Operation Plans (AOP) from the AOCS.

5.4. Data distribution[10]

SDC/MSC will be in charge of distributing all relevant data and information to SAX Observers. These data and information include the following :

_ ***SAX observational data,*** i.e. the science and housekeeping data collected by the SAX instruments and/or the SAX Ground Station (e.g. ranging data), and pre-processed at the SAX OCC (e.g. for attitude and orbit reconstruction). These data will be delivered to the Observer in the form of a ***Final Observation Tape (FOT)***, as explained here below.

_ ***calibration data,*** describing the instrument performance as necessary for the analysis of the observational data. In order to ensure that the Observer can always access the most up-to-date set of calibration data, these will not be distributed along with the FOT, but made available for network retrieval.

_ ***SAX software,*** necessary to access the FOT data, do SAX-specific reduction and processing, and interface with the major data analysis packages. This software, developed in the SAX Institutes and integrated care of SDC/SAC, will be portable to the major operating systems. It is described in section 5.5, and will be made available to Observers for network retrieval.

_ ***SAX documentation,*** assembled at SDC from inputs supplied by the SAX Institutes, will also be made available for network retrieval (as explained below) in Postscript format. The documentation will describe the SAX software, the calibration data and technical notes.

With the exception of FOTs (which will be dispatched to the Observers by post) all other data described above will be ***accessible over Internet and Decnet***. The intention is to keep at SDC/MSC an up-to-date archive of calibration data, software and documentation, in such a way that observers can easily retrieve what they need.

Access will be possible at least using ***anonymous ftp***. Access via ***WWW*** is under development.

It is our intention to ***maintain a mailing list*** of Observers and other interested parties, so that they can be notified whenever any calibration data file or software module is updated in the archive. This way observers can evaluate whether they are interested in the update and retrieve it whenever convenient. An up-to-date master copy of everything will be anyhow kept at SDC/MSC.

For the first AO round the documentation and the instrument matrices for

[10]Contribution by L. Chiappetti

simultation and other tools for proposal preparation will be distributed as explained in Annex A

5.4.1. FOT production and distribution

SAX science data will be generated on board by the Data Collection Modes described in Section 4. In addition to science data, instruments and other spacecraft subsystems will also generate a variety of housekeeping (HK) data, inclusive e.g. of the Attitude Reconstruction Data (ARD) generated by the AOCS (Attitude and Orbit Control Subsystem). All these data will be sent to the ground using ESA Packet Telemetry standard, therefore there is a natural "unit" in the data, represented by the original packets.
Additional data, like ranging data, will be generated by the Ground Station.

All these data will reach SAX OCC, where the original packet streams will be extracted from the transfer frames. Some data will be processed there, like ARD and ranging data, used by the relevant subsystem to reconstruct attitude and orbit information, while other data will be available for quick look. All data will finally reach SDC/MSC to be archived on optical media.

The archive (the so called Reformatted Raw Data, RRD) will be the starting point for the production of the Final Observation Tapes to be delivered to the Observers. Only science data, a relevant subset of HK data (inclusive of all instrument HK), reconstructed attitude, orbit and time correlation data, and some ancillary information will be put on FOTs, after some minimal reformatting in order to make access to the data easier.

The Observer will be offered a choice of the type of ***magnetic medium*** over which the data will be written, and he/she shall indicate the choice in the Observing Proposal Form. The current baseline allows :

_ ***Half-inch magnetic tapes***, at either 6250 or 1600 bpi
_ ***4mm*** Digital Audio Tape (***DAT***) 90 m ***cassettes***, at either 2 or 4 Gbyte per cassette
_ ***8mm EXABYTE cassettes***.

The following definitions (mutuated, as the name of *FOT*, from the experience of Exosat) are applicable to SAX FOTs, and are worth being noted, since they are used to describe the FOT layout.

_ an ***Observing Period (OP)*** is the time interval spent in stable pointing onto a given target to be observed, or (slew OP) the time interval spent manoeuvring from one target to the next. For extension, Observing Period denotes also all the data pertaining to the given time interval. An OP may be subdivided into *observations*.
_ an ***observation*** is a time interval during which the instrument and satellite configuration did not change. The data belonging to one observation can be analysed together (while data belonging to different observations can be analysed together only if the

instrument configurations are compatible). The following events will constitute observation boundaries : any commanded change in the instrument configuration, any commanded attitude change, other relevant events (like entering Earth eclipse or SAA, *TBV for all instruments*). By definition each instrument will have different observation boundaries.

_ an ***Instrument Data Set*** is the ensemble of all data relevant to one SAX instrument, produced during one Observing Period on a target, and during the preceding and following slew OPs. In principle one Instrument Data Set will correspond to a FOT.

Data from the WFCs or the NFIs will be always be put on separate tape volumes, however it is possible that Instrument Data Sets from different NFIs will be placed sequentially on a same tape. Note that data from each of the three MECS units will constitute a separate Instrument Data Set.
Multi-volume FOTs are also allowed in case a single Instrument Data Set won't fit on one volume.

The detailed layout of all data on a FOT will be presented in a separate document. However we present here an outline of how data will appear on a FOT. Note that the software needed to file the data from tape to disk, and to access the relevant data files, will be available at SDC/MSC.

- FOT
  - * Tape directory (ASCII, one record per tape file)
  - * Orbit file (ASCII, produced at OCC by processing of ranging data)
  - * Attitude file (ASCII, produced at OCC by processing of ARD)
  - * OBT UTC correlation file (ASCII ??, produced at OCC by processing of OBT packets)
  - * Several spacecraft HK files (binary; relevant to one target OP and the adjacent slew OPs)
  - *.....
  - Instrument data set #1
    - * Instrument directory (ASCII, one record per observation)
    - Observation #1
      - * Observation directory (ASCII, one record per data file)
      - * Experiment configuration file (ASCII, lists the setting of all commandable items for the given observation)
      - * Instrument HK file(s), binary, one record ~ one packet
      - *.....
      - * Instrument science data file(s), binary, one record ~ one packet
      - *.....
    - Observation #2
    - ....
    - Observation #n
  - Instrument data set #2 and following (if any)
  - .....

The principle is that there is one file per observation per data type. Ancillary data files common to more observations, or to more Observing Periods come in the front. Files are indicated by asterisks in the scheme above.

All files are fixed record length files (the actual record length may differ from file to file, and is usually a function of the original packet size and of the reformatting performed). Each kind of file is stored on tape in blocked format (i.e. more records will be packed in a tape block; all information necessary for unblocking is contained in the Tape Directory). The first step of any analysis will be the ***FOT filing***, i.e. recreating on disk the original files with the appropriate record length. Software to do this will be available at SDC/MSC, as part of the software described in section 5.5.

While ancillary files will be ASCII, usually readable with Fortran list-directed READ, the data files normally used by an observer will be binary. In order to simplify the decoding software, all fields in a record will be reformatted to either 8-bit bytes, 16-bit or 32-bit INTEGER values, so that no bit field handling will be necessary. Data will be in little endian order (as generated on board, and as handled by Digital Equipment machines at OCC and

SDC, which means that some byte-swapping may be necessary on some operating systems (this is likely to be included as an automatic post-processing step in the FOT filing software). All software necessary to interpret packet data, and to accumulate scientifically useful data structures (photon lists, images, spectra, light curves) will be available at SDC/MSC, as part of the software described in section 5.5.

5.4.2. Calibration data distribution

The responsibility of the calibration of SAX instruments during the flight will rely with SAX Experiment Investigator Teams and by SDC/SAC team, that will have the responsibility to verify instruments' cross calibrations. At launch preliminary calibration data, based on ground calibrations performed by Experiment Investigator Teams will constitute the initial versions of the calibration data files.
During the flight routine calibrations will be performed and the relevant ***results*** made available to Observers as ***calibration data files***.

The calibration data files will describe individual "components" (e.g. quantum efficiency vs. energy, energy resolution, time dependent effects, etc.) of the instrument response and constitute the building blocks from which the observer can generate, in conjunction with the information on instrument setup during his/her observation, the instrument response matrix. Software to do this will be provided in the framework of all other software described in section 5.5.

In order to ensure that the Observer can always have timely access to the latest calibration results, it has been felt more convenient (based also on the negative experience of some previous missions) not to distribute the data together with the FOT, but to make them available for network retrieval. Observers subscribing to an appropriate mailing list will be notified of any update.

Calibration data files will be made available, whenever size allows, in the form of ASCII files and FITS files.

5.5. Software for scientific data analysis[11]

SAX scientific software, necessary to access the FOT data, will allow any Observer to reduce SAX data in a specific SAX format (XAS) as well as in Flexible Image Transport System standard form (FITS). In this way, SAX observational data will be available and ready for analysis with software packages already existing and popular in X-ray astronomy community, including also “home-grown” software, and anyhow to be selected by each

[11]Contribution by L. Chiappetti, M.C. Maccarone; sect. 5.5.2 by F. Favata; sect. 5.5.3 by R. Jager

user according to individual taste.

From a general point of view, SAX scientific software will be devoted to the data reduction for all those modes available to the Guest Observers, as announced elsewhere in this handbook. The SAX scientific software will allow to read FOT and calibration data, to do SAX-specific reduction and processing, to accumulate photon lists, spectra, images and time profiles and create instrument response matrices.

Net reduced data are finally ready to be passed to the scientific analysis procedures, i.e. to dedicated packages for spectral, timing, and image analysis. SAX scientific reduced data related to **LECS** and **WFC** instruments are directly written in **FITS format** while data coming from **HPGSPC, MECS and PDS** instruments are primarily written in **XAS format** Scientific software related to **MECS** data will also have a part developed via **FTOOLS** producing **FITS** files for uniformity with the LECS data analysis system. The XAS files are directly readable by IDL and SAOimage packages but ***format converter*** programs can be used to convert them in "plain" FITS format (under a default set of simple conventions). Since different packages use different conventions, it is possible either to write a specific converter according to the target package, or leave the rearrangement according to the specific convention to a procedure within the target package. Compatibility of spectral and response matrices files with XSPEC will be provided. The scientific analysis (spatial, spectral, or timing analysis) can then be performed with the existing packages widely used in the astronomical community (e.g. IRAF/PROS, MIDAS/EXSAS, XIMAGE, XSPEC, XRONOS, IDL, ...).

SAX scientific software (including main programs, library routines, utility tools, related documentation and installation guide) will be available to Observers at SDC/SAC as well as for network retrieval, as explained in previous sections. The documentation, essential to any Observer to use SAX scientific software and data, will mainly include a ***User's Guide*** with commands references and cookbook (this will be the only document necessary to use SAX scientific software programs as distributed); a ***Calibration Data Guide*** with the complete description of calibration data files and of their usage (part of this information may appear in form of Calibration Notes and/or articles in the SAX Newsletters and be later incorporated in the Guide); a ***FOT Manual*** , including a description of the FOT layout and with the officially supported modes.

Moreover, for internal use only a ***Programmers Guide*** will be available, with the complete description of library routines, include and reference files, data file formats, compiling/linking procedures, in addition to the programming and documentation rules.

5.5.1. HPGSPC, PDS and MECS data analysis

XAS Scientific software primarily developed in SAX Italian institutes will be used for data analysis of HPGSPC, MECS and PDS.

Software for data analysis of the MECS under FITS/FTOOLS environment is developed by Italian Institutes in close collaboration with ESA/ESTEC to provide a common system

to LECS and MECS. Logical flow of this software and main modules are similar to those described in the next Sect.5.5.3.

The general philosophy used for the XAS development takes into account the following considerations and constraints:

_ All the software must be as unitary as possible for all the different instruments onboard SAX (same user interface and similar processing philosophy, although taking into account the different instrument requirements).

_ All programs of the XAS scientific software will use a consistent user interface, supporting command line arguments, command files (parameter files) and interactive input.

_ No monolithic data pipeline, but a series of standalone programs, directly callable by name, normally communicating through global variables.

_ No monitor program. This choice simplifies the maintenance of all the software and avoids recompiling and relinking the monitor when new programs are added. Abbreviations of command names and definition of command procedures (scripts) are left to the user which can use familiar operating system facilities, by invoking commands from system level (as DCL or UNIX shell).

_ Portability assured by the definition of a reduced subset of system calls, and their isolation in a Virtual Operating System (VOS) library. Currently, at the SAX Institutes, UNIX/Ultrix is supported; VOS for VAX/VMS, Sun and HP-UX systems are used too, but they are not officially supported. It is planned to add (or replace the existing) official support to AXP/OSF1 on Alpha platforms.

_ All high level programs and library subroutines in Fortran77. A layer of C routines is present practically only in the (UNIX version of the) VOS library.

_ Reduced SAX data files in FITS and/or in XAS format but with a set of programs to convert XAS files in plain FITS

The data reduction phase includes all the SAX scientific software utilities that are necessary to produce data in a form ready for subsequent scientific analysis, starting from FOTs and calibration data files. Time, energy, and spatial selection, corrections for different instrumental effects, background subtraction, are all tasks of this phase.

FOT filing is the first step of the data reduction phase. FOT filing procedure will recreate from FOTs on disk the original “packet” files with appropriate record length.

Accumulation is the second step of the data production phase. It decodes observation directories, accumulates mainly photon lists and also images, spectra, time profiles (including HK), where appropriate, from telemetry files by selecting data on a proper parameter set (time windows, energy ranges, SAA regions, Earth occultation, ...). Moreover, all the corrections that are going to be unchanged in subsequent processing (position dependent energy correction, energy correction for short term gain instability, ...) should be performed here.

Cross-accumulation allows further selection or filtering on the primary accumulated data (i.e. access to FOT data is no longer required). Cross-accumulation programs are

experiment independent and they mainly deal with list of photons to produce other reduced data structures, such as an image with selection in energy and time windows.

Reduction proper is strictly related to the instrument specific accumulations, and it only depends on experiment specific functions, as dead time correction, background subtraction, point spread function correction, and so on.

Response matrix generation. Programs to generate the response matrix of the experiments onboard SAX, appropriate to the observations under analysis, using calibration data, housekeeping data, and particular instrument settings, will be supplied. Matrices will be supplied either directly or by a dedicated Format conversion module, in XSPEC format.

Format conversion programs convert data from/to XAS format to/from plain FITS (or specific flavours of it, as XSPEC) formats, to analyse SAX observational data with many of the existing software packages. For some of them, as SAOimage and IDL, no conversion is required (and simple auxiliary interfaces are available). Conversion is instead necessary to analyse XAS observational data with MIDAS, IRAF, or XSPEC. A Format Conversion module specific to XSPEC will be developed for instrument response matrices and spectral files.

Some ***support programs*** to be applied on XAS data files may be available, devoted to several different purposes: access to the file content to show/print header information and/or content of a XAS data file, display data files in graphical form (simple plots, colour maps, contour maps), edit/modify data in a XAS file or in its header, generate time window reading cursor co-ordinates from a time profile plot, convert image co-ordinates to celestial ones, perform algebraic operations, etc.

Last but not least, all programs of the XAS scientific software shall be able to communicate between each other, in the sense that each program is able to access the results of a previous one (programs will be normally running sequentially in the same session), either via files as well as via global variables held in memory. A small package of ***environment access*** modules will be therefore available to set/modify any variable, perform programmatic access to the environment, save global variables (the latter applies only to UNIX operating systems).

5.5.2. LECS Data Analysis Software

The software system for the analysis of LECS data is being developed at SSD/ESTEC. The aim of the LECS package is to allow the user to go from the FOT to the final scientific analysis. In its current form the LECS data analysis system is strongly focused on the spectroscopic analysis of on-axis point sources for observations made in DIRECT (i.e. fully photon counting) mode. Minimal software support will be available for sources which are strongly off-axis, and no support will be available in the current release for diffuse sources, or for the analysis of SPECTRUM or IMAGE mode data.