DOCUMENT

document title/ titre du document

M CLASS INTERNAL REVIEW REPORT

SPICA

TECHNICAL & PROGRAMMATIC REPORT

prepared by/*préparé par* Review Board

reference/*réference* SRE-PA/2009/071/GC
issue/*édition* 3
revision/*révision* 2
date of issue/*date d'édition* 8 December 2009
status/*état* Final
Document type/*type de document* Report
Distribution/*distribution* Internal

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APPROVAL

Title *Titre*	issue 3 *issue*	revision 2 *revision*

author *auteur*	date 8 December 2009 *date*

approved by *approuvé par*	date *date*

CHANGE LOG

reason for change /*raison du changement*	issue/*issue*	revision/*revisio*	date/*date*
Update of draft issue 1 –comments of Board Members added	*2*	0	6 October 2009
Final versions with final corrections from Board Members	3	0	14 October 2009
Delta corrections to version 3.0	3	1	22 October 2009
Delta modifications to version 3.1- suggested by F.Safa (observer) agreed by Chair and Deputy Chair. Improvement of text, no change in the message.	3	2	8 December 2009

CHANGE RECORD

Issue: 3 Revision: 2

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*
Improvement of text, no change in the message	13 15	Section 4.1 Sections 4.3,4.4

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1 INTRODUCTION

This report highlights the findings of the Review Board for the SPICA M-Class Mission which is a joint Japanese Space Agency (JAXA) ESA mission. The ESA contributions are:

- The SPICA Telescope Assembly (STA)
- The SAFARI Instrument
- European Science Operation Centre (SOC)
- Contribution of Support to the Japanese Mission Operations Centre – ESA ground station

The review was carried out with respect to the Review Procedure (AD (1)).The main goal of the review is to provide a solid basis for the selection of the mission candidates to enter definition phase (including both technical and programmatic aspects). This top level aim is broken down to the following objectives:

- To assess the completeness and overall consistency of the mission requirements.
- To review the technical feasibility of the proposed mission (all elements), in accordance with the technology readiness level expected for M-class candidates.
- To verify the compatibility of the overall development risk with the schedule applicable to M-class missions.
- To establish the compatibility of the estimated ESA Cost at Completion (CaC) with the allocated M-class mission budget, including an adequate contingency level.
- In the case of international cooperation, to confirm the existence of adequate agreements on respective responsibilities and clearly defined interfaces.

Moreover, the review board shall also address the following points:

- Adequacy of the assessment study results and level of detail (also including model payload).
- Identification of areas requiring further attention during the definition phase.
- Completeness of the proposed technology development plan (both in terms of technology development activities and overall schedule).
- Potential risk mitigation areas, including need for specific test facilities.

1.1 Board Composition and Review Process

The below table summarizes the Board Composition and the area of expertise of the members

Position	Name and Address Code	Area covered
Chair	P. Jensen (SRE-PJ)	Mission
Deputy Chair	G. Crone (SRE-PTP)	System/STA lead, Mission
Secretary	N. Rando (SRE-PAM)	
Observer	T. Passvogel (SRE-PT)	
Observer	F. Safa (SRE-PA)	

Member	C. Jewell (SRE-PTP)	SAFARI Lead, cryogenic coolers, thermal, Mission
Member	A. Newerla (TEC-MSS)	Structures
Member	L. Gaillard (TEC-MSM)	Mechanisms
Member	I. Escudero (SRE-PAI)	Optics
Member	J-C. Salvignol (SRE-PJ)	Payload & STA AIT
Member	P. Verhoeve (SRE-PAI)	Detectors
Member	Z. el Hamel (SRE-MC)	Programmatics and costing
Expert	A. M. Heras (SRE-PA)	SPICA Study Scientist
Expert	D. Doyle (TEC-MMO)	Optics and STA AIT

In conducting the review three top level areas were addressed:

- The SPICA Mission and interfaces and concerns with respect to JAXA
- The SPICA telescope assembly
- The SAFARI Instrument

The Table below summarizes the plenary meetings held and their content.

Meeting	Date	Content
Kick off Meeting	2nd September	Introduction and Review Organization
Progress Meeting 1	9th September	Mission aspects Questions to JAXA System issues(STA and SAFARI) Design/ maturity/interfaces Definition of Splinter meetings
Progress Meeting 2	16th September	System issues(STA and SAFARI) Design/ maturity/interfaces Risks for Design Evolution Technology Status and Readiness Design, Development, Schedule and cost Definition of Splinter Meetings
Progress Meeting 3	21st September	Draft Final Presentation and Conclusions Open Discussion on Mission, STA, SAFARI
Progress Meeting 4	23rd September	Final presentation to Board and SPC Observers Conclusions and Recommendations Final report Planning

In addition to the above meetings a number of splinter meetings were convened to address issues identified in the plenary meeting. The following meetings were held:
Telescope mechanical design, analysis and requirements – G. Crone, A. Newerla, J-C. Salvignol
Telescope Issues, straylight, AIT, manufacturing and polishing - G. Crone, I, Escudero, D. Doyle (Expert)

Programmatics and costing – G.Crone, Z. el Hamel
Science Operations, P. Jensen, G. Crone, A, Heras

1.2 Applicable Documents

AD (1) SRE/PA/2009/013 - COSMIC VISION 2015/25 M-CLASS INTERNAL REVIEWS
AD (2) JAXA SPICA Mission Requirement Document
AD (3) SPICA RSSD -002 “SPICA Telescope Assembly – Science Requirement Document”
AD (4) SCI-PA/2008.031/NR/SPICA/RD – SPICA Telescope Assembly – Requirements Document
AD (5) JAXA-SPICA-SYS-ICS-0003, “SAFARI Interface Control Specification (ICS)
AD (6) JAXA-SPICA-IF0002. “*SPICA* Environmental conditions for SPICA Telescope Assembly”. JAXA – 15/1/2009 (2nd edition).
AD (7) JAXA-SPICA-IF0001. “SPICA Interface Conditions for SPICA Telescope Assembly”. JAXA – 15/01/2009 (2nd edition).

2 TECHNICAL REVIEW

2.1 Mission Issues

With respect to the Mission requirements it is of concern, although understandable that the coronagraph instrument is not yet baseline for JAXA. This instrument drives the technical requirements of the telescope, the design, development cost and schedule. Phase A/B1 has to assume the coronagraph for the design which will be non-optimal if not selected. This is seen to represent both a cost and schedule risk to the telescope activity.

Overall the requirement and interface documentation from JAXA is limited. The Mission Requirements document (AD (2)) which covers the science requirements is used to flow down to lower level engineering requirements. For the telescope, an ESA science requirements document for the telescope (AD (3)) has been used to establish the ESA engineering telescope requirement document (AD (4)). This document is in a reasonable format on which the previous phase has been based. Overall and for the continuation of the hardware phase both system level documentation and more formalized interface documentation needs to be supplied and agreed. In particular, a System requirement document, telescope interface control document, a single environmental requirement document and system level budgets would need to be advanced before the next phase. Also the harmonization of PA requirements ECSS versus JAXA standards need to be agreed.

For SAFARI, the key document, the instrument control specification (ICS) (AD (5)) has been issued by JAXA. It is a good framework on which to work for the finalized document, but it is currently incomplete. This is also partially due to the lack of definition of the final SAFARI design from the Consortium. Urgent work is needed in this area to converge. At the current level, the lack of definition is seen to be an overall risk with respect to system and instrument design and can result in re-design and potential schedule and cost overruns. Follow up is needed with SAFARI to progress the instrument design and with JAXA to fill in the missing spacecraft interfaces. This needs the iteration on both sides to establish a complete issue 1 of this document. This activity should continue within 2009 and be ready at the same time (February 2010) as the Cosmic Vision down selection.

Agreements need to be confirmed with ESA/JAXA/SAFARI consortium on the management and responsibilities of each with respect to the SAFARI Instrument. It is assumed that ESA are to act as the technical interface between JAXA and the SAFARI consortium, with ESA taking a lead role and responsibility for directly following the instrument development/progress, conducting the review cycle, being solely responsible for interfaces between JAXA and the Consortium, Flight acceptance of the instrument, delivery to JAXA and co-ordination of system level activities with JAXA (integration and test at spacecraft level, launch campaign, LEOP and in orbit commissioning). These tasks need to be discussed with JAXA and the Consortium and agreed.

Additionally agreement is needed from ESA to support the proposed SPICA European Science Operations Centre. The proposed scope and cost needs to be agreed by ESA management and ESA headquarters together with the project scientist and the SPICA project need to agree the content and work share with JAXA for its implementation.

Technical visibility of the JAXA system design needs to be extended to enable potential impacts on the design of both the telescope and SAFARI to be pre-empted. Question and answer records between JAXA and ESA have been kept which has helped build up the understanding. An improvement in communications and visibility is needed for the later phases. This needs to be established by participation with JAXA in the system level design aspects, via progress and interface meetings, participation in key JAXA reviews and regular two way reporting via progress reports and technical co-ordination meetings.

2.2 Telescope Design

The telescope design has been made with respect to the ESA telescope requirement specification. (AD (4)).The document represents a good basis on which to build upon. It needs to be completed together with JAXA during the upcoming period of ITT preparation for the Phase A/B1 from Q3 2009 to the issue of the ITT in 2010. It is understood that the optical design for the telescope for the Phase B2/C/D phase will be a CFI from ESA. This will include the telescope baffle on M1, including cold stop and on M2. The optical telescope design was prescribed for the previous phase, it was noted that some small differences in numbers have been noted between ASEF and TASF design reports. This should be consolidated in the update of AD(4) for the phase A/B1 ITT.

In general the telescope design from both ASTRIUM France (ASEF) and Thales Alenia Space France (TASF) show a good level of maturity with respect to these requirements for this stage of the activity.

Four key technical issues were raised on both designs:

Mechanical Design/ Analysis and Requirements
The secondary mirror assembly has a mass greater than 23Kg in both cases and is supported by 4 struts at a height of more than 3 meters. The required stiffness requirement (30Hz) and strength are challenging with ASEF showing a small negative margin on the stiffness requirement. The review considered that the specified design load on the M2 assembly (20g acceptance/25g qualification level) could be on the low side and performed an analysis using an FEM model of the telescope assembly with payload module and an assumed model of the SVM. The ESA predictions showed that loads were around the correct level under the condition that dedicated notches are implemented during sine vibration tests. However a more consolidated confirmation is required using the JAXA inputs of the coupled analysis with the spacecraft for the sine vibration predictions and the launcher coupled load analysis. This information is required from JAXA
The current designs of the M2 assembly are considered feasible but needs confirmation.

Thermal Design
With respect to the current thermal designs both are unable to meet the maximum heat load allocation of 15mW set by JAXA on the SPICA cooler. This has to be further iterated with JAXA to agree on an acceptable level. This allocation should evolve as the spacecraft level thermal design matures. The interfaces to the telescope are dependent on JAXA,, e.g. performance of the 11K thermal shield and the JAXA thermal interfaces to the telescope optical bench. This point is well known to JAXA and is not seen to be a showstopper.

Optical Design – Straylight
Initial indications show that at long wavelengths, one of the straylight requirements, i.e. (PR 13) in AD (4) (straylight coming from sources outside of the field of view, both natural and artificial, must not raise the background level (zodiacal light and telescope self emission) by more than 20%) will not be met. Values greater than 100% (TBC) are currently being expected from analysis by made by the Science Study Team. This is due to a combination of scattering and self emission from the JAXA external baffle and the assumption on the particle size distributions in the contamination model, where large particle scattering is seen to cause the problem.

The telescope specification at delivery is 300ppm and this can be met. The concern is that the contamination at spacecraft level during integration and finally in orbit taking into account the launch is currently assumed to be higher (5000ppm). This level needs to be iterated between JAXA/ESA and the instrument team to address the above mentioned non-compliance and the validity of the contamination specification. Additionally and compared to ISO, operating in a wavelength band from 2.5um – 200um , the particulate levels specified were much more stringent (800ppm). If the ISO levels were applied to SPICA, then AIT would have to be performed in class 100 at spacecraft level and further protection would be needed to maintain the requirement during launch. This also needs to be addressed with JAXA prior to the next phase

The molecular contamination levels also need to be confirmed. Comparing to ISO, would imply bake out of telescope at delivery and in orbit. It had been proposed by both TAS-F and ASEF to limit in-orbit telescope heating to only 180K which is sufficient to protect the telescope from water vapour freezing on the surface. This issue also needs to be followed up with JAXA prior to and in the next phase.

Telescope Focussing Mechanism
The mechanism is located at a very critical place at M2 with respect to loading, temperature and actuation accuracy. The only possible mechanism existing which could be ready to be extended for the SPICA application is the GAIA mechanism. It should be noted that the SPICA application requires (at actuator level) double the linear range at the actuator (+/- 0.5mm), mechanical loads about twice and an operational temperature of 5K versus 100K.
The design maturity as recognized is low and the current design does not foresee a launch lock, while the expected loading on the mechanisms are high and might become even higher during the mission development.

2.3 Telescope Technology Readiness

The telescope focussing mechanism
The mechanism is considered to have a high technical development risk although covered by a technology development activity (TDA) which covers delta qualification activities and design extension. The current technology readiness is agreed to be low (TRL 2 to 3) and the concern is that the activity if directed in a single design concept may fail.
In order to mitigate this risk it is recommended to start the TDA as soon as possible and to re-open the mechanism design trade-off at the start of the activity to consider use of launch lock with increasing M2 loads, mechanism not at M2 level (e.g. at the optical bench in optical path towards the instruments) and to re-visit 1 degree of freedom (re-focus only) with respect to three degrees of freedom.

Technology Readiness of SiC versus HB-Cesic
It is clear that the technology level of SiC for a 3.5 metre telescope is high TRL > 7. The polishing of the M1 to the higher level of accuracy for this size of mirror is a new process based on experience from polishing the Herschel mirror, but with extension and proposed to be performed at a different facility. Polishing will be developed during the next phase. The polishing facility is not seen to be a design risk but more a schedule risk. The overall development risk is seen to be medium.

HB- Cesic has only produced small products 65 cm and TRL for this size of blank is < 5. The HB-Cesic. TAS-F do not have experience in polishing large pieces, they have experience in smaller pieces to the accuracy level. In addition to this there is no experience with this size to perform, grinding and lapping. The development risk to reach TRL 5 by the end of Phase A/B1 is high.

2.4 SAFARI Design

Top level Instrument Design Issues

The design of the instrument is not considered to be at the level that is commensurate with the overall SPICA needs and schedule. This also impacts the engineering requirements and the Interface control document from JAXA which is quite incomplete (AD (5)).

Currently there a four potential detectors being carried forward and each candidate detector has fundamental drivers which impact the design of the complete instrument with three of the four requiring sub - K cooling to either 50mK or 150mK. This requires a two stage cooler assembly to be implemented within the instrument focal plane unit. This is a clear design driver and the late selection of detectors impedes finalizing the baseline instrument design. Many detailed design issues at instrument level have to be addressed, e.g. EMC, microvibration /microphonics, mechanical suspension of sub - K coolers and detectors taking into account a warm launch, thermal transients. The freezing of the instrument architecture and settling accommodation on and interfaces with the spacecraft as early as possible is a key task. Also the current design of the instrument only addresses one detector type i.e. Transition edge sensing bolometers (TES), which are considered to be the most design stressing option.

Detectors and Readout

The four detector types are: TES, Si bolometers (Si-Bolo),(Kinetic Induction Detectors (KIDS) and photo conductors (PC). It should be noted that the science case is based on the goal values for sensitivity and detector NEP. There is also a 'minimum acceptable detector NEP' which leads to a degraded sensitivity with respect to the goal. When it comes to the detector selection these requirements need to be clearly stated as requirement and goal.

There is concern that the first three which require sub Kelvin cooling may still not provide the required sensitivity (i.e. the goal sensitivity used to build the SPICA science case in the SPICA Yellow Book, draft 0.71,) at instrument level. The TES detectors at pixel level show the best performance to date and are approaching the NEP required for the minimum acceptable sensitivity to within a factor of 2, but is about an order of magnitude away from the NEP which is required to achieve the science case sensitivity. The photoconductors will never reach the sensitivity requirement and even achieving the minimum acceptable sensitivity is considered unrealistic. However, for all detector types, increasing the pixel size on the sky could be considered to improve the sensitivity at instrument level, at the expense of reduced mapping efficiency and/or an additional mechanism.

There are many design issues to be solved for the TES, Si-bolo and KID detectors, including the implementation in the array and read out electronics.

The readout schemes proposed for TES and, to a lesser extend, for KID's rely on complicated multiplexing schemes mandatory to make the heat load budgets acceptable.

Heat load budgets with respect to the current SPICA allocations are marginal or negative for PC, Si-bol and TES detectors.

The photo conductors, although less performing are at a sufficient level of maturity that they represent the natural back up solution, however with degraded performance in sensitivity and wavelength coverage, cosmic ray sensitivity and associated annealing, and linearity issues which are particularly problematic in an FTS application

Whilst all detector types, PC not yet confirmed, have conceptual focal plane assemblies, their interface requirements with respect to cooling requirements, harness, read out electronics are different. Convergence on the detector selection is crucial to progressing on the instrument design

Sub Kelvin Coolers
The proposed sub- Kelvin coolers, 3He sorption cooler and ADR coolers have flown on liquid Helium cooled missions but not on missions where mechanical coolers provide the pre cooling stage. The design of the coolers which make up the ensemble are individually mature and breadboarding of such an ensemble is being performed under TRP. However the detailed design and realization of the cooler ensemble matched to the SAFARI needs and operating with the selected detector type still needs to be performed after the TRP activities. This demonstration should be incorporated in the instrument design as early as possible. .

Fourier Transform Spectrometer (FTS) Mechanism
The spectrometer mechanism design is new, the mechanical and launch load specification is incomplete. None of the pre-developments have satisfied all the optical, accuracy and launch load requirements. It is considered mandatory to consider a launch lock in the case of magnetic bearings and to include this from the start in the overall design and optimization. The design maturity is seen to be low and many detailed issues need to be taken into account in the next design iteration.

2.5 SAFARI Technology Readiness

Detectors and Read-out
The TES and KID detectors have optimistic development plans and carry a high development risk to reach the required sensitivity and demonstrate the performance in the array environment. Also the read-out electronic performance, with multiplexing factors far beyond what has been demonstrated even on the ground is a high development risk. The Si-bolo development plan was not included in the review and is due in October 2009. These detectors have PACS heritage, but have to demonstrate 2 orders of magnitude improved sensitivity. The photoconductors development plan is seen to be relative low risk, having good heritage.
All three sub Kelvin options are at TRL 3 with TES having a slight edge. The photoconductors are at level 4 to 5.
The TDP foresees in activities for KID detectors and read-out, and PC readout. TRP activities are ongoing for TES detectors and for TES readout (driven by IXO).
All detector options would benefit from a reduction of the total number of pixels. This will greatly reduce the read out complexity and the heat load criticality and, if combined with larger pixel sizes on the sky, improve sensitivity while maintaining the same field of view.
The technical progress and schedule of the development for all detectors needs to be closely followed by the ESA team at each institute to help working towards the earliest possible down selection.

Sub Kelvin Cooler
An activity in TRP is currently running to develop a sub Kelvin cooler which addresses the ensemble of the 3He and ADR cooler, it is at CDR level now and it is anticipated to complete the activity by the end of 2010. The requirements for this activity are driven by IXO (the L-Class X-ray mission candidate) and the interfaces to the sorption cooler stage differ from SAFARI. In the

framework of SAFARI, CNES have been funding, the Sorption cooler stage. There is an activity in the TDP plan which is under National funding (24 months duration) and addresses, the realization of the SAFARI sub K cooler ensemble and its test with a simulator of the JAXA 2-4K J-T cooler. This activity is aimed at verifying interfaces between the two. The activity has not yet started and should be anticipated early in the instrument development, perhaps as part of the demonstration model activity should the sub Kelvin detector be selected next year. The activity is seen to raise the cooler to TRL 6 where the current TRP should raise to TRL 5 with respect to SAFARI requirements. Design modifications for SAFARI should be detailed as soon as detector selection is made next year. One option could be to use the existing CNES developed SAFARI sorption stage with the ADR from the TRP to have an early demonstrator ready for SAFARI.
Further development risk could be mitigated by increasing the scope of the end to end test by joining with JAXA to test the sub K cooler with the JAXA cooler bread board and a representative detector chain, to mitigate problems that may come from magnetic field interference from the ADR. Knowledge of the JAXA schedule and development plan would be needed for this to fully scope the TDA schedule. However the TDA should start as soon as detector selection is made. The development risk to reach the required level for SAFARI at the end of the phase A/B1 phase is judged to be medium to high dependent on the start of the TDA.

Spectrometer Mechanism
The technology readiness is low TRL (=2/3) with many open issues to address and development risks are seen as high given that the pre-development activity has now stopped. There is a TDA activity under GSTP that is in the plan but not yet taken up, this is a continuation of the previous activity, now on hold. The mandatory mechanism requirement specification improvement (especially at mechanical loading level) needs to be urgently advanced to ensure the continued effort on this critical SAFARI sub-system. It needs to be clarified how this TDA and the full nationally funded TDA on FTS breadboard (24 months duration with unknown costs) fits with the overall instrument development. The development risk is seen to be high.

Instrument
The SAFARI development plan and schedule needs to be stabilized and the need and schedule for all the TDA's need to be fitted to the needs of the development plan and the funding needs to be secured. At present it looks open in this respect. The development risk is seen to be high.

2.6 ESA SPICA Science Centre

The baseline is to establish a SPICA Science centre at ESAC to supply in parallel to the JAXA SOC, a European site that would both interface with the European astronomical community for all SPICA instruments and would fully represent and interface to JAXA on SAFARI. The baseline tasks are community support, preparation of SAFARI documentation for observers, implement SAFARI proposal submission tool and archive at ESAC, define with JAXA all operation and software interfaces between JAXA MOC/SOC and ESA/SAFARI, integration, testing and QA of ESA and SAFARI software delivered to JAXA (observing modes, pipeline etc.).

The Centre would support European observers in proposal submission, observation preparations and data reduction on all SPICA instruments with the view to maximizing European Science return for the observatory. It would provide a clear interface between ICC to JAXA and observers (e.g. very much in line with what is done today for a Herschel instrument.
The alternative would be for all observers to deal directly with the JAXA SOC and independently with the SAFARI ICC. There are various scenarios with options which address a baseline 3 years or extended operation to 5 years .There are also options which involve adapting and implementing utilities from Herschel.

The fundamental question needs to be answered with respect to the philosophy from the ESA Science Management as to the justification for this activity and if adopted would the European SOC provide a value added contribution to the programme increasing the science return to Europe compared to using the single JAXA SOC.

3 PROGRAMMATIC REVIEW

3.1 Development plan and schedule risk – STA ASEF

The development plan foresees a proto-flight model philosophy as baseline with the provision and delivery of a structure model (SM) for mechanical testing at spacecraft level. This is following the same approach as Herschel. The SM is essentially a mass dummy and ASEF offer as option a full STM, which would be structurally fully representative of the telescope assembly and incorporate the ground but unpolished M1 mirror that will be used as a flight spare. This option was supported by the Board. ASEF also offers the option of an Optical STM. The benefit of this is not yet supported however all should be maintained for early trade-off in phase A/B1. The Spare philosophy is in line with the needs and options.

The verification approach is considered acceptable. The approach to the cryo-optical testing is double pass interferometry with a rotating flat, multi-position mirror (12 positions) with phase stitching to construct the aperture (N.B. The same approach is proposed by TASF and JAXA for system level telescope testing). The cryo-optical testing of the telescope is foreseen to be implemented in an existing chamber (CSL FOCAL 5 used for Planck spacecraft tests). The flat mirror is cooled and ASEF offer to cool the telescope to 10K with a goal of reaching 5K the operational temperature. This is seen to be attractive and in line with acceptance testing at JAXA. The test set-up needs the detailed thermal and mechanical design of the dedicated optical ground support equipment (OGSE) (i.e. flat mirror positioning and cooling system), its commissioning and testing. Early detailed design is needed in phase A/B1 to ensure that it both fits in the existing chamber (Focal 5) and meets the thermo mechanical requirements in order to mitigate the risk of having to change the approach, find a new facility and re-design the OGSE find a different facility later in the programme.

With respect to the Herschel heritage, the need to upgrade the aluminium coating facility has been identified and will be performed as part of the Phase A/B1. Critical bread boarding, i.e. the breadboarding and test of the hexapod and M1 bipod assembly have been identified as part of phase A/B1. Two TDA activities which must run in parallel with the phase A/B1 are in the plan, the focussing mechanism previously addressed and the small reflector bread board and gravity compensation jig to verify the higher demands compared to Herschel for the polishing.

The polishing activity is on the critical path (2 year duration) and is the highest schedule risk .The overall schedule is marginally compliant with ESA and JAXA needs with start of Phase B2/C/D/E in mid 2012 with delivery of the STA end 2016 without contingency. The schedule is reasonable when compared to Herschel.

The activity relies heavily on the Herschel telescope heritage. Most of the facilities for manufacture are available and fully tested. Polishing is moved to a different supplier compared to Herschel and the accuracy requirements are higher. Only moderate pre-developments are needed. It is considered that ASEF can provide the STA with a high degree of confidence within the time scale. Stopping phase A/B1 and waiting for down selection is seen as a risk and continued working and early release of the manufacturing activities would be preferred.

3.2 Development plan and schedule risk – STA TASF

The development plan foresees a proto-flight model philosophy as baseline with the provision and delivery of a full STM for mechanical testing at spacecraft level which will be structurally fully representative of the telescope assembly and incorporate the ground but unpolished M1 mirror that will be used as a flight spare. In addition to this the model philosophy includes a precursor mirror activity which starts in parallel to phase A/B1; this precursor would be a pre-requisite to raise the HB Cesic manufacturing capability to larger diameters and follows on through phase B2/C/D as a pre-cursor, undergoing grinding, polishing and cryo-optical testing. The continuation in phase B2/C/D however offers little feedback into the FM design and manufacturing process and hence it may be better to move directly to the 3.5 metre activity after the phase A/B1 phase of the feasibility breadboard.

The approach to the cryo-optical testing is double pass interferometry with a rotating flat, multi-position mirror (24 positions) with phase stitching to construct the aperture (N.B. The same approach is proposed by ASEF and JAXA). The cryo-optical testing of the telescope is foreseen to be implemented in an existing chamber (CSL Focal 6.5) however the chamber, which was used to test the Herschel Telescope, needs to be extended in height to accommodate, the SPICA geometry. The reasons for the selection of this configuration (optical axis vertical) is not justified in the development plan ‘re-use of Herschel GSE is quoted’, and a statement to re-open the trade –off in the next phase. The flat mirror is at room temperature and the testing is only foreseen down to 50 K.

The test set-up needs the detailed thermal and mechanical design of the dedicated optical ground support equipment OGSE (e.g.. flat mirror positioning system), its commissioning and testing. Early detailed design is needed in phase A/B1 to ensure that it both fits in the extended Focal 6.5 and meets the thermo mechanical requirements and that the gravity off loading can be implemented in order to mitigate the risk of having to find a different facility later in the programme.

TDA's covering the focussing mechanism and early sample testing of HB-CeSic to 5 K are included in the plan. These need to be ready to start in parallel to Phase A/B1 Kick-off.

Many of the manufacturing facilities (e.g. carbonisation and infiltration) needed to produce the a 3.5 metre mirror in HB-Cesic do not exist today and need to be designed, manufactured, commissioned and be ready for manufacturing within the Phase B2/C/D. This activity is on the critical path and represents a high schedule risk. Polishing is the next element on the critical path with 24 months duration including, lapping. The proposed development schedule is not compatible with ESA and JAXA needs with delivery end Q3 2017 against JAXA need of Q1 2017.

TASF with extensive predevelopments and facility procurement could be in a position to deliver the STA but with high programmatic risks on a schedule that is already non- compliant.

3.3 Development plan and schedule risk SAFARI

SAFARI foresees a model philosophy comprising of EM, CQM/STM, PFM, and AVM.
The Development plan is only at an early level of detail and much work is needed to get it into a realistic status upon which a reliable schedule can be built.

The detector selection is not planned until June 2010 and the design to date is only based on the TES detectors. All the detectors are still at a low development level and have not yet been fully demonstrated to meet requirements. Activities are ongoing at individual institute level but the status and feasibility needs to be continually monitored to enable a faster down selection The Photoconductors have the highest level of readiness. TDA's exist in the TDP plan for KID detector arrays and read out electronics under national funding and 18 months duration but with no cost envelope and no indication of start date.

The work on the FTS mechanism has now stopped and will be continued when GSTP funding is available to support the continuation. National funding for FTS Breadboard is also in the TDP under National funding but also with no costing, start date and 24 months duration. These need to be folded in to the stabilized development plan and schedule.

The instrument schedule, benchmarked with Herschel SPIRE instrument as comparison with a similar model philosophy with an effective start at IRR/SVR 10th September 2010, only 3 months after detector selection, foresees the delivery of the FM instrument December 2015. This is unrealistic; compared to SPIRE more than seven years were required with starting level of maturity of the instrument design higher than SAFARI is today.

The development and schedule are not in line with the SPICA needs and urgent action is needed. The development plan needs consolidation with the Consortium and a realistic and reliable schedule needs to be established.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 SPICA Telescope Assembly

Technically both ASEF and TAS-F are capable to design, develop, manufacture, test and deliver the telescope assembly to SPICA. There are no fundamental show stoppers and the development programmes as highlighted in the documentation support this.

The focussing mechanism, should be achievable on time provided that the TDA efforts start early enough and in parallel to the Phase A/B1 activity and are able to stay in step with the detailing of the telescope design.

Astrium-F with the SiC technology and Herschel heritage are in a better position to deliver the SPICA telescope on time with moderate technical and programmatic risks.

HB-Cesic needs more steps in their development plan and significant investments to bring the TAS-F activity up to the same level as Herschel. The current schedule presented by TAS-F is non-compliant with the SPICA need dates. In going forward with TAS-F anticipation of early pre-development of facilities prior to down selection in 2012 would need to be considered. It should also be noted, that the programme of work presented in the cost proposal is still not consolidated.

The way forward on SPICA was debated in the review board: Should one maintain parallel activities in phase A/B1 or select through competition the telescope provider for securing the development schedule and saving costs?

The final decision should be made by the Science Directorate taking into account that the development tasks to be performed for HB-Cesic, both in terms of preparing the new manufacturing facilities and in extending the technology to 3.5 metres is seen to represent a high development risk with respect to the schedule. It also represents a high investment, and it is not obvious that the Science Programme in the medium term will require other telescopes of this class.

4.2 SAFARI

The development plan is not believed to be in line with the needs and schedule of SPICA. This is driven by the late selection of the detectors and the current feasibility of their design and their ability, including read out electronics to reach the science requirements in the instrument environment. This in turn effects the progress on the detailing the design of the instrument such that progress can be made with JAXA at spacecraft level to establish and detail the instrument performance at system level and to progress on the interface control document.

The development plan of the instrument needs to be stabilized and the key technologies which need pre-development, i.e. detectors, Sub Kelvin cooler, and spectrometer need to be fully implemented into the instrument development and schedule. The pre-development activities and their needed start dates need to be confirmed and efforts have to be made to get these started and implemented within the instrument development needs. These activities fall into TRP, GSTP and National funding and their start dates are not necessarily in-line with the instrument needs or requirements. Quite some effort will be needed to get these ready, including iteration with the different programmes and national agencies. Early start will need advancing funding from these entities.

Taking into account, the above the delivery of SAFARI, within their current development plan is foreseen for December 2015. Giving the tasks to be performed and the current status of the plan and benchmarking with the Herschel SPIRE instrument they will never meet this date. SPIRE with a similar programme of work and complexity took over seven years to execute such a plan with the SPIRE instrument being at a higher level of definition compared to SAFARI today.

The recommendation is to start work with the SRON and the Consortium as soon as possible and before detector selection to establish together a solid development plan, schedule and delivery date, also taking into account the needed TDA activities. Prepare the statements of work for the TDA's. Within this framework, to follow up with the PI teams the developments and progression all four detector types, with a view to also making early eliminations prior to June 2010, if the development status of a detector shows that it will clearly not be ready. In parallel, progress further on detailing the instrument design with photoconductors as a back up and iterate this with the SAFARI scientists. The requirements on sensitivity, wavelength coverage and pixel size need to be revisited with a view to set requirements that are achievable in a realistic timeframe in order to support the development of a low risk back-up solution. This action with respect to sensitivity, pixel size/field of view is also needed for the other detector types where early indications show that they may also have difficulty in meeting the science goal requirements. Clear distinction between requirement and goal is needed with science impacts being assessed for both.

To permit this iteration, ESA has to be formally accepted as the interface between the SAFARI consortium and JAXA and be accepted into the instrument management role, similar in form to Herschel/Planck and more favourably to the JWST MIRI ESA model. The following points need to be agreed

- ESA to manage interfaces between JAXA and SAFARI
- ESA to be responsible for interface changes from JAXA
- Contingency funding to be secured for ESA for interface changes
- ESA actively follow up on instrument development and progress
- Full progress reporting and meetings with ESA and SAFARI
- ESA perform the design review cycle for the instrument
- SAFARI deliver instrument to ESA and then ESA to JAXA
- ESA participation in System level AIT with JAXA for SAFARI
- ESA participation in launch, LEOP activities and up to Commissioning

Prior to the above formal agreements a mechanism needs to start and be agreed with all parties to start the work on the development plan in parallel.

4.3 Science Operations Centre at ESAC

The Science Operation Centre existence is linked to the agreement with JAXA on the observing time allocated to Europe and to a higher level policy decision. This issue is not considered to be in the domain of the Review Board mandate.

4.4 ESA Support to JAXA MOC Activities

This activity requests/foresees the additional station coverage by ESOC to the JAXA MOC for periods of either 4, 6 or 8 hours per day. The activity is only use of a station from the ESA network and does not involve any use of ESOC to support further the JAXA MOC. These options have been costed by the Review Board. This issue is passed for decision to ESA Science Management as an element in the overall negotiation and confirmation on the scope of the ESA/JAXA agreement on SPICA