DOCUMENT

document title/ titre du document

M CLASS INTERNAL REVIEW REPORT –

EUCLID

TECHNICAL AND PROGRAMMATIC REPORT

prepared by/*préparé par*	EUCLID REVIEW BOARD
reference/*réference*	SRE-PA/2009/051
issue/*édition*	1
revision/*révision*	2
date of issue/*date d'édition*	14 December 2009
status/*état*	Final
Document type/*type de document*	TN
Distribution/*distribution*	INTERNAL

European Space Agency
Agence spatiale européenne

ESTEC
European Space Research and Technology Centre - Keplerlaan 1 - 2201 AZ Noordwijk - The Netherlands
Tel. (31) 71 5656565 - Fax (31) 71 5656040 www.esa.int

APPROVAL

Title *Titre*	EUCLID TECHNICAL AND PROGRAMMATIC REPORT	issue 1 *issue*	revision 0 *revision*

author *auteur*	Review Team	date 31 Oct 2009 *date*

approved by *approuvé par*	G.Racca	date 7 Nov 2009 *date*

CHANGE LOG

reason for change /*raison du changement*	issue/*issue*	revision/*revision*	date/*date*
Chapter 4, new paragraph added	1	1	13/11/2009
Editorial changes prior to external release by board observers	1	2	14/12/2009

CHANGE RECORD

Issue: 1 Revision: 2

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*
Editorial changes prior to external release by board observers	4	2.1, 2.1.1
	5	2.1.1.1
	6, 7	2.1.2
	8, 9	2.3
	10,	2.4.2
	11,	3.1
	12	4

Issue: 1 Revision: 1

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*
New paragraph added	11	Section 4

TABLE OF CONTENTS

1 INTRODUCTION

The composition of the Euclid Review Board was:
G. Racca, chair
A. Elfving, vice-chair
C. Damasio (thermal)
J-L. Parquet (structural)
B. Harnisch (optical)
J-P Lejault (attitude control)
T. Paulsen (data processing)
J-L. Bezy, replaced by C. Scharmberg (instruments)
Z. el Hamel (cost)
F. Safa &T. Passvogel (observers)

T. Paulsen and C. Scharmberg were opted to support payload aspects, particularly supplementing J-L. Bezy who was absent partially, through illness.

The Review activities were supported by
D. Lumb, secretary
L. Duvet, N. Rando, G. Saavedra-Criado and R. Laureijs as Study team members

The Kick-off meeting of the Review was held on October 2 , 2009.
The dates of subsequent working meetings were 8th October, 19th October and 22nd October was the final Review Board Meeting.

1.1 List of documents

The following documents were provided for the review Kick-off.

a) *ESA Study Team Inputs*

Title	Reference	Issue
Science Requirements Document	*DEM-SA-DC-0001*	v 3.2 24 Aug2009
Mission Requirements Document	*SCI-PA/2008-034*	v3.1 18 June 2009
Payload Definition Document	*SCI-PA/2008-038*	v4.2 1 Sep 2009
Science Operations Assumption Document	*Euclid-SA-Dc-0003*	v0.2 25 Aug 2009
Euclid Mission Assumption Document	*DOPS-MIS-MAD-1004-OPS-HSA*	v1.1 24 July 2009
Euclid Environment Specification	*Euclid_environment_JS-22-09*	30-Sep-2009

Yellow Book	Euclid_YB_2009_10_01	V 0.9 2 Oct 2009
EUCLID Technical and Programmatic Report A	SRE-PA/2009/051	(Draft)
EUCLID Cost at Completion Report B	SRE-PA/2009/061	(Draft)
CDF Report	CDF 73A	June 2008
Euclid Technology Development Plan	SRE-PA/2009-036/DL	V1.3 8 Oct 2009
Euclid Consolidated Report on Mission Analysis	MAS Working Paper No. 533	Iss 1 rev 1 Nov 21 2008
MRD Compliance Table	SRE-PA/2009/064	draft
Template Cost worksheet	Cost_Estimate_Template_euclid.xls	V2 29-Sep-2009

b) *Thales Alenia Space*

Title	**Reference**	**Issue**
Thales Final Presentation Material	Euclid Final Presentation 090910_rev4	V4 10-Sep-09
System Design Report	SD-RP-AI-0601	V 4 28-Sep-09
System Budget Report	SD-RP-AI-0602	V 4 28-Sep-09
THERMAL DESIGN AND ANALYSIS REPORT	SD-RP-AI-0609	V 2 31-JUL-09
PRELIMINARY DEVELOPMENT AND VERIFICATION PLAN	SD-TN-AI-1194	V 2 28-Sep-09
Point Spread Function Requirements Analysis	SD-TN-AI-1248	V 2 28-Sep-09
Photometric Model of the NIR Instruments	EUCLID-KT-TN-003	V 6.4 17-SEP-09
Euclid VIS Radiometric Model	EUCLID - VIS radiometric model_v4.xls	V4 04-AUG2009
Data Processing	EUCLID-KT-TN-06	V 1 24-Sep-09
Dithering Concept	EUCLID-KT-TN-004	V2.2 21-SEP-09
Memo on Sky Scanning Strategy	EUCLID-DMS-TEC-MEM03	V1.1 8 Sept 2009
Euclid Executive Summary	SD-TN-AI-0613	V1 25-Sep-09

c) *EADS Astrium Gmbh*

Title	**Reference**	**Issue**

Astrium Final Presentation Material	ASG_EUCLID_HO_008_FP	9 Sep 2009
System Design Report	ASG_EUCLID_TN1.3	v2.1 02.09.2009
Thermal Analysis	ASG_EUCLID_TN1.5	v2.0 02.09.2009
Development and AIV Plan	ASG_EUCLID_TN2.1	v1.1 02.09.2009
Technology Readiness Evaluation and Technology Development Plan	ASG_EUCLID_TN3.2	v1.1 02.09.2009

d) *Instrument Consortia*

Title	**Reference**	**Issue**
ENIS Development Plan	EU-NIS-IASFBO-PL-001	V1 30-Sep-2009
ENIS Design Report	EU-NIS-PST-RP-006	V1 30-Sep-2009
ENIS management Report	EU-NIS-IASFBO-RP-007	V1 30-Sep-2009
EIC Development Plan	EUCL-PL-00012-CEA	V2 28-Sep-2009
EIC Design Report	EUCL-RP-00011-CEA	V2 24-Sep-2009
EIC management Report	EUCL-PL-00024-CEA	V1 30-Sep-2009

1.2 Review Activity

At the Kick-Off meeting the SRE-PA management provided guidelines for the review. The Study team presented an overview of the mission design as presented by the industry and payload consortia. This was followed by a presentation of open issues and concerns that had been raised during the course of the assessment study. Finally the review tasks were allocated to board members.

At the second and third meetings, the review team presented their interim findings. The final meeting consisted of summary presentations, with the presence of SPC observers. This report has been compiled to reflect the overall findings. The minutes of the meetings are detailed in references [1-4].

Review criteria were provided in [5].

2 TECHNICAL REVIEW

2.1 Spacecraft design

At a top level the following summary findings were agreed:

- System Requirements: The translation of mission requirements to system requirements have been performed in a preliminary manner. In some cases this is considered adequate, while in other cases (e.g. straylight, cleanliness, PSF ellipticity, survey coverage requirements) more work is required to critically assess the design implications and to consolidate the derived requirements;
- Spacecraft Design: Consistent with a pre-Phase A study, only a top level conceptual design was provided. The design is supported by inadequate analyses, e.g. in areas such as straylight, AOCS performance and thermo-elastic effects
- Definition Status: Euclid is conceived as a Survey mission based on consolidated European experience. However, the following topics were identified to be of major concern and are consequently detailed in the following paragraphs:
  - The optical requirements of the payload module are challenging with the potential for high technical and programmatic risk;
  - The mass budget is assessed to be critical w.r.t. Soyuz capability and thus seen as a technical risk;
  - The Attitude control performance is also challenging, and is viewed as a technical risk;
  - High thermo-elastic stability was determined to be essential for ensuring performance that presents a technical risk;
  - Instrument Data Processing was found to lack a detailed definition, but the analogy with other missions (GAIA) of similar complexity, reduces the potential technical risk;
  - The definition of the interface between Instrument and Spacecraft has not been consolidated and this raises a potential programmatic risk.

2.1.1 TELESCOPE

The telescope is critical both in terms of achieving the WFE performances and maintaining it stable under operational conditions in space. The two consortia have baselined two different materials for the primary mirror: SiC and Zerodur. Each of these materials leads in our view to contrasting risks issues, as detailed in the following sections.

- The driving performance requirement is the PSF ellipticity requirement ($e<0.1$);
- The deduced VIS imaging performance requirement of 60nm rms at cryo temperatures leads to an ambient on ground performance requirement for the optical elements of 41nm rms. The allocation for the M1 mirror is about 30nm rms, which is stringent for a 1.2m light weighted mirror;
- This will require a polishing strategy of large tool polishing with final ion beam figuring.
- In addition to the 30nm rms for the M1 mirror, local gradients on all optical elements have to be minimised in order to meet the ellipticity requirement;
- M1-M2 distance tolerance of 5 micrometer absolute alignment for an inter mirror distance of 1.75 m is rather demanding, therefore a refocusing mechanism is required and baselined by both industrial consortia;
- Defocus has a strong impact on the ellipticity performance;
- The lack of adequate straylight analysis does not allow to clearly identify the possible impact on the ellipticity calculation of the targets (mission primary objective). However it is envisaged as baseline to apply a coated (CVD SiC) mirror in order to reduce the in-field straylight.

2.1.1.1 SiC

Euclid large mirror (1.2 m) can be manufactured in silicon carbide with existing facilities by making use of brazing technology. However, the straylight requirements will ask for depositing a SiC layer prior to polishing using Chemical Vapour Deposition process (SiC-CVD). Brazed SiC mirrors of various sizes have been manufactured (up to 3.5 meters, Herschel) and CVD large mirrors have also been produced with an optical quality in cryogenic environment comparable to that requested for Euclid (e.g. Gaia, 1.5 x 0.5 m, NirSpec).

However, combining the deposition of a SiC-CVD layer with brazing technology was not achieved so far on large mirrors. The development risks are:

- the mastering of petal alignment during brazing process for ensuring a sufficient SiC CVD thickness everywhere on the reflector surface prior to polishing,
- the ability to polish the brazed joints with low wavefront error; This is demonstrated on samples, but would deserve a verification on a mirror of appropriate size,
- the bi-metallic behaviour of the mirror under cryo conditions due to the SiC CVD layer thickness variations and to the brazing joints.

A dedicated technology development contract of full relevance to Euclid is currently running with AMOS since October 2009, for a nominal duration of 24 months. This development actually includes the combination of SiC-CVD and brazing for a mirror of appreciable size (900 mm diameter) and should significantly lower the above mentioned risks, since the mastering of petal alignment and the polishing of brazed joints are expected to be demonstrated by end 2011. However, a cryotest was not initially foreseen in this activity. Although bi-metallic behaviour may be evaluated with appropriate finite element modelling, it is highly desirable to achieve this verification by test as soon as possible on a demonstration mirror. The Review Board recommends to complement this activity for that purpose (e.g. add a cryo-test for a demonstration mirror under development) for securing Euclid development schedule, should SiC technology be retained for the telescope.

2.1.1.2 Zerodur

The Zerodur has a higher TRL but is heavier than SiC. Scaling with comparable ground based telescopes was used for mass comparison on a base of the manufactured M2 Zerodur mirror for the ground based Gemini telescope with a diameter of 1m. The EUCLID mirror has a 45% larger area than the Gemini M2, and by applying a conventional area mass scaling factor ($\sim r^{2.7}$) a higher mass than accounted for in the TAS mass budget (+12 kg) is found. The manufacturing time (light weighting and polishing) is estimated to 24 months, of which a significant contributor is the light weighting ratio. Therefore there is high risk for a mass increase after detailed design and manufacturing.

2.1.2 AOCS

Of the critical service module items, the AOCS is particularly important to enable the very stable pointing and relatively frequent slew and dither steps. In particular the compliance with the Relative Pointing Error (RPE) requirements of 25 milli arcseconds (mas) over 500 s is considered very challenging and a potential risk. The pointing stability requirement is considered to be at least as challenging as for GAIA, with delta-qualifications requested for the actuators:

- The Astrium baseline is to use cold-gas micro-propulsion, applying the GAIA heritage. However, the equivalent RPE specification is ~20 times more demanding for Euclid. As the compliance against the RPE requirement is already marginal for GAIA and the cold-gas noise and dynamic response are difficult to be achieved, this raises concerns about their applicability for Euclid. Also the cold-gas consumption is a concern since the fuel budget will be very sensitive to the uncertainty between the centre of mass and centre of solar pressure of the overall S/C;
- TAS has baselined magnetically suspended reaction wheels, which are under development, but TAS has not considered micro-vibration impacts;
- An independent and preliminary close-loop AOCS simulation run with both actuators has been achieved by the Review Board. In both cases, the requirement the requirement could not be met by a factor > ~ 2. Although this result is obtained through a worst case analysis and could be improved by further optimisation of the controller, the simulation confirms the criticality of RPE requirement;
- A Focal Plane Guidance Sensor (FGS) is required for relative pointing. Basic definitions of its interfaces are lacking, e.g. accommodation within the focal plane, image acquisition rate and data processing interfaces with the SVM. Moreover, in case of the DMD based spectrometer instrument, the FGS would have to meet a much more stringent AME requirement (100 mas) for which a dedicated FGS on-board star catalogue should be used. Presently no star catalogue (e.g. Hipparcos) can provide such accuracy and completeness for faint stars;
- The impact of the disturbance torques originating from the instrument filter wheel movement during a staring period is not properly addressed in the studies. A compensation mechanism could be needed.
- The analysis of the slosh impact is immature

The controller design and the command of the filter wheel can take benefit from the long integration time and step-and-stare period for smoothing the internal perturbations. This may ultimately require a balance between AOCS requirements and the effective observation efficiency. Globally, the pointing requirement is not perceived to be out of reach but a substantial effort will be required in the Definition Phase for consolidating the RPE performance. A relaxation of this requirement using on-ground calibration should be considered and assessed.

At system level, mass impact resulting from nearly constant external torques will have to be carefully tracked and monitored. The dominant torque results from the solar pressure and from the residual actual distance between the centre of mass and centre of solar pressure. The mass impact results from the extra propellant needed, from the cold gas itself or for desaturating the wheels.

The following development risks have been identified for AOCS:

- Delta-qualification needed for the micro-propulsion to extend its range from 0.5 mN to 1mN or 2mN. Further verification on the noise and dynamic performance is required;
- Magnetic bearing wheels are under development at Rockwell Collins (former Teldix in Germany). TRL 5 seems to be compatible with Euclid, but its development is not

controlled by ESA. The preliminary requirements of a magnetic bearing wheel have to be consolidated;

- A compensation mechanism to counteract the filter wheel rotation, if confirmed;
- FGS development and validation.

2.1.3 STRUCTURES

Nominal operations are performed with constant Sun Aspect Angle at 0° where the thermoelastic stability should be adequate. However, the use of a refocusing mechanism on M2 is expected to be needed to reach optical performance after launch and zero-gravity settling.

In case “Equinox operations” are needed to cover the full sky, a SAA up to 30° is envisaged. In this case a very long settling time is required to reach thermal equilibrium. Moreover, there may be interference between refocusing control operations and thermo-elastic “creep”. The review team suggests to allow longer operation time to avoid “Equinox operations” and enable a simplified thermal design to ensure a deterministic optical performance over the complete sky.

A significant risk for the project is that the dimensional stability for end to end optical performances is verified with the thermo-optical tests in vacuum only at the end of the development,. Furthermore verification of the worst flight cases will be completed even later since the models correlations (thermal and thermo-elastic) are only performed after test completion.

The standard 20% mass maturity margin is low considering the uncertainties in proposed P/L structure and mechanisms. A 30% mass margin would be more appropriate taking into account the pseudo-isostatic mountings effects on the dimensional stability, i.e. very specific mountings by introducing rotational flexibilities or clamped joints during the launch with associated in-orbit release system.

The micro-vibrations are not addressed at the level of transmissibility and at the level of source determinations (for mechanisms as reaction wheels, filter wheel, etc…).

The evaluations of the effects of the imperfections of the iso-static mountings between the SVM and the PLM on the dimensional stability (thermo-elastic) have not been addressed.

2.2 Instrument Definition

2.2.1 INSTRUMENT INTERFACE DEFINITION

While the interface of the VIS instrument is well established at the focal plane, the industrial and instrument consortia have adopted different interfaces for NIS and NIP. In particular for the NIS, the interface of the telescope to the instrument is for ASTRIUM in the afocal telescope exit pupil where the grism is located. The Thales Alenia interface is defined in the intermediate focal plane after the telescope M2 mirror. The wavefront error is in both planes too high (120nm rms in the

grism plane, while 7 micrometer rms in the telescope Cassegrain focus). Using these interfaces does not allow an independent NIS verification without the telescope. The manufacturing of a dedicated OGSE, rebuilding the telescope aberrations would imply a high programmatic risk. As a consequence the NIS instrument will need a re-design, to improve the wavefront error at the grism interface and to provide more clearance between the correction lenses and the optical beams to avoid vignetting.
Using the established interface definitions for VIS, NIP and a redefined interface of NIS as described above, no independent instrument verification can be done without the telescope. Therefore a dedicated telescope simulator must be manufactured, which have to rebuild the aberrated wavefront of the telescope beam at the optical entrance plane for the instrument FoV.
In summary the review team proposes to plan for:

- a telescope simulator, supplied by the PLM contractor to each instrument provider for instrument performance verification;
- an OGSE representing each instrument, supplied by each instrument provider, to be used by the PLM contractor to verify the end-to-end optical performance at instrument detector plane.

2.2.2 INSTRUMENT DATA PROCESSING

The NIS instrument requires significant on-board data processing: some GFLOPS, depending on more detailed algorithm assessment. Depending on the algorithm characteristics this throughput performance may be achieved by mainly applying pre-processing FPGAs or ASICS. If more complex algorithms are envisaged, GAIA experience confirms feasibility of achieving the required throughput but will require access to ITAR restricted PowerPC processing boards from Maxwell.

The DHS can be centrally provided by the spacecraft as proposed by Astrium, or dedicated per instrument as proposed by TAS, ENIS and EIC. Either approach is feasible, but entails different share of resources, responsibility and cost.

2.2.3 SPECTROMETER GRISM

The grism has a grating constant of 15 lines/mm, giving a ruling constant of 66 micrometer. This is hardly feasible with the standard grating process of ruling in gold and ion-beam etching. The largest ruling constant of the James Webb NIRSpec grating is 30 micrometer.
An alternative process is the one of the lithographically manufactured transmission grating with a sub-wavelength structure, developed for the GAIA RVS channel. As foreseen in the planning, a technology development is needed.

2.3 Budgets

Both assessment studies present system mass close to stated launcher performance (2160kg). The Service Module and Sunshield mass budgets can be compared to past experience by the review team and were confirmed to be adequate, but with no substantial extra-margins. The Payload Module has instead large design uncertainties and it is suggested that a 30% mass maturity margin ought to be applied at this stage. This is amplified by the lack of clear interface definition between the telescope assembly and the instrument consortia, and also a lack of mechanical/thermal detailed modelling. Specific areas identified include:

- Isostatic design principles of full PLM, telescope and sub-assemblies;
- Design philosophy for the Focal Plane Assembly, i.e. single optical bench or distributed optics and instruments;
- Launch contamination protections with an opening lid cover;
- Areal mass of M1;
- Design for thermo-elastic stability;
- Uncertainties in instrument design;
- Large discrepancies in the estimate of cold-gas fuel.

By implementation of this additional margin, the mass budget violation was estimated to be in the order of 5% (100kg), representing a technical risk. This gain should essentially come from the payload – namely the focal plane instruments and/or the telescope assembly- and the Review Board recommends to achieve this mass saving at the beginning of the Definition Phase, while minimising the impact on the basic science performance. Besides, aiming at simplifying the instrument focal planes – in particular the number of IR detectors – will also enable bringing back the launch schedule in 2018 (see section 3 below)
The DMD based spectrometer design was not considered in the mass evaluation. This design was only provided by ENIS. The quoted mass figures for the four spectrometer assembly are considered very optimistic and would require substantial additional mass savings - which are difficult to quantify at this stage - for preserving the compatibility with Soyuz launcher.

2.4 Technology readiness

The spacecraft and payload equipment requiring technology development have been identified by the ESA Study Team in SRE-PA/2009-036/DL V.1.3. The review team considers the document complete and adequate, although at a preliminary stage. In the following sections we have listed the items requiring particular attention.

2.4.1 PLATFORM

The technology developments for the service module are not particularly severe, but a particular attention is required to these items:

- FGS / AOCS: As explained above FGS is required in order to meet the RPE. In addition in case of the slit solution, the AOCS would need to meet the AME requirements. Potentially critical;
- Micropropulsion: based on GAIA experience the development should make sure that the noise and dynamic characteristic of Cold-Gas can meet the AOCS performance;
- Magnetic suspended reaction wheels: DLR technology development is on-going. ESA should become involved to verify relevance of the applied performance requirements and the criteria to judge adequate TRL level by 2012.

- K-Band system: Europe does not have a RF system (transponder/antenna) in the 26 GHz K-band, thus this would require some development. However, it should be investigated to what extent the Ka-band (32 GHz) technologies could be used, so that heritage of existing systems (e.g. Bepi-Colombo, SMART-1) can be reused.

2.4.2 PAYLOAD

The technology development for the instruments is more critical and needs to be further scrutinised. The following items require attention:

- The SiC mirror with CVD SiC coating and brazing: the running technology activity should be complemented by a cryogenic test for covering all Euclid needs;
- CCDs and read-out electronics: technology based on GAIA, minor modifications, but surprises may arise;
- IR Detectors: No European alternatives are envisaged to be ready on time, although a development has started. If American Hawaii devices by Teledyne are procured, including ASICS, the main problem will be the procurement time and the responsibility/funding issue;
- Grating: as explained above the optimal line density of the grism could require manufacturing process development;
- DMD: this item is not recommended by the review team for further considerations as the science requirements are met with the slitless solution. In case it is selected, a major development needs to be performed to space qualify these commercial devices from Texas Instruments initially designed for Cinema applications;
- Tip – Tilt mechanism: alternative development required to avoid ellipticity degradation. No simple defocus method exist;
- Cryo-mechanisms: are required in NIP and VIS with very demanding alignment accuracies, therefore potentially critical development.

3 PROGRAMMATIC REVIEW

3.1 Development plan and schedule risk

The top level assessment is the following:

- The proposed development philosophy (only AVM and PFM) is very risky, especially for the PLM and the instruments, with high probability for late surprises and rework;
- A rudimentary schedule is available but with inadequate level of detail. Despite the lean model philosophy the schedule is tight with inadequate contingency (3 months). This is viewed as a High Programmatic Risk;
- Cost : Cost estimates are available and complete, providing an adequate basis for evaluation

The perceived level of instrument heritage by the two consortia is different: for TAS-I it is low and for Astrium is high.

The development schedules have been essentially designed to fit within an artificial schedule constraint of 2018 launch. This implies instruments development schedules of less than 4 years to PFM DRB. The review team considers this is not credible compared with similar instruments. For example the Herschel instruments took 9 years from selection to FM DRB, the schedule for the two James Webb instruments shows 6.5 and 8 years from SRR to planned delivery. The best comparable case could be the GAIA instrument with a 5 year development duration, however no FM DRB has been reached yet. It is noted that for a fair comparison with GAIA, a substantial funding for Euclid instrument detector procurement and GRISM development would be needed before the final down selection.
Also on the instrument side, it is noted that the VIS and NIP model philosophy (STM, PFM) contains a high risk for "late surprises".
NIS needs to decide for either a slitless or DMD design solution in the near future. The recommendation from the Review board is that as a consequence of the TRL status and the significantly more demanding system requirements, the DMD slit spectrometer option should be rejected as being not compatible with M class mission constraints.

4 RECOMMENDATIONS

Euclid is conceived as an astronomy survey mission based on consolidated European experience; however the mission presents a number of programmatic and technological challenges.

The critical mass budget together with the telescope mounting principle (level of iso-staticity and thermoelastic distortion compensation), the focal plane configuration (common optical bench or distributed optics and instruments) and the optics material (SiC vs. Zerodur/CFRP) constitute the main Payload module technical risk and need to be solved by a more in-depth trade-off. This trade shall also involve science requirements, possible reduction of telescope diameter and sky coverage requirements, in order to re-gain margins.

On the technology side, apart from some development required in the SVM judged at medium risk, a number of developments (grating, detectors, cryo-mechanisms, mirror manufacturing) need to be performed by the Instrument entity. This is considered highly critical.

The development schedule is considered underestimated even assuming the unrealistic assumption of the instrument pre-development before the mission selection. However, given a more realistic development schedule (~1.5 year extension) the review team conclude that the mission as defined is feasible and that the space segment development is challenging but achievable. The following fundamental issues have to be tackled as a matter of priority:

- Definition of clear instrument/spacecraft interfaces to allow effective parallel refinements by instrument providers and industrial study teams for design and verification aspects;
- Constrain the observation scenario to Sun Aspect Angle = 0 deg, by allowing longer operations and/or reduced sky statistics, to bound the criticality of thermo-elastic effects on the optical performances;
- In order to contain the mass budget uncertainties, accelerate the efforts to achieve TRL confidence for:
  - main mirror in SiC with adequate WFE performance;

- magnetic bearing reaction wheel with adequate low noise and torque resolution performance.

Moreover, the review board recommends to have a strong ESA lead for the instrument developments, with a clear consortium organisation and space industry strongly involved, and starting at an early stage of the Definition Phase. This is perceived mandatory to ensure control on cost and schedule in such a demanding mission.

5 REFERENCES

[1] Euclid Internal Review Board Kick Off Meeting Minutes SRE-PA/2009.066
[2] Euclid Internal Review Board Working Meeting 1 Minutes SRE-PA/2009.074
[3]] Euclid Internal Review Board Working Meeting 2 Minutes SRE-PA/2009.075
[4]] Euclid Internal Review Board Final Meeting Minutes SRE-PA/2009.0nn
[5] SRE-PA/2009/013.