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DPC Implementation Status Report

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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	20.12.2006	All	First Version	SGS-IR
2.0	18.06.2008	All	Global review	SGS-RR

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1 INTRODUCTION

1.1 SCOPE

This report, the Planck/LFI DPC Implementation Status Report, is aimed at describing the status of the implementation of the LFI Data Processing Centre (DPC). It will be a self standing document summarizing the status of the DPC pipeline implementation for the Planck SGS-RR. The report includes all the development activities based on Work Packages [AD02]-[AD03] and focuses on the main important topics at this stage of development. It should be noted that the SGS1 activity was reported, during the last three years, in the usual bimonthly report as recommended in the SGS-DR (Nov 2004) and the SGS2 activity was reported in form of presentations during the Science Team Meetings, quarterly based.

1.2 SGS1 AND SGS2 DEFINITION

It was noted by the Science Ground Segment Design Review Technical Panel that, conceptually, the Planck Science Ground Segment (SGS) can be divided into two fundamentally different components, which have different time scales associated and different levels of criticality.
SGS1: The first component consists of the entire infrastructure – HW, SW, plans, procedures, interfaces and staff – required to acquire the Planck data and ensure that they are of sufficient quality for the mission to achieve its scientific goal. It is mandatory that this component be ready, validated and fully operational at launch. This component can be defined as the "minimum launch system", or SGS1. As for the ESA responsibilities, SGS1 contains the Survey Planning and Performance evaluation Tool (SPPT) developed by the PSO, all of the MOC subsystems and ground stations. As for the LFI DPC part, SGS1 includes the IOT and its operations plans and procedures, the DPC-developed RTA, TQL and LIFE software, and in general all DPC Pipeline Level 1 systems required to process the telemetry, monitor the performance of the instrument in near real time and off-line (trend-analysis), assess the quality of the science data and generate quality reports, and archive the data for later processing, as well as all the interfaces between these components.
SGS2: The second component consists of the infrastructure necessary to extract the scientific results from the Planck mission and to serve the scientific community. This second component, or SGS2, contains the science DPC pipelines, internally divided in Level 2 and Level 3, and including Level S, IDIS, the ESA science archives, their interfaces, and all the procedures, documentation and expertise required for a proper exploitation of the Planck data. Though SGS2 is ultimately as important if not more so than SGS1, it is less critical in the sense that it does not need to be fully ready and operational at launch.

2 APPLICABLE/REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

AD01 LFI Science Operations Implementation Plan, PL-LFI-OAT-PL-001

AD02 Planck LFI DPC Work-Package Breakdown and Description, PL-LFI-OAT-PW-001

AD03 Planck LFI DPC Product Tree and Work Breakdown Structure, PL-LFI-OAT-PW-002

AD04 Planck LFI DPC Deliverable Document List, PL-LFI-OAT-LI-001

AD05 Planck LFI DPC Schedule, PL-LFI-OAT-RP-003

2.2 REFERENCE DOCUMENTS

RD01 Planck IDIS DMC Exchange Format Design Document, PL-COM-OAT-SD-003

RD02 LFI DPC Software Integration and Testing Plan, PL-LFI-OAT-PL-006

RD03 LFI Data Processing Document, PL-LFI-OAT-SP-001

RD04 Planck LFI DPC Software Project Development Plan, PL-LFI-OAT-PL-003

RD05 Planck LFI DPC Software Product Assurance Plan, PL-LFI-OAT-PL-004

RD06 Planck LFI DPC Software Configuration Management Plan, PL-LFI-OAT-PL-002

RD07 Real-Time Assessment User Requirements Document, PL-LFI-OAT-UR-001

RD08 Planck LFI – TQL Software Specification Document, PL-LFI-GADC-SS-001

RD09 Planck LFI – TMH Software Specification Document, PL-LFI-GADC-SS-002

RD10 LFI Pipeline Levels 2+3 User Requirements Document, PL-LFI-OAT-UR-006

RD11 LFI Pipeline L2 and L3 Architectural Design Document, PL-LFI-OAT-AD-007

RD12 IDIS Process Coordinator User Requirements Document, PL-COM-MPA-UR-001

RD13 IDIS Data Management Component URD, PL-LFI-OAT-UR-001

RD14 IDIS Software Component User Requirements Document, PL-COM-SSD-UR-003

RD15 SCOS 2000 System Level ADD, S2K-MCS-ADD-0001-TOS-GCI, Issue 3.5, June 2002

RD16 Planck LFI Test Plan for TQL/TMH Software, PL-LFI-OAT-PL-009

RD17 LFI DPC SGS1 Test Report, PL-LFI-OAT-RP-017

RD18 LFI DPC SGS2 Test Report, PL-LFI-OAT-RP-018

RD19 LFI DPC pipeline Tests Procedures, PL-LFI-UMI-PL-001

RD20 LFI LIFE User Requirement Document, PL-LFI-OAT-UR-009

RD21 LFI LIFE Software Specification document, PL-LFI-OAT-AD-006

RD22 LFI User Manual, PL-LFI-PST-MA-001

RD23 LFI Operation Plan, PL-LFI-PST-PL-011

RD24 Planck LFI DPC Hardware Design, PL-LFI-OAT-SP-005

RD25 KST User Requirement Document, PL-LFI-PST-UR-008

RD26 PGS-ICD-030 DPC-DPC Timelines Exchange, PL-LFI-OAT-IC-001

RD27 PGS-ICD-032 DPC-DPC Calibration Information, PL-LFI-OAT-IC-003

RD28 LFI DPC HW Design & Implementation Plan, PL-LFI-OAT-SP-005

RD29 Leach et al. 2008, submitted to Astronomy & Astrophysics; babbage.sissa.it/abs/0805.0269

RD30 Stompor et al. 2008, submitted to Montly Notices of the Royal Academic Society (MNRAS); babbage.sissa.it/abs/0804.2645

RD31 Maino et al. 2006, MNRAS, 374, 1207

RD32 Bonaldi et al. 2006, MNRAS 382, 1791

RD33 Poutanen et al, A&A 449, 131 (2006)

RD34 Ashdown et al., A&A 467, 761 (2007)

RD35 Ashdown et al., 2007, submitted to A&A, astro-ph/0702483

RD36 PGS-ICD-031 DPC-DPC Maps and Power Spectra Exchange; PL-LFI-OAT-IC-002

RD37 PT-PMOC-OPS-RP-6414-OPS-OAP, Planck SOVT-1 Test Report

RD38 Planck/PSO/2005-026, Planck SGS2 E2E Test definition

RD39 IDIS System Test Specification for LFI, PL-COM-MPA-TP-53

RD40 IDIS System Test Report Compilation for LFI, PL-COM-MPA-TR-54

ACRONYMS LIST

AD	Applicable Document
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
BBM	(DPC software) Bread-Board Model
CC	Change Control
COTS	Commercial-Off-The-Shelf
DDL	Data Description Layer
DDS	Data Disposition System
DM	(DPC software) Development Model
DMC	Data Management Component
DPC	Data Processing Centre (for Planck)
DPCM	Data Processing Center Manager
DPCT	Data Processing Centre development Team
DRS	Data Reduction Software
ERCSC	Early Release Compact Source Catalogue
ESA	European Space Agency
ESOC	ESA Space Operations Center
FM	(Instrument) Flight Model
H/W	Hardware
HEALPIX	Hierarchical Equal Area and Latitude PIXelisation
HFI	High Frequency Instrument
ICD	Interface Control Document
ICR	Instrument Commanding Request
ICWG	Instrument Coordination Working Group
IDIS	Integrated Data and Information System
IIRD	Internal Interface Requirements Document
IOT	Instrument Operations Team
IRD	Interface Requirements Document
ISDC	Integral Science Data Centre, Geneva
IW@MOC	Instrument WorkStation at MOC
LFI	Low Frequency Instrument
MIBs	Mission Information BaSe
MOC	Mission Operations Centre
MPA	Max Planck Institut fuer Astronomie, Garching
OAPd	Osservatorio Astronomico di Padova
OAT	Osservatorio Astronomico di Trieste
OM	(DPC software) Operations Model
PA	Product Assurance
PGSSG	Planck Ground Segment System Group
PSO	Planck Science Office
QA	Quality Assurance
QLA	Quick-Look Analysis
RCA	Radiometers Chain Assembly
RD	Reference Document
RTA	Real-Time Assessment
RTSI	Real Time System Interface
S/W	Software
SGS-DR	Science Ground Segment Design Review
SGS-IR	Science Ground Segment Implementation Review
SGS-RR	Science Ground Segment Readiness Review
SIP	Science Implementation Plan

SIRD	Science Implementation Requirements Document
SISSA	International School of Advanced Studies, Trieste
SPPT	Survey Planning and Performing evaluation Tool
SPR	Software Problem Report
ST	Science Team
SVVP	Software Verification and Validation Plan
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TC	TeleCommands
TM	TeleMetry
TMH	Telemetry Handling
TOD	Time-Ordered Data
TOI	Time-Ordered Information
TPF	Task Parameter File
TQL	Telemetry Quick-Look
URD	Users Requirements Document
WBD	Workpackages Breakdown Document
WP	WorkPackage

3 LFI DPC OVERALL STRUCTURE

In Figure 1 the LFI DPC product tree of the whole LFI DPC pipeline is depicted. The necessary resources and details of each WP are provided in [AD02]. In this document we will describe the status of each work package: the overall status is graphically summarized in Fig 1 using the following colour code:

- **Green** represents completed work-packages related to software modules, already integrated in the Operations Model, and eventually undergoing tests;
- **Blue** show that development is ongoing (specially the integration), and the design was closed;
- **Red** show that the development is still to start or is at the design level.

It is to be noted that the boxes in blue and red refer to elements of the SGS-2 pipeline which are to be implemented at the very end of the data processing and analysis flow, just before data release while the most important modules are already integrated in the LFI DPC pipeline Operation Model (green).

Conclusion on status of the pipeline is reported separately for SGS1 and SGS2, it tries to summarize the information detailed in the work packages.

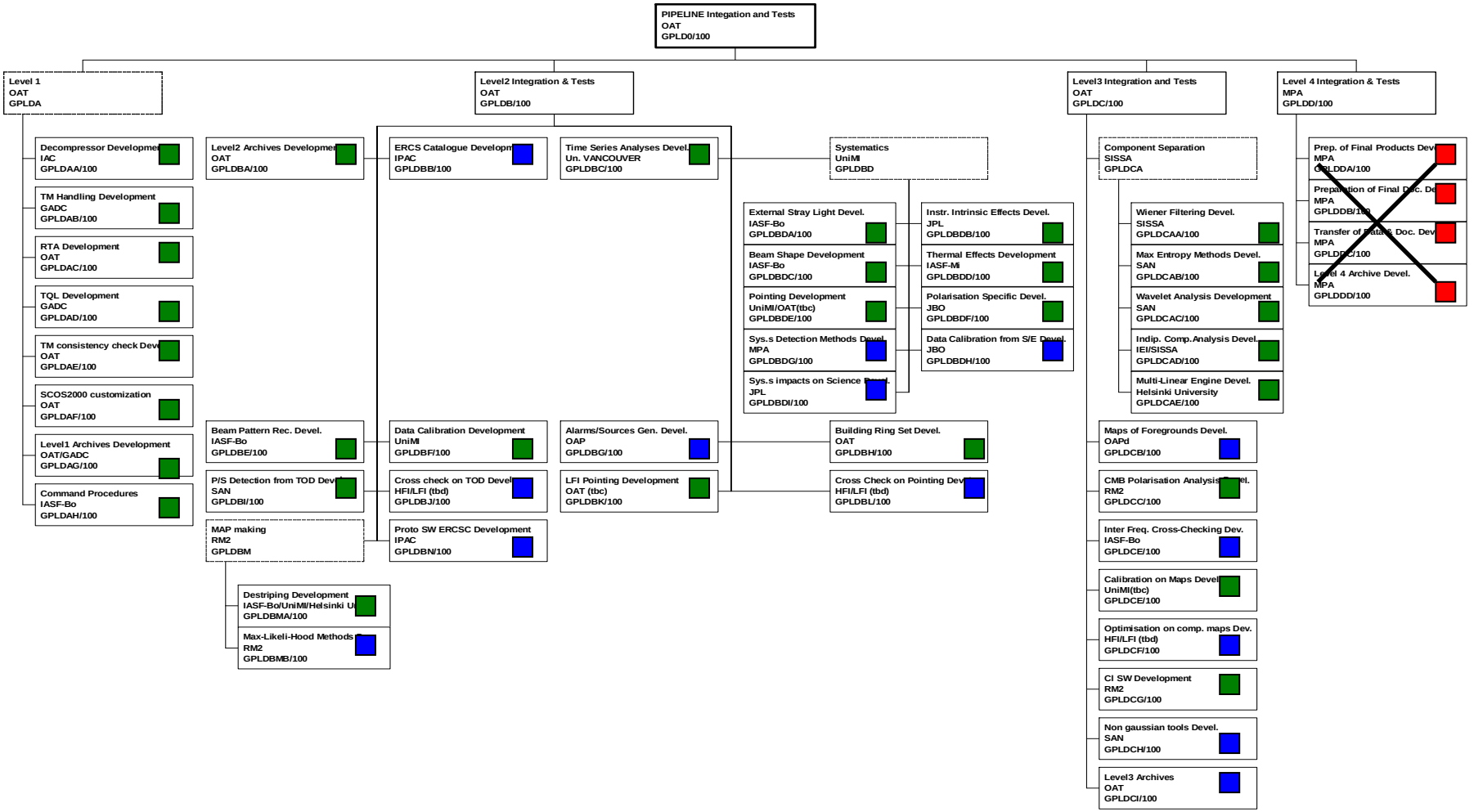

FIGURE 1: *LFI DPC Pipeline Product Tree*

4 SGS1 IMPLEMENTATION STATUS

SGS1 corresponds, in the LFI DPC structure, to the Level 1 pipeline. The detailed designs of the modules that are part of SGS1 are reported in [RD-03] - [RD-07] - [RD-08] - [RD-09] - [RD-15] - [RD-21].
Two models (QM and OM), based on the same core, were built for the Level 1 pipeline. The QM was necessary to show that the design fulfils the requirements and to acquire data during the RAA ground tests. Based on the QM version the OM was released with changes due to the differences on the way how we will get the data during operations.
As the SGS1 is critical for the mission, a strict PA/QA is applied and deep tests are performed. The QM model was released by LFI-DPC in May 2005 [AD-05] and it was used to acquire data during the RAA QM campaign (autumn 2005), the RAA FM campaign (summer 2006), the test campaign performed on the integrated Planck telescope in Cannes (from July 2007 to January 2008). The QM software model is still used for the Planck tests that are performed in CSL. Different tests were applied to this model:

- Simulated HK and science telemetry were ingested in the Level 1 pipeline to check the ability to deal with the telemetry structure defined inside the SCOS2k MIBs tables.
- Real telemetry, with known input signal (square wave), was ingested into the Level 1 using the AVM hardware to check if the telemetry reconstruction was performed correctly.
- Real telemetry, with unknown signal as acquired during the RAA campaigns, was ingested into the Level 1 to verify its performance and capability to show/analyze and store data as it will be during operations.

Plan, test results and cross matching matrix between user requirements and test results are reported in [RD16] and [RD17].
The first delivery of the OM software model, tagged as version 1.0, was released in November 2006 in two versions:

- Level 1 to be run at the DPC during operations;
- Level 1 to be run at the IW@MOC during operations;

as specified in [RD08] - [RD09]. System tests were performed using the same input data sets used to test the QM model, in order to cross-validate the output (TOIs) produced by the OM pipelines. The first integration tests with the MOC DDS interface were started on February 2007, mainly testing the format of a subset of the files generated by the DDS server. The interface coverage performed in the integration tests has grown slowly, following the MOC DDS server release schedule. Almost full integration tests were possible starting from April 2008, thanks also to the availability of real Planck telemetry data produced during the RMS tests performed in Cannes. The integration tests of the RTSI interface were more smooth: first tests with MOC were performed on May 2007 and the last integration tests were succesfully performed during the SVT1 Planck tests (using the IW@MOC). Finally, the System Operational Validation tests (SOVT1), covering all the Planck Science Ground Segment software, including the LFI Level 1 OM software, and testing the complete mission operation chain, have been performed starting from the 26th of May till the 30th of May 2008. The results of these tests are reported in [RD-37]. Note that they were run with the HPDDS offline consolidation, delta SOVT1 test with the online consolidation (as will be in operation), will be performed in July (TBC).

4.1 LEVEL 1 IMPLEMENTATION & INTEGRATION (SGS 1)

WP status:

- GPLDA – "DPC Implementation & Integration – Level 1" – active (development/design closed, maintenance active).

Activities

- The last version of the operational model (OM) of the Planck LFI Level 1 system, tagged 3.0, has been released (through the Planck CVS) on May 16th 2008. The integration tests with the MOC DDS were repeated on this version to verify the proper resolution of the SPRs and SCRs before the SOVT1 validation tests.
- The results of the SOVT1 tests are reported in [RD-37]
- Maintenance of the QM Level 1 (TQL/TMH 3.1.3) to support the CSL integrated tests is still active.

Problem Areas:

- See subsections

4.1.1 MOC INTERFACE AND DATA DECOMPRESSION

WP status:

- GPLDAA – "Data Decompression" - (development/design closed, maintenance active).

Activities

Data Decompression

- During the RAA test some problems on the performance of compression algorithm were identified. NCR were raised and new software was delivered to be integrated in the FM model. This version was tested during the RAA FM campaign and the decompression algorithm was integrated in the Level 1 DM and OM.
- Analysis on the compression performance was shown during the Instrument Calibration Workshop (16-17/11/2006) and shows that the goal was reached.
- Tests on decompression capability are detailed in [RD16] and [RD17]

MOC Interfaces

- During the integration tests with the MOC DDS interface, a performance issue as been identified due to TM packets with the SCET flagged as invalid or inaccurate. Such packets can have an on-board time which belongs to an already processed hour of data. This causes a reprocessing of the entire hour, in order to merge the new data found. MOC has suggested to usually retrieves only TM packets with good time quality. We have applied a software change in order to retrieve all the TM packets in a certain hour, but performing a special treatment on the TM packets with bad or inaccurate SCET: these packets are backed-up in the Level 1 archive without been transformed into TOIs.
- The DDS, RTSI and HPFTS interfaces have been tested successfully during the SOVT1 tests, showing that the LFI Level 1 overall implementation of the RTSI and DDS interfaces is correct and in-line with the performance constraints [RD-37].

- An issue has been identified in the handling of the Time Correlation Coefficient (TCO2) packets. To recalculate the UTC correlated to the OBT, the level 1 program "scet_check" doesn't discriminate the records flagged as invalid or inaccurate. Hence the obtained UTC can be inaccurate and in that case the TOI data contains an incorrect time quality flag. This is considered a minor issue and an SPR has been raised in order to discriminate inaccurate or invalid TCO2 records.
- Support to the OOL packets provided by the DDS is under evaluation. For the LFI HK data the LFI Level 1 software performs the out of limit checking using the information gathered from the MIB tables. But the OOLs for other subsystems (e.g. the SCS) make use of the SCOS synthetic parameters, defined with the SCOS Operational Language, and they cannot be interpreted outside the SCOS environment. Hence, in our Level 1 pipeline we are considering the usage of the DDS OOL packets for the non-LFI parameters.

Problem Areas:

- Minor: handling of inaccurate or invalid records in TCO2 packets.
- Normal: discussion at PGSSG level of the special treatment to be applied to TM packets with inaccurate or invalid SCET is needed.
- Normal: usage of OOL packets for non-LFI HK parameters.

4.1.2 TM HANDLING

WP status:

- GPLDAB – "TM Handling" – (development/design closed, maintenance active)

Activities

- With the last release of the LFI Level 1 OM software (version 3.0) all the programs which are part of the Level 1 pipelines have reached a good level of stability and completeness, also confirmed by the SOVT1 test results.
- With respect to the implementation review status, some tasks that were at design level have been completed and tested. In particular the fits2dmc program, ingesting the LFI and SCS TOIs into the MPA DMC has been completed and now the MPA DMC is considered the nominal archive for the LFI Level 1 data. It has shown performances in-line with the DPC Level 1 requirements. The tm_request program was been modified in order to support the retrieval of the command history packets provided by the DDS.
  The following additional tasks have been developed and tested:
  - sc_calibration: calibrates all the scientific TOIs of one data set. Some LFI HK parameters are required to find the correct calibration values.
  - scet_check: using the TCO2 packets, it checks that the SCET time provided in the DDS header of each TM packet is within a certain threshold.
  - tc2ascii: this program converts the command history packets into an ASCII representation (similar to the Telecommand History ascii printout provided by MOC through the HPFTS).
- Change to the RTSI Corba interface in the MOC HPMCS recent releases has been applied to the RTSILib library (that is responsible to receive the real-time telemetry from the

IW@MOC point of view). A new function to check the RTSI connection status has been proposed at PGSSG level and successfully tested.
- Proper calibration of a set of 4K cooler and CMDU (spacecraft) HK parameters, needed for the LFI DQR, has to be assessed. For these two subsystems, conditional calibrations are not yet supported since the LFI Level 1 software has a limited handling of the synthetic parameters (custom handling only for the Sorption Cooler).

Problem Areas:
- Additional functionalities to be added to the limit_check program needed in order to use the OOL packets for non-LFI subsystems
- Usage of the conditional calibration for a small subset of 4K cooler and CMDU HK parameters is under study.

4.1.3 RTA

WP status:
- GPLDAC – "RTA" – (design closed, development closed, maintenance active)

Activities
- LFI DPC RTA is based on the definition of the SCOS2k MIB Tables in CCS format.
- LFI FM Tables were delivered to ALCATEL (version 4.4.2) and ingested into the HPSDB system. This is also the version included in the integrated MIB tables used by MOC, LFI and HFI during the SOVT1 tests. It includes several changes to improve the monitoring capabilities on the LFI HK parameters, OOLs for ambient temperature, validity checks based on a set of synthetic parameters, improved Event packets usage, some OOL values corrections, adding of command verification stages, etc. Each release of LFI FM database is accompanied by a TN where all these info are reported.
- The last release of the LFI AVM Tables, 1.3.0, has been ingested in the HPSDB system.
- Tests on the RTA were performed during the integration tests and the SOVT1 tests.

Problem Areas:
- None

4.1.4 QUICK LOOK ANALYSIS (TQL)

WP status:
- GPLDAD – "Quick-Look Analysis" - (design closed, development closed, maintenance active)

Activities *(R. Rohlfs)*
- The last TQL programs version released is part of the LFI Level 1 OM 3.0 delivered the 16th of May 2008.
- User Manuals for the TQL components have been written as distinct pdf documents.
- All the programs were tested during the RTSI integration tests and the SOVT1 tests [RD-37].

- A new task to improve the status monitoring of all the LFI Level 1 pipelines is under development. It will be able to extract relevant information from logs in more human readable format.

Problem Areas:

- None

4.1.5 TM CONSISTENCY CHECK

WP status:

- GPLDAE – "TM Consistency Check" – (design closed, development active)

Activities

- This tool will be used during operations to verify if the telemetry received at MOC in near real time is consistent with the same telemetry downloaded through the HPDDS. It is composed of a simple algorithm that checks the output of selected timelines. It has been used to cross-check the telemetry retrieved during the SOVT1 tests.

Problem Areas:

- None

4.1.6 SCOS2000

WP status:

- GPLDAF – "SCOS2000 customization" – (only maintenance)

Activities

- At present, two different SCOS2k Version are in use at the DPC:
  1. SCOS2k HPCCS (needed for Integration tests);
  2. SCOS2k 3.1 (the version chosen for the operations).
- The usage of SCOS HPCCS has required some maintenance on the LFIGateway software, handling the connection between the HPCSS server (used by TAS) and the HPCCS client of LFI. Recently, it has been modified to handle directly the connection with the TMH/TQL QM model.
- A better integration of SCOS 3.1 EGSE with the RTSI interface has been developed. A custom SCOS task, called RTSIClient and using the RTSILib, is now part of the LFI RTA system.
- A DDS TM player for SCOS 3.1 has been recently added by the group leaded by Serge Valera to satisfy a common requirement of LFI and HFI. This new task is able to reply DDS data directly with SCOS.
- An agreement between project and instruments was reach for the maintenance of the SCOS2k 3.1 version in the operations period.

Problem Areas:

- **None**

4.1.7 LEVEL 1 ARCHIVES IMPLEMENTATION

WP status:

- GPLDAG – "Level 1 Archives implementation" - (development/design closed, maintenance active)

Activities

- Maintenance of the archive system to deal with data from the RCA, RAA tests and all the ground tests.
- About 650 GB of LFI Ground Tests data were stored on the GTD online database.
- New hardware system to be used during operations was acquired and installed at DPC in April 2008. It consists of a storage system with 16 TB of RAID 5 disk Space mirrored.

Problem Areas:

- none

4.1.8 COMMAND PROCEDURES

WP status:

- GPLDAH – "Command Procedures" - (main development closed, upgrade active)

Activities

- All the nominal procedures were reported inside the LFI User manual [RD22] – [RD23] and they were checked during the LFI ground tests.
- Contingency procedure were defined and reported inside the LFI User manual [RD22].
- Instrument Commanding Request (ICR), controversial and non-controversial, were exercised during the SOVT1 test [RD-37] as should be during operation.

Problem Areas:

- Normal: is not clear how one DPC can control the ICR and correlated TPF issued by the other DPC. A deep knowledge of the other instrument is needed. This point will be discussed at the ICWG level.

4.2 SGS1 STATUS CONCLUSION

LFI SGS1 is in good shape and ready for operations, with minor adjustment. All modules were developed and integrated first into the DM model that was/is used during the Ground test campaign. This was a very good test bench that demonstrated that the design was correct and the software core works appropriately. At the same time the data acquired during the Ground test were used to verify the integration of the OM model and was/will be used to validate the software (every time we release a new head version). During the SOVT1 test [RD-37] we finally were able to test the interfaces with the MOC (IW@MOC and HPDDS) as should be in operation, with the caveat that the online consolidation was not yet available at that time. These interfaces were developed using the configured ICDs and all the inconsistency between reality and documentation was raised in for of SPR. We would like to raise a warning on the late upgrade of this documentation that can generate misunderstanding. Note that during the SOVT1 lots of gaps in the consolidated data were detected, this is not an issue of the DPC but we stimulate the MOC to identify reason of these large gaps and adopt solutions.
In the Implementation status reports issued for the SGS-IR we raised a warning on the multiplication of different SCOS2k versions and on the fact that the version to be used during operations was not fixed. This was solved with the decision to adopt the SCOS2k3.1 for the operation and with the agreement with the project to maintain this version for all the operation period.

In Figure 1 only the SGS1 pipeline structure was reported: additional software, that is external to the pipeline, was added to perform the off-line analysis of the instrument performance. It is able to create the Daily and Weekly reports to be sent to the PSO/MOC/HFI during operations. These activities were tested too during the SOVT1 test [RD-37]. The software, named LIFE (see [RD20] and [RD 21]), was used during the Ground test campaign to evaluate the instrument performance and compute the best set of parameters to be sent to the LFI electronic acquisition system (REBA) used to compress/quantize the scientific output. For the Operation point of view we develop new modules, as the Daily and Weekly Quality reports, added to the LIFE Operation Model, and the outputs were already tested during the SOVT1 test [RD-37] performed in the last week of May 2008.

The last point that should be mentioned is that the SGS1 OM was completely integrated with the LFI MPA-DMC (see section 6), with satisfactory performance, as it will be the entry point to the Level 2, but at the same time, as imposed by the PA/QA manager, the FITS files are still used as backup solution to reduce risks avoiding a single point failure.

5 SGS2 IMPLEMENTATION STATUS

SGS2, in the LFI DPC pipeline structure, is mapped in two different levels: Level 2 and Level 3.
Level 2 starts when data from sky and reference are stored into the Database through the MPA-DMC in a format compliant with the one specified in the LFI DDL. The goal of Level 2 is to produce calibrated, cleaned, frequency maps, as well as intermediate maps (single detector, detector pair attached to the same leg of one radiometer), both in temperature and polarization. To do this, as for the SGS1 part, we followed a phased development starting from a very rough model of the scientific pipeline, the Bread-Board Model – BBM, moving to a more refined and realistic treatment of data in the Demonstration and Operational Models (DM and OM respectively) [RD03-RD11].
The DM has been used to test the DPC machine capability of handling the largest LFI data set namely the whole set of 70 GHz channels and has been used and improved starting from summer 2005 up to the release of the next SGS2 pipeline model in autumn 2006.
The OM-0 model was used for internal scientific validation of the SGS2 pipeline and parts of these tests were included in the ESA End-to-End tests of the DPC SGS2 pipelines [RD19]. The OM-0 was too used to perform the ESA End-to-End test phase 1 [RD 18].
The considerable improvement of OM with respect to the DM consists mainly in all those tools and software modules needed to evaluate instrumental properties and behaviors. To get this information out of the data (both simulated and real) several sub-pipelines have been identified which, at the same level, could operate in parallel (i.e. output from one sub-pipelines are not necessarily the inputs of another sub-pipeline). The basic sub-pipelines are:

- Gain modulation factor: this very simple pipeline has the goal of computing the gain modulation factor to produce differenced data from the outputs of sky and reference.
- Noise properties: on differenced data (both calibrated or un-calibrated) it is necessary to estimate the noise properties of each detector. To do this, the signal has to be removed from the data since it will appear as spikes at the spin-frequency and harmonics which contaminate and complicate the fitting procedure. This is achieved by projecting data into a map, re-scanning this map according to observing strategy and subtracting the almost signal dominated TOI obtained from the original one.
- Beam pattern and focal plane: this pipeline makes use of planet crossings to get information on beam properties. It uses a bi-variate gaussian approximation of the beam. The code returns the beam FWHM, beam ellipticity and orientation on the focal plane, peak signal of the source and an indication of the beam position on the focal plane. Before doing this data will be cleaned with a destriping algorithm. This is to be intended only for letting the beam fit code works properly
- Map-making: this pipeline has to create detector and frequency maps in temperature and, when possible, in polarization. There is a whole set of map-making codes of different flavors (destriping, IGLS and hybrid codes)
- Once frequency maps have been obtained, they have to be combined properly to extract genuine CMB signal as well as foreground emission useful for astrophysical studies. The code actually in use is based on the Independent Component Analysis which has been proved to work well also on real data (COBE-DMR and WMAP).
- Power Spectrum estimation is the final step. On optimal linear combinations of frequency maps to get clean CMB signal, the angular power spectrum is computed making use of the cross-spectrum computing spectrum from frequency independent channels. In this way noise

knowledge does not bias the estimation of the angular power spectrum and enters only in the evaluation of the power spectrum error bars.

The OM-0 was required several improvements since the end-to-end tests Phase 1; the LFI DPC has substantially upgraded the SGS2 data analysis tools, in particular to characterize and minimize the impact of systematics on the scientific products, consequently a new head (OM-1) of the operational model was released.
In its current implementation, OM may deal with many non idealities, such as realistic pointing, gaps in the data, bandpass effects, frequency spikes in the TODs, sidelobes spillover, variable pointing periods. It was internally validated and will now be used to perform the incoming E2E test ph2.

It is worth to outline another major improvement in the OM with respect to the DM, namely the proper use of the data interface defined in the LFI DDL and in the MPA- DMC. All S/W modules were interfaced with the DMC back-end based on a DBMS which, in the LFI case, is the Oracle DBMS.
Another important step in the integration of the DPC system with IDIS tools is the usage of the Process Coordinator (ProC) for editing, constructing, configuring and handling the pipelines. Interfaces with the ProC and the PBS scheduling system is now available and are used on the LFI cluster.

Note that for security reason the SGS2 OM-1 interacts with two physically separated databases: the first, the SGS1 database, is seen as read-only database and the second, the SGS2 database, is used to store the output of the SGS2 OM-1 modules.

5.1 LEVEL 2 INTEGRATION AND TEST

5.1.1 LEVEL 2 ARCHIVE DEVELOPMENT

WP status:

- GPLDBA – "Level 2 Archive development" – (design closed, development/upgrade active)

Activities

- Maintenance of the archive system used to store the simulations, OM and E2E ph1 test results
- About 2 TB of simulations and test results are stored on the 2.2 archive available.
- New hardware system to be used during operations was acquired and installed at DPC in May 2008. It consists of a storage system with 16 TB of RAID 5 disk Space mirrored.
- Addition 24 TB will be added before September to reach the final SGS2 storage configuration.

Problem Areas:

- None pending

5.1.2 ERSC CATALOGUE DEVELOPMENT

WP status:

- GPLDBB – "ERCSC catalogue development" – (design active, development start)

Activities

- No head software was received at the DPC, only prototype (see the section 5.1.14).
- ICD status: the first that describe how the LFI DPC will release the data to the USDC (USA Data Centre that is in charge to build the ERCSC catalogue) was signed and approved, the second that define the contents of the ERCSC catalogue is in final form will small issue to be discussed.
- The ERCSC interface and catalogue will be tested during the incoming ESA E2E ph2 tests [RD-38].

Problem Areas:

- ICD not yet signed.

5.1.3 TIME SERIES ANALYSIS

WP status:

- GPLDBC – "Time Series Analysis" – (design closed, development active)

Activities

- Interface development is ongoing using the KST tool. It will be used to cross correlate LFI and HFI data using the format defined in the [RD-26].
- Base capability, as described in the URD, are implemented and verified. We are waiting for the CSL test to verify if additional features are required.
- Data to be used to verify the I/O interface was delivered in June 2008 reflecting the last agreed changes in the ICD [RD-26].

Problem Areas:

- None pending

5.1.4 SYSTEMATICS

5.1.4.1 EXTERNAL STRAY LIGHT

WP status:

- GPLDBDA – "External Stray Light" – (design closed, integration in OM ongoing)

Activities

- Code to simulate the "external" (Solar System) straylight developed, delivered and integrated in Level S and in OM.
- The Semi Blind approach was previously integrated in the DM and now is integrated into OM-1.
- The Blind approach in under investigation/development.

Problem Areas:

- None pending

5.1.4.2 INSTRUMENT INTRINSIC EFFECT

WP status:

- GPLDBDB – "Instrument Intrinsic Effect" – (design closed, development ongoing)

Activities

- Using the RAA FM and RCA data, Instrument intrinsic effects have been investigated to produce modules to be ingested into SGS2 pipeline. Using the data acquired during the LFI FM test campaign, a simulation code has been implemented to generate the effect of frequency spikes on the scientific timelines. This code has been delivered and integrated in Level S. As for the Level 2 Pipeline, an algorithm was built to identify the spikes signal and to remove their contaminations from the astrophysics signal. The performances of this analysis tool are currently being tested at the LFI DPC.

Problem Areas:

- None pending.

5.1.4.3 BEAM SHAPE

WP status:

- GPLDBDC – "Beam Shape" – (design closed, development closed, upgrade active)

Activities

- All LFI main beams X and Y polarised have been computed, at the central frequency, using the GRASP code and RCA data. The complete beam dataset is currently at the LFI DPC. The band shape effect has been also taken into account: dedicated datasets of beams have been computed for each frequency channel and stored at LFI DPC in to the instrument model.
- A complete dataset of intermediate beams and 4pi beams are stored at DPC. Sidelobes have been computed subtracting the main beam computed with Physical Optics from the 4pi beam and their parameters have been included in the Instrument Model and currently used by LevelS.
- Several tests have been done on the Level S routines that handle and convert beam in GRASP format to other format for the pipeline (grasp2stokes, beam2alm, synbeam_cxx). This defined a lower bound on the spherical harmonics coefficients l and m needed to accurately represent the LFI beams

Problem Areas:

- None pending

5.1.4.4 THERMAL EFFECT

WP status:

- GPLDBDD – "Thermal Effect" – (design closed, development closed, upgrade active)

Activities

- The module based on High Pass Filtering was integrated and validated into OM-1.
- As for the Level 2 Pipeline, an algorithm to deal with thermal fluctuations and to remove their contaminations from the astrophysics signal, has been developed. This module, based on High Pass Filtering, is currently being tested versus the efficiency of a simple destriper.

Problem Areas:

- None pending

5.1.4.5 POINTING DEVELOPMENT

WP status:

- GPLDBDE – "Pointing Development" – (design closed, development closed, upgrade active)

Activities

- The module based on the code by Floor Van Leuween was integrated first into DM and successively into OM-1.

- A module, AHF2LOS, which convert AHF (Attitude History File) from satellite reference frame to LOS frame taking into account the satellite/telescope alignment Matrix (SIAM) is now under validation test.
- A module converting from quaternions (both in Level S format and AHF file format) to detector pointings (i.e. sky coordinates plus beam orientation in the sky) has been implemented and integrated.

Problem Areas:

- None pending

5.1.4.6 POLARIZATION SPECIFIC

WP status:

- GPLDBDF – "Polarization Specific" – (closed, maintenance ongoing)

Activities

- Polarization specific was integrated into the mapmaking code and released into the DM and successively into OM-1.
- A new module able to check from the astronomical point of view the polarization calibration is in development as follow:
  Check that the polarization orientation of each feed is consistent with its design value. The procedure is to make as accurate as possible measurements of the Crab Nebula using the Time-ordered data to avoid loss of precision via binning onto sky pixels.
  - For each detector, calculate band-integrated main beam profiles in each Stokes parameter assuming the spectral index of the Crab nebula (beta = -2.3);
  - for each visit (i.e. contiguous sequence of scan circles) of each detector to the Crab Nebula, perform a weighted fit of the beam to the TOD to determine the amplitude;
  - use the amplitude data corrected for bandpass gain errors and known cross-polarization of the beam profile, to calculate position angles for the Crab nebula, for each horn separately and for each pair of matched horns;
  - in the light of the consistency of the results (between the horns and horn pairs in each frequency band, between different bands, and between Planck and external datasets such as WMAP), assess whether either the nominal horn polarization position angles or their uncertainties need to be revised.

Problem Areas:

- The above mentioned algorithms are being developed and tested; not yet integrated at the LFI DPC.

5.1.4.7 SYSTEMATIC DETECTION METHODS

WP status:

- GPLDBDG – "Systematic Detection Methods" – (design closed, development ongoing)

Activities

- Using the Ground FM test and RCA data Systematic Detection Methods are under investigation to produce modules to be ingested into the SGS2 pipeline. These methods will, in most cases, correlate with the housekeeping telemetry.
- A method for detecting frequency spikes in the Fourier domain has been developed and tested within the Level 2 Pipeline.

Problem Areas:
- None pending

5.1.4.8 DATA CALIBRATION FROM SYSTEMATIC EFFECT

WP status:
- GPLDBDH – "Data Calibration from Systematic Effect" – (design closed, development ongoing)

Activities
- Using the RAA FM and RCA data Calibration from Systematic Effect are under investigation to produce modules to be ingested into SGS2 pipeline.

Problem Areas:
- None pending

5.1.4.9 SYSTEMATIC IMPACT ON SCIENCE

WP status:
- GPLDBDI – "Systematic Impact on Science" – (design closed, development ongoing)

Activities
- Simulations of several systematics are being produced to study their impact on science. This will involve Level S modules, for generating the effects, and Level 2 modules, to minimize the systematic impact on the final products. This analysis is currently ongoing.

Problem Areas:
- None pending

5.1.5 BEAM PATTERN RECOGNITION

WP status:
- GPLDBE – "Beam Pattern recognition" – (design closed, development closed, maintenance active)

Activities
- The Beam Pattern recognition code was delivered integrated into OM-1 and tested (see [RD-18]).
- The Beam Pattern recognition code has been tested on simulated Jupiter transits, with non-ideal pointing and assuming the *realistic* beams produced by GRASP (see section 5.1.4.3).

- The beamfit code has been used in the end-to-end tests phase1 and within internal tests at the LFI DPC. It is currently being extended, to allow for more general fits than bivariate Gaussian shapes.
- Optimization on the fitting area.

Problem Areas:

- None pending

5.1.6 DATA CALIBRATION

WP status:

- GPLDBF – "Data Calibration" – (design closed, development closed, maintenance active)

Activities

- The Data Calibration modules were integrated into OM-1 and were tested, see [RD-18]
- It uses as input the simulated TOD and the reconstructed R factor to monitor in different timescales fluctuation on the gain constant. It will be used on short timescales, about one hour, to monitor thermal instabilities while on longer timescales it will be used to convert volts to antenna temperature.

Problem Areas:

- None pending

5.1.7 ALARMS SOURCE GENERATION

WP status:

- GPLDBG – "Alarms Source Generation" – (design closed, development closed, upgrade active)

Activities

- The QDS (Quick Detection System) was integrated first into OM-0 in October 2006, it was so upgraded in November 2007 into OM-1 and totally integrated with the MPA-DMC to be able to get TOD directly from the database.
- We plan to test the QDS tool in blind mode using the simulation that should be provided for the incoming E2E ph2.

Problem Areas:

- Deep test are required

5.1.8 BUILDING RING SET

WP status:

- GPLDBH – "Building Ring Set" – (design closed, development closed, upgrade active)

Activities

- This module was tested as single unit during the implementation phase. It was integrated into OM-1. It allows to build ring-sets of arbitrary length from the TODs.

Problem Areas:
- None pending

5.1.9 POINT SOURCE DETECTION FROM TOD

WP status:
- GPLDBI – "Point Source Detection from TOD" – (design closed, development closed, upgrade active)

Activities
- The development was closed and tested outside the pipeline. It was yet integrated into OM-1.

Problem Areas:
- None pending

5.1.10 CROSS CHECK ON TOD

WP status:
- GPLDBJ – "Cross Check on TOD" – (interface defined, design open)

Activities
- This is a common LFI-HFI WP. IUCD were agreed in past an, based on the experience acquired during the E2E test ph1 some changes were applied.
- Software able to cross correlate LFI and HFI data using the EFDD format was developed and now under test (see 5.1.3)
- Special group is in formation to work with the incoming CSL data and try to identify clear methodology to be applied during operations.

Problem Areas:
- Not at the moment

5.1.11 LFI POINTING

WP status:
- GPLDBK – "LFI pointing" – (design closed, development closed, upgrade active)

Activities
- The module based on the code by Floor Van Leuween was already integrated into the DM and successively into OM-1. Tested during the E2E test ph1. It follows the WP defined in section 5.1.4.5.

Problem Areas:

- None pending

5.1.12 CROSS CHECK ON POINTING

WP status:

- GPLDBL – "Cross Check on Pointing" – (design closed, development ongoing)

Activities

- This WP was merged into HFI pointing reconstruction as specified in [RD-27]. It verify the focal plane reconstruction provided by HFI with respect the point sources detected in the LFI TOD.
- It is under internal validation test to be ready for the ESA end-to-end test phase2.

Problem Areas:

- None

5.1.13 MAP MAKING

5.1.13.1 DESTRIPING

WP status:

- GPLDBMA – "Destriping" – (design closed, development closed, maintenance active)

Activities

- Springtide, a basic destriper, is being ported at the LFI DPC.
- The MADAM algorithm, v3.4 [RD 33- RD 35], based on the destriping technique was implemented under the OM-1 pipeline and already tested using phase 1 inputs and parameters, see [RD-18].
- The same module are also used to produce polarization maps.
- A new release, Madam v3.5, has been released and integrated in to the OM-1 at the LFI DPC. Madam builds destriped maps from TOD with variable baseline length and with a noise filter. The code is capable of producing both single-detector and multi-detector maps.
- New features in version 3.5:
    - Pointing data may be given either as individual detector pointings or as satellite pointing (in which case the focal-plane database is used);
    - Version 3.5 accepts variable pointing periods.
    - Output maps may be written in eclicptic or galactic coordinates;
    - Unobserved pixels are outputted in a form compatible with Healpix routines.
    - Baseline length is a fully free parameter, not connected to the scanning period duration

Problem Areas:

- Madam 3.5 cannot read FITSIO files exceeding in size 2^{31} rows. This is a known problem in the Fortran interface of the FITSIO library and is being fixed.
- A pixel-to-pixel noise covariance module (NCVM) has been developed by the Madam team, but is not yet integrated in the OM-1 at DPC.

5.1.13.2 MAXIMUM LIKELIHOOD METHODS

WP status:

- GPLDBMB – "Max likelihood Methods" – (design closed, development closed, upgrade active)

Activities

- The module ROMA, map-making code based on GLS on temperature and polarization, was installed and successfully tested on simulated data at the supercomputing system at CINECA
- ROMA is now being ported at the LFI-DPC. The temperature-only version is already installed. The code needs to use the new pointing library and must be generalized to different length TODs.

Problem Areas:

- None

5.1.14 PROTO SW ERCSC

WP status:

- GPLDBN – "Proto SW ERCSC" – (design closed, development open)

Activities

- PowellSnakes is a new fast Bayesian approach for the detection of discrete objects immersed in a diffuse background. It consistently defines the threshold for acceptance/rejection based on priors.
- The version 2.0 has been ported to the LFI-DPC OM-1 pipeline successfully.
- The PowellSnakes code has been extensively compared to other discrete source codes within the CSI, Compact Source Investigation collaboration (created to help build the ERCSC pipeline at IPAC). For this purpose it has been applied to the ERCSC - 1 single detector simulations and to the Full Focal Plane 1, FFP 1, simulations. These simulations include the PSM templates + (white + 1/f) noise and the scan strategy. It is one of the codes selected for both the P0 and P1 ERCSC pipelines, hence to be applied to the E2E simulations phase2 within the ERCSC - pipeline.
- Version 3.0 now ready to replace Version 2.0 (having issues with very high sources) and to be ported and validated. It includes auto-calibration and proper tackling of very bright sources added. Future releases:
    - Version 4.0 - Ongoing work to implement a proper treatment of the galaxy;
    - Version 5.0 - Inclusion of multi-frequency case.

Problem Areas:

- None

5.2 LEVEL 3 INTEGRATION AND TESTS

5.2.1 COMPONENT SEPARATION

5.2.1.1 WIENER FILTERING

WP status:

- GPLDCAA – "Wiener Filtering" – (design closed, development closed, closed)

Activities

- This module was tested as single unit during the integration in the BBM model. So it was integrated into the DM and in its evolution into OM-0 and OM-1.
- Test shows that the Wiener Filtering methods was superseded by more sophisticated analysis methods reported below.

Problem Areas:

- None Pending.

5.2.1.2 MAXIMUM ENTROPY METHODS

WP status:

- GPLDCAB – "Max Entropy Methods" – (design closed, development closed, closed)

Activities

- The code was first integrated into the HFI pipeline and successively in the LDI DPC OM-1.

Problem Areas:

- None pending

5.2.1.3 WAVELET ANALYSIS

WP status:

- GPLDCAC – "Wavelet Analysis" – (design closed, development active)

Activities

- A robust algorithm based on the wavelet analysis (see 5.2.2.2) has been developed, tested and optimized for point source detection. It has been installed and validated at the LFI DPC in the OM-1 model.

Problem Areas:

- None pending

5.2.1.4 INDEPENDENT COMPONENT ANALYSIS

WP status:

- GPLDCAD – "Independent Component Analysis" – (design closed, development closed, upgrade active). Different algorithms were developed and integrated inside the OM-1

Activities

- The module (FASTICA), separation algorithm based on statistical independence of the different diffused emissions [RD31], was integrated into OM-0.
- A new parallelized version (ALTICA) substituted the previous one and was integrated and validated in to the OM-1.
- New features of ALTICA:
  - capability of pre-compressing multi-frequency channels to reduce dimensionality when the number of components is less than the number of frequency channels;
  - possibility of realizing Monte Carlo runs on component separation;
  - capability of constraining output components to have a known frequency scaling, reducing to the Internal Linear Combination method.
- ALTICA has been adopted in the e2e testing Phase I. It also run on Planck simulated data in the WG2 (Component separation) challenges; the results were published in Leach et al. 2008 [RD 29]
-

Problem Areas:

- Error assessment will require Monte Carlo simulations;
- Actual limitations in separating different Galactic scalings never properly tested or quantified. Needed a baseline for dealing with varying foregrounds spectral indexes.

5.2.1.4.1 Correlated Component Analysis (cca)

Description:

The CCA code implementing this method [R 32] has been tested and is being integrated at the LFI DPC. The Mixing matrix estimation is based on second order statistic of diffuse astrophysical components.

Using the spatial correlation functions of the multi-frequency maps, this component separation algorithm parameterizes the spectral behaviour of the foregrounds and provides a fit for the unknown parameters. Parallel implementation to deal with varying spectral indices of foregrounds was included. This algorithms was run on Planck simulated data in the WG2 (Component separation) challenges, both in Temperature and in Polarization and on real data (WMAP) in Temperature.

Activities:

- evaluate the algorithm performances at low multipoles
- tests based on the use of optimal power spectrum estimation codes have been planned;
- test on polarized simulations (WG2 activity) are ongoing
- preparation for the ffp2 (Full Focal Plane simulation 2) test is ongoing.

Problem Areas:

- Error assessment through MonteCarlo only.

5.2.1.4.2 Miramare

Description:

A new code has been developed, to allow a detailed analysis of the properties of galactic components on specific regions of the sky. MIRAMARE implements the maximum likelihood foreground spectral parameter fitting algorithm of Stompor et al. 2008 [RD 30]. The algorithm operates in the pixel domain on frequency maps smoothed to a common resolution. Foreground spectral indexes are estimated using MCMC exploration of a likelihood function that combines the constraints from all pixels within user-defined regions, with built-in marginalisation over the foreground and CMB amplitudes. In a second step, component separation is achieved via the generalized least squares technique operating pixel by pixel, which provides maps of all components and an estimate of the component error covariance matrix. The method has been implemented at SISSA and is being tested on Planck total intensity and polarization simulations provided by Working Group 2.

Problem Areas:

- Preprocessing of sky maps and weights, currently handled in IDL, to be pipelined.
- Add Monte-Carlo capability, to improve the assessment the impact of the CMB and noise on the determination of foreground parameters. Evaluation of CMB and foreground angular power spectra on cut-sky, via the MASTER algorithm or using Spice.

5.2.1.5 MULTI LINEAR ENGINE

WP status:

- GPLDCAE – "Multi Linear Engine" – (design closed, development closed, upgrade active)

Activities

- The code Linear_filter_PSD was produced to detect point sources above a certain signal-to-noise threshold. It has three different linear filters built in: the 1st and 2nd members of the Mexican Hat Wavelet Family, as well as the Matched Filter.
- The first version of the code was installed and validated in the LFI DPC in fall 2007. It has been extensively tested on simulations in the framework of the WG2 Challenge in 2007, ERCSC-CSI Full Focal Plane simulations in the spring of 2008 and in the ongoing WG2 Polarization Challenge as of June 2008. It was used during the end-to-end tests phase 1.

Problem Areas:

- The performance of the code is not yet optimal (too many spurious detections) for the highest Planck frequencies after the inclusion of more realistic compact source emissions and of clustering in the infrared frequencies.

5.2.1.5.1 Cluster extraction

Activities

- The MatchMultiFilter code successfully installed on the LFI-DPC machine. The code was tested on WG2 challenge maps with different combinations of foregrounds. Performances will be better evaluated after point sources and galactic foreground subtraction.

Problem Areas:

- Low performances when operating on very extended/bright clusters;
- Slightly affected by point source contamination;
- the code works on full sky, so it is optimised globally, not locally. As a consequence, the performance over patched sky approaches the local estimate of the noise.

5.2.2 MAPS OF FOREGROUNDS

WP status:

- GPLDCB – "Maps of Foregrounds" – (design closed, development close, upgrade active)

Activities

- See Par 5.2.1.4

5.2.2.1.1 Bandpass modeling

Activities

Correction of bandpass effects requires an estimate of the foreground spectrum at each sky pixel and frequency band. This implies that a few iterations between Level 3 and Level 2 are required, as follows:

- For each detector, use the bandpass profile stored in the Instrument Model to calculate the bandpass-dependent gain error f(β) as a function of spectral index. Two independent IDL modules to do this were developed in the context of E2E activities and their results have been validated by cross-checking. (Leahy & Foley 2006, Leahy, Moss & Foley, December 2007).
- From intermediate Level 3 foreground modeling, construct spectral index maps at each frequency. The spectral index should be stabilized against large signal fluctuations at high latitude pixels. The algorithm is under development (S. Leach & P. Leahy)
- For each detector, use the spectral index maps and the Level 3 foreground maps in each frequency band to derive maps of the spurious signal: $f(\beta) \times T_{foreground}$. An IDL module to do this was developed in the context of E2E activities (Leahy, Moss & Foley 2007).
- For each detector, simulate TOI matched sample-to-sample with the observed TOI by "observing" the spurious signal maps. Either use Level-S simmission code or new software required.
- Subtract spurious signal TOI from observed TOI. (In the pipeline this step should be done after Gain calibration.). Results should be stored in the DMC and used as input to map-making. New code required, in preparation.

Problem Areas:

- None.

5.2.2.1.2 Point sources subtraction

Activities

Bright compact sources represent highly localized regions with discrepant spectral indices from the surrounding diffuse emission, which can negatively impact attempts to model the diffuse components (including CMB). Under this work package, point sources found during initial Level 3 analysis will be subtracted from the TOD for maximum accuracy.
The planned activity follows this scheme:

- From the point sources detected in Level 3 analysis, select the subset which are clearly identified with a source known to be compact on the scale of the Planck beam (well represented by a delta function on such scales), and with accurate position known from ancillary data.
- Generate band-integrated beam response for each detector based on spectral index of a "typical" compact source.
- For each detector, generate model TOI using time-domain convolution with the appropriate beam of all point sources in the list; then subtract TOI from observed TOI.

The required tools are in common with 5.2.2.1.1

Problem Areas:

- None pending

5.2.3 CMB POLARIZATION ANALYSIS

WP status:

- GPLDCC – "CMB Polarization Analysis" – (design closed, development closed, upgrade active)

Activities

- ROMAster (see 5.2.7.1) is a code based on the pseudo C_ℓ approach to provide estimates of the angular power spectrum of the sky in total intensity I, as well as in the E and B polarization channels and all cross spectra that can be formed mixing the three components. After tests inside WG3, the code has been successfully installed at the LFI DPC. It will be integrated in the OM-1 before summer 2008.

Problem Areas:

- None pending

5.2.4 INTER FREQUENCY CROSS CHECKING

WP status:

- GPLDCD – "Inter Frequency Cross Checking" – (design closed, development active)

Activities

- This tasks as decided within the internal SGS2 review, will be moved to the OM-2 integration phase.

Problem Areas:

- None pending

5.2.5 CALIBRATION ON MAPS

WP status:

- GPLDCE – "Calibration on Maps" – (design closed, development closed, upgrade active)

Activities

- The calibration on maps will make use of long term (12 months) G estimates coming from the sub-pipeline described above (see 5.1.6)
- It was integrated into OM-1 and tested.
- A Possible extension on maps is in discussion.

Problem Areas:

- None pending

5.2.6 OPTIMIZATION ON COMPONENTS MAPS

WP status:

- GPLDCF – "Optimization on Components Maps" – (design open)

Activities

- This activity has been enclosed in the component separation work package 5.2.1: optimizing the component maps is the core of validation plans for separation algorithms.

Problem Areas:

- None pending

5.2.7 CL SOFTWARE

WP status:

- GPLDCG – "Cl Software" – (design closed, development closed, upgrade active)

5.2.7.1 ROMASTER

Activities

- ROMAster, an evolution of the MASTER algorithm, has been included into the more sophisticated mapmaking algorithms (ROMA).
- The fully functional version has been implemented at the LFI DPC. The code has been used for the end to end phase 1 analysis. Since Monte Carlo maps were not available for this test, only the cross spectrum mode has been used and error bars have been computed via bootstrapping.

- Both self consistency and cross consistency tests (i.e. with different codes, including Crossspect and Xfaster) have been carried out, mostly in the context of a thematic comparison handled by Planck WG 3. No major issues with the code were discovered during testing.

Problem Areas:

- The tests performed on ROMAster assumed an idealized sky signal (a CMB only sky, albeit assuming a realistic mask), the only systematic effect present being the elliptical beam. In addition, a limited number of channels were simulated (the twelve 70 GHz detectors). A testing campaign encompassing more realistic inputs will be carried in the near future.
- ROMAster is unoptimal in the low ℓ regime. Different codes will be used to this extent (e.g. BolPol).

5.2.7.2 BOLPOL

Activities

- BolPol is a code implementing a quadratic maximum likelihood algorithm for C_ℓ, aimed at the low ℓ ($\ell < 30$ to 60) regime. The code, developed as a joint collaboration between INAF/IASF Bologna and Roma "Tor Vergata" is fully parallelized. Only the autospectrum approach has been implemented, although a cross spectrum approach is also viable.
- BolPol has not yet been integrated at the LFI DPC.
- The code will be tested on realistic data, including the effectiveness of degrading schemes for the input map.
- Future plans include the implementation of a pixel based likelihood approach using part of the BolPol routines.

Problem Areas:

- The computational scaling of the algorithm makes it unfeasible to run BolPol at Nside > 32.
- It is not straightforward to derive accurate models of the CMB likelihood out of BolPol estimates. However, part of the routines BolPol is built on can be used to that purpose: this will be the goal of future activity

5.2.7.3 CROSS SPECT

Activities

- CrossSpect is a code for Cross Power Spectrum estimation (temperature and polarisation). It is based on the uncorrelation of noise between different detectors. It requires Monte Carlo simulations of signal+noise for the error bars estimation. It requires Monte Carlo simulations of the signal (only) for the estimation of the transfer function. It can deal with partial sky coverage. Currently, different power spectrum codes are being tested within the CTP activity (paper in preparation)

Problem Areas:

- CrossSpect turns out to be not optimal for low ℓ multipoles.
- No 'quick' analytical estimation of error is currently available.

- Asymmetric beam deconvolution is currently approximated by an effective Gaussian FWHM + transfer function evaluation.

5.2.8 NON GAUSSIAN TOOL

WP status:

- GPLDCH – "Non Gaussian Tool" – (design closed, development active)

Activities

Four tests are being carried out to check different aspects of the non Gaussianty tools:

- assessment of different implementations of the same tools. In particular, two implementations of the Spherical Mexican Han Wavelet and two more for the Minkowski Funtionals are under inspection to study possible incompatibilities.
- Evaluate the performances of the non-Gaussian tools to validate the CMB maps coming out from the component separation algorithms. On going work in collaboration with WG4.
- Impact of radiometer spikes on the statistics built with the baseline non-Gaussian tools. Simulations are already available.
- Impact of map-making process on the statistics built with the baseline non-Gaussian tools. Simulations are already available. Work between in collaboration with WG4.

Problem Areas:

- None pending

5.2.9 COSMOLOGICAL PARAMETERS

Cosmological Parameters evaluation is not a DPC formal task but we will obviously use it to improve our assessment of the DPC product. This is the reason why it is listed here.

Activities

A test plan has been identified for evaluating the performances of the algorithm COSMOMC:

- Validate parameter constraints from COSMOMC at Planck noise levels. Establish levels of intrinsic bias in mean of marginals and verify they are small compared to the random error. (This test has been done for single realisations, but biases are less well studied.)
- Numerical errors in Boltzmann codes.
- Recombination errors.
- Reionization uncertainties.
- Verify above findings in larger parameter space including Ω_K, r, $dn_s / d\ln k$, m_ν, Y_{He}, T_{CMB}. Need to include weak external priors for geometric degeneracy.
- Impact on parameter constraints of residuals of thermal and kinetic SZ, and of compact sources.
- Definitive statement on recombination. Comparison of RECfast and PICO emulators in COSMOMC.
- Replace Gaussian lensed CMB realisations with properly lens-mapped simulations and verify the expectation that power spectrum covariances can be ignored for Planck.

All the above tests will be done with idealised Planck (single resolution, full-sky, uniform and uncorrelated noise). Lensed CMB to be simulated as a Gaussian field. Only simple six-parameter ΛCDM models. Use WMAP5 best-fit model as fiducial.

Problem Areas:

- None pending

5.2.10 L3 ARCHIVE

WP status:

- GPLDCI – "L3 Archive" – (design closed, development active)

Activities

- At the moment the Level 3 archive is in common with the Level 2 archive
- New hardware system to be used during operations was acquired and installed at DPC in May 2008. It consists of a storage system with 16 TB of RAID 5 disk Space mirrored.
- Addition 24 TB will be added before September to reach the final SGS2 storage configuration.

Problem Areas:

- None pending

5.3 L4 INTEGRATION AND TEST

WP status:

- GPLDD – "L4 Integration and Test" – (design open)

Activities

- This WP contains the following packages:
  - GPLDDA – "Preparation of Final Products"
  - GPLDDB – "Preparation of Final Documentation"
  - GPLDDC – "Transfer of Data and Documentation"
  - GPLDDD – "Level 4 Archive"
- The L4 WP change its status as results of the SGS-IR. It now consists only in the interface between the DPCs and the ESA archive. ICD is not yet issued but, as it will be necessary very late in the mission, we expect to start the discussion in the next months.

Problem Areas:

- None pending

5.4 SGS2 STATUS CONCLUSION

The present status of the SGS2 reflects the big effort produced to improve the quality of the DM, now evolved into the OM-0 and so in the more sophisticated pipeline model OM-1.
Many milestones have been reached since the development of the DM. First of all, while the OM-0 was able to handle the usual FITS files (as was the case for the DM), OM-1 was totally integrated with the MPA-DMC in its DBMS incarnation. Integration of OM-1 under CVS at LFI-DPC is completed in all essential part (at least one code/approach has been developed for each task). The XML description is ready for all modules, which is a necessary operation for the pipeline management with ProC. The mostly important modules relative to the radiometers balancing and data calibration (both relative and absolute) have been implemented and accurately tested under the guidelines of Phase 1 end-to-end test definitions.
The calibration sub-pipeline has been parallelized, to optimize performances when calibrating on short timescales (1 hr) to monitor the instrument thermal stability. Ring sets of arbitrary length can be generated from TODs. The basic properties of noise (white and and 1/f) are handled, and the noise power spectrum can be produced according to the operation plan needs, on daily and hourly timescales. Sophisticated destriping techniques have been developed and implemented in the OM-1 to control the residual 1/f noise. The present pipeline model is able to extract point sources on TODs, and, as a parallel branch of the point sources analysis, a Quick Detection System has been integrated in order to allow the detection of peaks caused by point sources and to generate alarms.
One fundamental aspect of the SGS2 in its current status is the capability to deal with realistic, asymmetric beams: the analytical bi-variate Gaussian parameters are fitted by a recently integrated module.
Different map making algorithms have been developed and tested, and, besides temperature maps, they generate Q and U (Stokes parameters) sky maps, as well the angular power spectra. The cross-spectrum code has been integrated, and preliminary test results are promising.
The OM-1 model undergone several internal tests within the LFI DPC infrastructure, and it [revious version (OM-0) was fully operating during the ESA's Phase 1 end-to-end tests showing in most cases excellent and reliable performances.
However, Phase 1 end-to-end tests assumed many "idealities" in the configuration of the simulated mission; OM_0 needed a substantial upgrade in order to deal with several systematics, which will be inserted in the Phase 2 of the end-to-end tests and that will be a major point during the real data analysis. Since October 2007, OM-0 included new tools or upgrades of the software, while still huge work is progressing to deal with non idealities, creating the OM-1 version. The most recent OM-1 upgrades include: use of quaternions to reconstruct pointings; beam reconstruction optimization, including errors in pointing analysis; bandpass effects; use of the beam far sidelobes in the beam modelling; algorithm for removing frequency spikes; map making with variable pointing periods, gaps in the data, use of galactic coordinates. A substantial improvement has been acquired in the Level 3 part of the SGS2 pipeline, both for component separation optimization and compact sources extraction tools, as well as for power spectra analysis. A robust plan has been also established to validate non-Gaussianity algorithms and cosmological parameters estimation. Noticeably, a parallel activity started to set up massive Monte Carlo simulations, which will provide a strong support to data analysis tools, particularly concerning the error assessment.

While some of the new functionalities of the OM-1are still being optimized and tested, we expect to produce reliable data analysis already in the Phase 2 of the end-to-end tests, planned for Spring-Summer 2008.
An issue which still deserves a deep investigation is the handling of an adequate cross-checking between the two instruments, covering many tasks, from the focal plane geometry reconstruction to component separation. A dedicate common core team will take care of this activities.

6 IDIS IMPLEMENTATION

IDIS is a collection of infrastructure software for supporting the Planck DPCs in their management of large quantities of software, data and ancillary information.
The full IDIS can be broken down into five major components, each of which is treated as a separate task each with its documentation under CCB:

- Document management system - to store and share documents – DMS
- Software component - to provide a configuration-controlled software development environment - SWC
- Data management component - to store and archive and share all science data both from the instruments and analysis - DMC - more recently divided further into MPA and HFI DMCs.
- Process coordinator - to provide processing of data over a LAN of computers – ProC
- Federation component - allowing objects to be inter-related across all components - FL

The DMS and SWC IDIS component are resident at ESTEC and are used daily to store/retrieve software and documentation. The MPA-DMC, ProC and FL are deliverables to be installed at the DPCs.
MPA-DMC: The version 2.5 was installed and integrated at the LFI DPC. System test were performed as planned (see RD-39 and RD-40). They show that the performances are in line with the requirements.
ProC: The ProC version 2.5 was integrated at the DPC and the SGS2 pipeline, released for the operation model (OM-1), was integrated using the ProC with the compatible xml files description.
FL: The Federation Layer version 2.5 was delivered. It was integrated in to the LFI DPC SGS2 pipeline in February 2008. The main function of FL is the authentication mechanism used to retrieve which user has the privilege to run the official product pipeline at DPC. As the FL server is running in ESTEC a local FL mirror, to avoid stopping the SGS2 pipeline runs if the network between the DPCs and ESTEC (where the LDAP database used to authenticate users is located) is down, was installed al LFI DPC. This is particularly relevant for the LFI-DPC, in which no pipeline is allowed to run outside the physical location of the DPC site (OATs). At the moment the FL interface still have problem due to bad configuration of LDAP database made by the LFI IDIS representative. Solution is ongoing.
I would like to note that the entire IDIS system (MPA-DMC) was used as it will be during operations, during the SOVT1 test:

- All the data downloaded from the DDS were automatically ingested inside the database using the MPA-DMC interface.
- The LIFE tool in charge to creates the DQR and WHR used the MPA-DMC interface to extract the data from the database.
- The first part of the SGS2 Pipeline necessary to compute the gain modulation factor extract the data from the SGS1 database using the MPA-DMC interface with the inside the ProC run environment and wrote the output in the SGS2 database.
- The entire OM-1 was integrated using the MPA-DMC interface and ProC module description and will be used in the incoming E2E ph2.

We expect to receive the IDIS version 2.6 (after system test) before the summer, it will contains some additional features to simply the installation procedure and the user interface.

7 HARDWARE IMPLEMENTATION

The present situation of the hardware at the LFI DPC follows the design reported in [RD24]. The system is composed of:

- 2 ISDN dedicated lines with MOC (nominal and backup, both managed by MOC)
- 2 Routers for the lines with MOC (nominal and backup, both managed by MOC)
- 3 PCs for SGS1 interactive work (SCOS/RTA; TQL; LIFE/PEGASO)
- 2 SGS1 data processing servers
- 5 Data servers (2 storage servers, 2 database servers, 1 FITS file server)
- 1 Super-cluster (Entmoot) with high-speed connection links (Myrinet) composed of
  - 32 PCs P IV IBM 64 CPUs Planck Reduction Cluster
  - 128 PCs P IV Nocona IBM 256 CPUs Planck SGS2 Cluster
  - 8 PCs P IV IBM 16 CPUs Test Cluster
  - 256 PCs P IV IBM 512 CPUs cold backup

The system has been put under configuration control as reported in [RD28].

The SGS1 subsystems have been tested extensively off-line and during SOVT1.

For what concerns SGS2, a smaller system (44 CPUs, Beowulf-based) was tested during the E2E Phase1 tests and found appropriate, with the only exception of the Least Square Mapmaking (ROMA code), the only algorithm needing more CPU and RAM, which was tested and validated on the CLX super-cluster at CINECA supercomputing centre. The full CLX system was transferred to the LFI DPC in April 2008, and ~ half of it (336 CPUs) constitutes the Entmoot cluster mentioned above. A fraction of it (80 CPUs) was installed earlier (November 2007) and fully tested. The cluster will be tested extensively off-line and during the E2E Phase2 tests.

The small Test cluster will be used to validate any upgrades to the OM model, during operations, before their introduction in to the production pipeline.

The overall system fulfils the requirements, especially from the SGS2 CPU/memory consuming point of view.

8 PA/QA ACTIVITY

Following a decision taken after the SGS-DR of November 2004, the LFI DPC performs PA directly, avoiding any delegation to institutes contributing software prototypes and concentrating this activity at the Main Site (OATs), where the SGS-1 and SGS-2 systems are integrated and are operational.

The PA Manager is familiar with software quality and software development related activities, and structured analysis, design, coding, and testing; he is familiar with the history of the LFI DPC project and applies to it the relevant standards and guidelines. The PA Manager is also the LFI DPC point of contact with ESA for PA topics.

The other persons involved in SPA are the members of the DPC Integration Team, and they are all located at the DPC Main Site in Trieste; they exert their SPA functions while integrating, usually together with code developers, the software within the DPC itself.

The SPA Team at the LFI DPC is currently the following:

- Marco Frailis for SGS-1,
- Francesca Perrotta for SGS-2,
- Samuele Galeotta for instrument-related code,
- Federico Gasparo for hardware/software standards,
- Gianmarco Maggio as Documentation Librarian,

under the coordination of Fabio Pasian as PA Manager. All of them will exert SPA activities part-time, with an estimated effort of 0.2 FTE each.

SPA informs and keeps up to date code developers about development standards and rules, i.e. development software environment, coding standards and, for reference, the Software Policy and the Software Integration and Testing Plan.

At the time of code integration at the DPC, the DPC Integration Team as part of their SPA activities for each module performs the following steps:

- test module scientific and system performance by using simulated data provided by code developer,
- check scientific performance of module against relevant requirements,
- verify appropriateness of module documentation (module I/O in appropriate format, code comments, detailed design),
- estimate of manpower effort used for development (in terms of FTE);
- check for compliance with coding standards,
- document module integration in section of appropriate report.

The integrated software shall therefore conform to the defined quality standards. It is to be noted that, being the integration step basically performed in the presence of the developer of the prototype code being integrated, the information related to the module can be completed jointly by the Integration Team member and the module developer, so to satisfy the requested quality standards.

At the time of pipeline integration and testing at the DPC, the DPC Integration Team, as part of their SPA activities and support to the testing teams, for the global integrated pipelines performs the following steps:

- test pipeline scientific and system performance by using simulated data provided by independent sources (double-blind testing),
- check scientific performance of pipeline against requirements,
- verify appropriateness of global documentation,
- check for compliance with integration standards,
- document pipeline integration in section of appropriate report.

Integrated pipeline(s) shall conform to the defined quality standards. It is to be noted that, being the testing step basically performed in the presence of the DPC Testing Team, the information related to the pipeline can be completed jointly to satisfy the requested quality standards.

Software tools are routinely used to trace problems and SPRs in the LFI DPC software: Mantis (at ESTEC) for the SGS1 system, ST (at Trieste) for the SGS2 system.

SPA, routinely or whenever relevant, additionally performs the following activities:

- assessment of plans, standards, procedures and tools;
- assessment of configuration management system;
- assessment of software repository;
- assessment of software delivery;
- assessment of storage and handling;
- assessment of supplier products;
- assessment of user requirements analysis process;
- assessment of software requirements analysis process;
- assessment of software design process;
- assessment of software implementation and integration process;
- assessment of testing process.

Another relevant task of the SPA Team is keeping up-to-date the LFI DPC internal Risk Register, liaising with the DPCM, the National Managers and with the Integration Team. The PA Manager is also the LFI DPC point of contact with ESA for the updating of the global SGS Risk Register.

SPA checks that the scheduled backups of the DPC systems are routinely implemented by the relevant DPC staff.

Bi-weekly teleconferences of the LFI DPC pipeline testing team (held regularly since April 2005) are routinely supported by SPA.

Finally, members of the LFI DPC SPA Team support the IDIS CCB.