued. The SGS will have scheduled integration tests (e.g. interface tests, data flow tests, “end-to-end” tests) until the SGS integration is complete and operationally ready.

The operational elements of the SGS will be included at least 2 relevant space-ground segment system tests (e.g. System Operations Validation Tests) in order to test their interfaces with the satellite and the other elements of the ground segment prior to launch.

The SGS will be scientifically validated in give confidence in the final and intermediate data products. As far as possible this activity will commence and conclude before launch,

however further in-orbit testing should be foreseen and the SGS should be able to support such validation activities in parallel to routine operations.

5.4 SGS Development Assumptions

All SGS development will be performed according to agree engineering guidelines. These engineering guidelines should include coding standards, data models, naming conventions, measurement units, reference frames, common physical and mission parameter definitions, etc.

All information relating to spacecraft or spacecraft component specification, design, implementation, test data or characterisation necessary for the design, implementation or validation of the Euclid SGS will be made available to the consortium as formal deliveries. All deliverables from ESA to the EMC will be governed by an Interface Control Document with a delivery schedule and agreed by ESA and the EMC.

Software developed specifically for Euclid jointly by ESA and its partners will be put under a worldwide license such as LGPL. In accordance with SPC(2009)6 approval for this action will be sought from the ATB (Agency Technology Transfer Board).

6 PROGRAMMATIC ASSUMPTIONS

In this section consideration is given to the overall management of the SGS.

6.1 Compliance to ECSS standards

ECSS standards form the core set of standard applicable to the development of the SGS. During the definition phase these standards will be tailored to meet the needs of Euclid SGS development. Production of the tailoring will be led by the SOC. This tailoring will be documented with a compliance matrix to the ECSS standards.

6.2 Management Assumptions

The SOC Development Manager will be assigned and given the responsibility to ensure the timely delivery of all the SOC deliverables and execution of all SOC tasks.

The Euclid Mission Consortium will be led by a single person, the Euclid Consortium Lead (ECL). The ECL is the single formal interface for the consortium with the ESA project office. For the SGS he/she will be supported by the Euclid Consortium Science Ground Segment Manager (ECSGSM) for the consortium contribution to the Euclid SGS.

The ECL and ECSGSM are responsible for the timely delivery of all the EMC SGS deliverables and execution of all EMC SGS tasks.

Experience from other missions (e.g. Gaia) have indicated that a dedicated and independently funded Project Office with personnel responsible for the project management activities (project control, schedule control, product assurance, risk management, document and product tree definition, document management and configuration control, etc.) would be an effective management approach for the Euclid SGS.

Each SDC will be led by an SDC Manager who reports to the ECSGSM.

6.3 Product Assurance Assumptions

All SGS elements will be produced in accordance to the agreed management and engineering plans. In order to facilitate this a common Product Assurance Plan will be produced and implemented by the EMC and ESA in order to assure compliance to the management and engineering plans.

During all phases of the SGS implementation and operations each contributor will carry out a Product Assurance/Quality Assurance (PA/QA) activity.

PA/QA aspects will be also addressed at each review of the various components (i.e., SOC and SDCs) of the Ground Segment as well as during the reviews of the entire Ground Segment and the Mission Level reviews.

6.4 Configuration Control and Management Assumptions

All SGS elements will be produced in accordance to a common Configuration Management Plan. This Configuration Management Plan will be applicable to documentation, software and hardware configuration control within SGS through all mission phases.

All Euclid SGS processing systems, documentation and data items will be delivered for integration and storage in accordance to the agreed configuration control system.

6.5 Reviews and Reporting Assumptions

The entire Euclid SGS will follow a schedule of reviews adapted from the standard ECSS review cycle. The review cycle will be defined by ESA and agreed with the EMC SGS Manager during the definition phase.

Management reports will be produced on a regular (typically quarterly) basis in a format and frequency to be agreed with ESA. These reports will be prepared by each OU and SDC and submitted to the EMC SGS Manager. These reports, together with an overall summary, will be included in the reporting to ESA.

6.6 Common Tools and Facilities

The SGS will use common tools and facilities to support the development and management of the SGS. Candidates for such tools include

- Requirements management, including facilities for requirement capture, maintenance and verification purposes,
- Document management. The ESA Livelink system has been used successfully in other missions and is a natural candidate for this system,
- Planning and schedule tracking,
- Software issue tracking and source code configuration control,
- Data model definition.

More general categories include Wikis, mailing lists, web-forums, etc. Provision of these tools will be agreed during the definition phase. The appropriate plans and guidelines will make reference to these tools.

7 SUMMARY OF AO PROCESS FOR THE EUCLID SGS

7.1 Expected contents of proposal

The proposal to be made in response to this AO by the Consortium for SGS-related activities must contain two elements. The first is a proposal for EMC definition phase activities and the second is an outline proposal for EMC activities for all other phases of the mission. In more detail, these elements are to expected to contain:

- Proposed planning for SGS definition phase
  - A technical/programmatic description of the Consortiums' approach to supporting the SGS activities during the definition phase
  - A management proposal (c.f. Section 3.1.4 of the AO) including a Work Breakdown Structure and set of Work Package Descriptions which identify the activities required to support the SGS definition.
  - A financial plan (c.f. Section 3.1.5 of the AO)
- Proposed planning for the SGS implementation phase
  - An Implementation Proposal describing the technical and programmatic planning for the implementation phase (c.f. Section 3.2.3 of the AO)
  - A management proposal (c.f. Section 3.2.4 of the AO)
  - A financial plan for the implementation phase (c.f. Section 3.2.5 of the AO)

7.2 Definition phase activities

To make this SGSID self-contained the following two paragraphs and figure are repeated verbatim from the AO section 3.1.3:

In order to define a coherent and optimised SGS, it is expected that all SGS-related activities in the definition phase shall be carried out in close co-operation between ESA (SOC) and the EMC. It is expected that the SOCD and draft SIRD will be jointly generated during the definition phase. As shown in Figure 1 [in AO], the draft SIRD after review and any necessary updates will be formally issued by ESA Project after the definition phase as an input to subsequent phases. Each party will be responsible for their draft SIP which responds to the draft SIRD.

Activities are expected to build upon those carried out in the assessment phase and in the Consortium proposal preparation. Thus, as summarised in Figure 1 [in AO], the starting points for definition phase work will be the Science Management Plan (SMP), the Euclid SGS Interfaces Document (SGSID, derived from the assessment phase Science Operations Assumption Document (SOAD) and defining the responsibilities, interfaces and high-level assumptions/requirements of the SGS), the Consortium proposal for definition phase activities (WBS/WPD, see management proposal paragraph, part IV [in AO]) and the Consortium Implementation Proposal (IP, see section 3.2.3 for details [in AO]). During

the course of the definition phase, it is expected that the SGSID will evolve into the draft SIRD and the IP into the draft SIP for the Euclid Mission Consortium contributions (see overall schedule in table 1 [in AO]).