LOFT LARGE AREA DETECTOR
Guide to prospective LOFT LAD response

	Name	**Date**
Prepared by	R. Campana E. Bozzo For the LOFT LAD Team	2011-10-18 issue 1.0 2012-01-24 issue 1.1 2012-02-12 issue 1.2 2012-08-21 issue 1.3 2012-09-18 issue 1.4 2012-11-15 issue 1.5 2012-12-02 issue 1.6 2013-05-04 issue 1.7

Document Change Record

Issue	Date	Changed Section	Description of Change
1.0	2011-10-18	All	First issue
1.1	2012-01-24	2; 3; 4; Appendix I; Appendix II	Updated the version of the ancillary, response (V4) and background (V3.1) files. Updated the corresponding descriptions. Added Appendix I and II with the Change-log of the ARF, RMF and background files.
1.2	2012-02-12	2.1; 2.2; Appendix II	Updated the version of the background (V4) file. Updated the corresponding description.
1.3	2012-08-21	1; 2; 3; Appendix I; Appendix II	Updated the version of the ancillary, response (V5) and background (V6) files. Updated the corresponding descriptions.
1.4	2012-09-18	Appendix I	Minor update of the version of the response files (arf, rfm)
1.5	2012-11-15	1; 2; 3; Appendix I; Appendix II	Minor update of the version of the LAD "Goals" response files (arf, rfm, bkg). Updated "Requirements" LAD response files are only placeholders of the previous version for archival and numbering purposes.
1.6	2012-12-02	1; 2; 3; Appendix I; Appendix II	Minor update of the LAD effective area following improvements in the LAD panel design. The response files have been updated to take this into account.
1.7	2013-05-04	3	Changed the statement on the usability of the LAD background for long integration times.

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1 Introduction

The Large Area Detector (LAD) of LOFT is designed as a *classical collimated experiment.* The key feature of the LOFT design that allows reaching for the first time a very large effective area and a improved energy resolution is the low mass per unit area enabled by the solid-state detectors and capillary plate collimators. The basic set-up of the instrument is a set of 6 Detector Panels tiled with ~2000 *Silicon Drift Detectors* (SDDs), which operate mainly in the energy range 2-30 keV and have an energy resolution of ≤ 260 eV FWHM at 6 keV. In the energy range 30-80 keV only a coarse energy binning of ~2 keV is expected.

The modular structure ensures a high level of redundancy and the robustness of the instrument against single units failures. The field of view of the LAD is limited to ~1 degree by X-ray collimators. These are developed by using the technique of micro-capillary plates, the same used for the micro-channel plates (see here for more details). The stopping power of Pb in the glass over the large number of walls that off-axis photons need to cross is effective in collimating X-rays below 50-80 keV.

Spurious modulations of the detected source flux are avoided by optimizing the collimator design and making use of the satellite pointing stability. The combination of these ensures a sufficiently flat response of the instrument toward the pointing direction (few arcminutes).

2 Spectral response, effective area and background

The present development stage of the various LAD components and the constraints derived from the main science requirements of LOFT, allows establishing a set of minimum observational capabilities for the LAD that are indicated below as "requirements".

On-going optimizations of the LAD technological aspects are likely to improve these capabilities up to a certain level that constitutes the instrument "goals".

The main LAD requirements and goals are summarized in Table 1: note the difference in the effective area, spectral resolution, low energy threshold, and capability of observing brighter sources for longer time intervals.

To simulate the response of the LAD, we provide below 4 different sets of files. One set assumes the basic requirements of LAD observational capabilities, while the second takes into account the extended performances described in the "goal" column. In each of the two cases, two more sets of files are provided to simulate both the response of single-anode events (only about ~40% of the total number of events but having a better spectral resolution) and that of multiple-anode events (larger number of counts but with a lower spectral resolution).

For a more detailed explanation of single and multiple-anode events the reader is referred to the PDD (see here).

Table 1. LAD Requirements and Goals overview

Item	Requirement	Goal
Effective area	4 m^2 @ 2 keV 8 m^2 @ 5 keV 10 m^2 @ 8 keV 1 m^2 @ 30 keV	5 m^2 @ 2 keV 9.6m^2 @ 5 keV 12 m^2 @ 8 keV 1.2 m^2 @ 30 keV
Energy range	2 – 80 keV	1.5 – 80 keV
Energy resolution	260 eV @ 6 keV 200 eV (singles, 40%) 2 keV above 30 keV (allows for binning)	200 eV @ 6 keV 160 eV (singles, 40%)
Time resolution	10 μs	7 μs
Dead time	< 1% @ 1 Crab	< 0.5% @ 1 Crab
Background	< 10 mCrab	< 5 mCrab
Max flux (continuous, no loss of info)	> 500 mCrab	> 500 mCrab
Max flux	15 Crab	30 Crab
On-board memory (transmitted over more orbits)	15 Crab, 3 orbits	30 Crab, 3 orbits

2.1 LAD "Requirements"

2.1.1 Response files for double-anode events

File name	Comments
LOFT_Requirement_v5.3.rmf LOFT_Requirement_v5.3.arf background_Requirement_v6.3.bkg	**ARF and RMF version (V5.3) assume:** -Effective area 10 m^2 at 8 keV; -Spectral resolution 260 eV @ 6 keV; -2048 Channels in 2-80 keV, energy width 60 eV. Note: from 30-50 keV only a coarse energy binning of ~2 keV is expected (**to be implemented**); the energy range 50-80 keV will be used mostly to monitor the X-ray state and variability of highly off-set bright sources that might contribute to the background (the instrument response at these energies is fairly limited). The nominal "Requirement" energy band is 2-30 keV, channels below 2 keV have to be ignored. **BACKGROUND (V6.3) assumes:** - Updated geometric description of the LAD, divided into 6 panels. One panel is treated in more detail (including the adoption of a proper grid to separate the panel into 21 independent modules); the other 5 are "dummy panels", i.e. a simplified version of the first one (see App II).

2.1.2 Response files for single-anode events

File name	Comments
LOFT_Requirement_single_v5.3.rmf LOFT_Requirement_single_v5.3.arf background_Requirement_single_v6.3.bkg	**ARF and RMF version (V5.3) assume:** -Effective area 4 m^2 at 8 keV (40% of total events); -Spectral resolution 200 eV @ 6 keV; -2048 Channels from 2 to 80 keV, with energy width of 60 eV. Note: from 30-50 keV only a coarse energy binning of ~2 keV is expected (**to be implemented**); the energy range 50-80 keV will be used mostly to monitor the X-ray state and variability of highly off-set bright sources that might contribute to the background (the instrument response at these energies is fairly limited). The nominal "Requirement" energy band is 2-30 keV, channels below 2 keV have to be ignored. **BACKGROUND (V6.3) assumes:** -As in 2.1.1, but the effective area has been scaled accordingly.

2.2 LAD "Goals"

2.2.1 Response files for double-anode events

File name	Comments
LOFT_Goal_v5.3.rmf LOFT_Goal_v5.3.arf background_Goal_v6.3.bkg	**ARF and RMF version (V5.3) assume:** - Effective area 12 m^2 at 8 keV; - Spectral resolution 200 eV @ 6 keV; - 2048 Channels from 1.5 to 80 keV, with energy width of 60 eV. NOTE: as in 2.1. **BACKGROUND (V6.3) assumes:** -As in 2.1.1, but the effective area has been scaled accordingly.

2.2.2 Response files for single-anode events

File name	Comments
LOFT_Goal_single_v5.3.rmf LOFT_Goal_single_v5.3.arf background_Goal_single_v6.3.bkg	**ARF and RMF version (V5.3) assume:** - Effective area 4.8 m^2 at 8 keV (40% of total events); - Spectral resolution 160 eV @ 6 keV; - 2048 Channels from 1.5 to 80 keV, with energy width of 60 eV. NOTE: as in 2.1. **BACKGROUND (V6.3) assumes:** -As in 2.1.1, but the effective area has been scaled accordingly.

3 Recipe for simulations

Simulations need to be performed with the HEASARC tool XSPEC[1]. A simple way to do it is:

- Open Xspec
- Define your spectral model. E.g., an absorbed power-law model:
  `XSPEC12> model phabs*pow`
- Run[2]: fakeit none (or "fakeit backgroundfilename" to include explicitly the background in the simulation)
- When asked for the RMF and ARF file, give to Xspec one of the sets of files defined above according to your needs
- Define, when asked, the total exposure time

  NOTE: updated studies showed that the LOFT orbit is particularly favorable in making the LAD background stable – less than 10% orbital modulation - and predictable - only <15% of the background rate is due to particles, see Campana et al. (2012,2013) and the webpage: http://www.isdc.unige.ch/loft/index.php/instruments-on-board-loft
  The anticipated knowledge of the instrument background systematics obtained through preliminary simulations is better than 0.5% (well within the 1% level of the present LAD requirements), and is expected to be realistically improvable down to a level of 0.3-0.1%. The sensitivity curves show that integrating exposure times up to about 150 ks leads to a sensitivity improvement. Beyond that, the limiting sensitivity is basically reached. The LOFT team thus encourages the usage of the presently provided LAD background file to perform simulations involving integration times up to about 150 ks.

- Group the spectrum to have at least 20-25 photons per energy bin by using the tool grppha[3]. Example:
  `grppha infile=test.pha outfile=test_grp.pha backfile=background.bkg comm="group min 20 & exit"`
  Here, `test.pha` is your simulated spectrum, `test_grp.pha` is the output file after grouping has been applied, 20 is the minimum number of photons per energy bin and `background.bkg` is one of the background files chosen appropriately from the sets defined above).
- To simulate the proper energy binning of the LAD Requirements in the 30-80 keV range, the following syntax can also be used:
  `grppha infile=test.pha outfile=test_grp.pha comm="backfile=background.bkg chkey RESPFILE responsefile.rmf && chkey ANCRFILE arffile.arf && group min 20 &&`

1 See URL http://heasarc.gsfc.nasa.gov/docs/xanadu/xspec/

2 http://heasarc.nasa.gov/docs/swift/proposals/swift_xspec_sim.html

3 http://heasarc.gsfc.nasa.gov/ftools/fhelp/grppha.txt

```
group 484 2048 34 && exit
```

Here, `response file.rmf` and `arffile.arf` are the response files chosen from the above sets according to your needs.

- Load the grouped spectrum in Xspec and check your result (you might need to rearrange the model normalization and perform a second simulation depending on the flux that you want to obtain).

  If you are using the "Requirements" files, type:

  ```
  XSPEC12> data test_grp.pha
  XSPEC12> ignore **-2. 50.-**
  ```

  (the lower energy range expected for the LAD according to the "Requirements" is 2 keV). For the "Goal" files, please use:

  ```
  XSPEC12> data test grp.pha
  XSPEC12> ignore **-1.5 50.0-**
  ```

Apart for a few very bright and hard sources, data in the energy range 50-80 keV are not expected to be of real use for scientific analysis (given the fairly reduced efficiency of the instrument response at these energies). These data will mostly be used to monitor the behavior of bright X-ray sources that might contribute to the background even if they are at large off-set angles with respect to the pointing direction.

4 Help, questions, suggestions

Requests for help, questions or suggestions are welcome at loft.webmaster@gmail.com

Appendix I: **Change-log of the ARF and RMF files**

Version	**Date**	**Description of Change**
3.0	2011-10-18	Initial public release
4.0	2012-01-24	Correction of bugs regarding the redistribution file, normalization and numerical integration of Compton cross sections.
5.0	2012-08-21	Extended the energy range up to 80 keV.
5.1	2012-09-18	Correction of array limits to ensure compatibility with the PINTofALE package and to reduce overall file dimensions. Corrected a bug in the name of the first column of the EBOUNDS extension of the RMF file.
5.2	2012-11-15	Only the "Goals" responses have been updated to include a lower energy threshold down to 1.5 keV instead of 2 keV. "Requirements" response files are only placeholders of the v.5.1 used for archiving and numbering purposes.
5.3	2012-12-02	Update of all arf files, following an improvement in the design of the LAD panel. This resulted in an increase of about 3% in the LAD effective area.

Appendix II: **Change-log of the Background file**

Version	**Date**	**Description of Change**
3.0	2011-10-18	Initial public release based on GEANT simulations of the LAD panel configuration as in the initial LOFT M3 proposal.
3.1	2012-01-24	Adapted to the array limits of the ARF and RMF version 4.0
4.0	2012-02-12	Improved algorithm for the rejection of multi-anode particle-generated events. Improved geometrical model and updated collimator thickness and lead-glass composition (Phillips 3502 instead of NIST lead glass).
6.0	2012-08-21	Included a geometrical description of the LAD divided into 6 panels. The first panel is considered in more detail (including a frame grid to separate the panel into 21 independent modules) whereas for the other 5 panels only the mass and chemical composition is included.
6.1	2012-11-15	Only the "Goals" background has been updated to account for the lower energy threshold down to 1.5 keV instead of 2 keV. "Requirements" background is only a placeholder of the v.6 used for archiving and numbering purposes.
6.3	2012-12-02	Same as v6.1. Change number only for archiving and numbering purpose.