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SIRTF Science Center

Downlink Segment

Subsystem Design Specification

AOT Products Subsystem: SATMASK

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SIRTF Science Center

Subsystem Design Specification

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1 Revision History

Version	Description	Date
1.0	Initial version	January 25, 2001
2.0	This version accounts for the new implementation in on-board software of setting all pixel values in the difference data plane which are suspected to be UN-saturated *to zero*.	March 12, 2001
2.1	• Thresholding in the slope-to-difference ratio for radhit detection has been removed since the method has been questionable and not enough information is available. Only thresholding in the difference plane is performed to flag saturated pixels. • When slope-pixel replacement due to saturation is desired (optional feature), only a single (slope) image plane is output and the difference image is discarded. Also, the user has the option of replacing "fatal" input pixels in the output image with NaNs.	June 20, 2002
2.5	Re-scale the input "Diff_Sat_Threshold" parameter internally according to the EXPTIME keyword value in the input FITS header. On input, it is assumed that "Diff_Sat_Threshold" pertains to a "30 sec" exposure in input image units.	August 19, 2002
2.6	This version replaces slope pixels with difference pixels (optional feature) only if the saturation d-mask bit has been pre-set instead of directly thresholding. This allows pixels to be replaced downstream in a pipeline with no recourse to thresholding on a "new" pre-processed image.	August 26, 2002

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1. Introduction

1.1. Purpose and Scope

The Subsystem Design Specification is a document that describes the basic requirements, assumptions, definitions, software-design details and necessary interfaces for each subsystem. The document will be used to trace the incremental development of each subsystem and also to allow trace-back of levied requirements; this document should have sufficient detail to allow future modification or maintenance of the software by developers other than the original developers. This document is an evolving document as changes may occur in the course of science instrument hardware design and maturity of operational procedures. This document is not intended to repeat sections or chapters from other Project documents; when appropriate, references to proper sections of primary reference documents will be made.

1.2. Document Organization

This document is organized along the major themes of Requirements; Assumptions; Operational Concept; Functional Descriptions; Functional Dependencies; Input; Output; Other S/S Interfaces; Algorithm Descriptions (when applicable); and Major Liens.

The material contained in this document represent the current understanding of the capabilities of the major SIRTF systems. Areas that require further analysis are noted by TBD (To Be Determined) or TBR (To Be Resolved). TBD indicates missing data that are not yet available. TBR indicates preliminary data that are not firmly established and are subject to change.

1.3. Relationship to Other Documents

The requirements on the operation of SIRTF flow down from the Science Requirements Document (674-SN-100) and the Facility Requirements Document (674-FE-100). The Science Operations System is governed by the SOS Requirements Document (674-SO-100). The current document is also cognizant of the requirements that appear in the Observatory Performance and Interface Control Document (674-SEIT-100) as well as the Flight Ground Interface Control Document (674-FE-101). This document is also affected by the FOS/SOS Interface Control Document (674-FE-102) that governs interfaces between the Flight Operations System and the Science Operations System. Related Software Interface Specifications (SIS) will be as indicated in Section 2.2 of this document.

1.4. Change Procedure

This document is a level 4 document according to the SIRTF Project Documentation Plan (674-FE-103). Changes to this document after approval require the approval of the SOS Change Board (TBD). The process for change control is described in the SOS Configuration Management Plan.

2. Overview

The SATMASK program reads a SUR-mode 2-plane FITS image cube and applies a set of user-specified thresholds to the "difference" plane to report saturated pixels, or, pixels predicted to saturated in the ramp. It also (optionally) performs pixel replacements between these planes whenever unreliable slope values are expected. The primary outputs of the software are an up-dated bit-mask image reporting saturation in the SUR-mode, and optionally, a new single plane (slope) image with pixels replaced by those in the difference plane. SATMASK is written in standard C.

2.1. SATMASK Requirements

SATMASK is initiated by a startup script under the control of the pipeline executive and does its required functions for a given DCE image or pre-processed DCE image; this involves performing the following tasks.

A.) Retrieve the command line parameters passed by the start up script and use them to run the program.

B.) Read in as input a standard SUR-mode FITS file and mask-images.

C.) Produce as primary output an updated d-mask and optionally, a new slope FITS image containing pixels replaced with difference values.

D.) Provide exit codes to the pipeline executive and also provides logon and logoff messages identifying the version number and write any error messages to the standard output devices.

E.) Produce a processing summary.

2.2. Applicable Documents

The following documents are relevant to the SATMASK program of the AOT PRODUCTS Subsystems.

A.) The SOS Downlink Requirements Document

B.) The SOS Requirements Document

C.) The SOS Downlink Software Development Guidelines

D.) The following Software Interface Specifications (SIS)

SOSDL-SIS-PD-3000 (real*4 DCE data input)

SOSDL-SIS-PD-3001 (p- and d-mask inputs)

2.3. Version History

2.3.1. Version 1.0

Initial version created on January 25, 2001

2.3.2. Version 2.0

This version accounts for the new implementation in on-board software of setting all pixel values in the difference data plane which are suspected to be UN-saturated to zero.

2.3.3. Version 2.1

This version includes two changes:

1. Thresholding in the slope-to-difference ratio for radhit detection has been removed since the method has been questionable. Only thresholding in the difference plane is performed to flag saturated pixels.

2. When slope-pixel replacement due to saturation is desired (optional feature), only a single (slope) image plane is output and the difference image is discarded. Also, the user has the option of replacing “fatal” input pixels in the output image with NaNs.

2.3.4. Version 2.5

This version re-scales the input “Diff_Sat_Threshold” parameter internally according to the EXPTIME keyword value in the input FITS header. On input, it is assumed that “Diff_Sat_Threshold” pertains to a “30 sec” exposure in input image units.

2.3.5. Version 2.6

This version replaces slope pixels with difference pixels (optional feature) only if the saturation d-mask bit has been pre-set instead of directly thresholding. This allows pixels to be replaced downstream in a pipeline with no recourse to thresholding on a “new” pre-processed image.

2.4. Liens

No major liens have been identified.

3. Input

3.1. SATMASK Input

SATMASK takes all of its input from either the command line or namelist file, which is set up by the startup script that is controlled by the pipeline executive or standalone. If the namelist is not specified, then all required inputs are expected from the command line. If both namelist and command-line inputs are specified, then the command-line inputs override the namelist values. Prior to reading namelist and/or command-line parameters, default values for the relevant parameters are assigned.

3.1.1. SATMASK NAMELIST Input

SATMASK reads the NAMELIST file whose name is passed to it by start-up script. The name of the NAMELIST is SATMASKIN. The parameters that can be defined in the NAMELIST are listed in Table 1.

Namelist variable	Description	Dim.	Type	Units	Default

FITS_Image_Filename1	Input (2-plane) FITS-image filename	161	C	DN/T_INT	Null
FITS_Image_PMask_Filename	Optional PMask image filename	161	C	-	Null
FITS_Image_DMask_Filename	Optional DMask image filename	161	C	-	Null
FITS_Out_Filename	Optional output single plane FITS-image filename containing replaced pixels	161	C	DN/T_INT	Null
Log_Filename	Output log filename	161	C	-	Stdout
Ancillary_File_Path	Pathname where supporting source files are installed	161	C	-	./ (current directory)
Diff_Sat_Threshold	Optional saturation threshold in difference plane pertaining to a 30 sec exposure.	1	R*4	Input image units	0
PMaskFatal	Fatal PMask data bits	1	I*2	-	24576
DMaskFatal	Fatal DMask data bits	1	I*2	-	16384
DMask_sat	DMask data bit flag indicating saturation	1	I*2	-	8192
Replace_With_NaN	Replace fatal input pixels with NaNs in output image? 0=No; 1=Yes.	1	I*1	-	0

Table 1. Namelist file

The following is an example of the contents of a SATMASKIN NAMELIST file that might be used, where the values specified are not necessarily realistic.

```
  &SATMASKIN
 Comment = 'Generic namelist file for satmask, default values.',
 Ancillary_File_Path = '../satmask_v1',
 FITS_Image_Filename1 = './testing/dntoflux_bcd.fits',
 FITS_Image_PMask_Filename = './testing/pmask.fits',
 FITS_Image_DMask_Filename = './testing/dmask.fits',
 Comment = 'Output SINGLE plane slope-image with sat. pixels replaced:',
 FITS_Out_Filename = './testing/dntoflux_bcd_replaced.fits',
 Log_Filename = 'stdout',
 Comment = 'Saturation threshold in difference plane, Arizona value: 810',
 Diff_Sat_Threshold = 1600,
 PMaskFatal = 24576,
 DMaskFatal = 16384,
 DMask_sat = 8192,
 Comment = 'Replace fatal input pixels with NaNs in output image?
           0=No; 1=Yes',
 Replace_With_NaN = 0,
&END
```

3.1.2. SATMASK Command-Line Input

Alternatively, all inputs can be specified via command line, in which case, a namelist file is not needed. Or, inputs can be provided with a hybrid of both namelist and command-line mechanisms, with the latter overriding the former. Table 2 lists the available command-line options associated with their namelist-variable counterparts, as well as other options for specifying the namelist-file name and making the standard output more verbose.

3.1.3. SATMASK FITS Input

SATMASK uses the FITSIO library routines to read in the FITS-formatted input data file. The routines used are: fits_open_file, fits_read_keys_lng, fits_read_keys_dbl, fits_read_img, and fits_close_file.

Command-line option	Value Name

-n	Namelist_Filename
-i1	FITS_Image_Filename1
-ip	FITS_Image_PMask_Filename
-id	FITS_Image_DMask_Filename
-o	FITS_Out_Filename
-l	Log_Filename
-a	Ancillary_File_Path
-s	Diff_Sat_Threshold
-fp	PMaskFatal
-ff	DMaskFatal
-fs	DMask_sat
-r	Replace_With_NaN
-v (verbose switch)	-
-vv (super-verbose switch)	-
-d (debug switch)	-

Table 2. Command-line options

4. Processing

4.1. SATMASK Processing

SATMASK begins processing by writing its name and version number to standard output (verbose mode only), and then it initializes relevant variables with defaults values, and checks that the required namelist parameters and/or command-line parameters were passed to it. If this condition is not true, then it writes a message stating which parameters are missing, recommends a look at this document, and terminates by issuing an appropriate exit code to the pipeline executive; otherwise it proceeds as follows.

If an error occurs during processing, an error message is written to standard output, a termination-status code is written to the log file, and an exit code to the pipeline executive issued.

After processing, the program name and version number, namelist filename (if used), input, and output filenames, values of other input parameters, date and time, processing time, and a termination-status code are written a log file.

4.2 SATMASK Processing Phases

SATMASK operates in six phases: initialization, data input, saturation flagging algorithm, pixel replacement, FITS-image output, and termination. This processing level is depicted in Figure 1.

4.1.1. SATMASK Initialization

SATMASK initializes itself by performing the following tasks.

A.) A message is printed to STDOUT (verbose mode only), which includes the program name and version number.

B.) If specified on the command line, the NAMELIST file is opened and read. If any errors are encountered, a message is printed, and execution aborts.

C.) The remaining command-line inputs are read and checked for correct data range, consistency, etc. If any errors are encountered, a message is printed, and execution aborts.

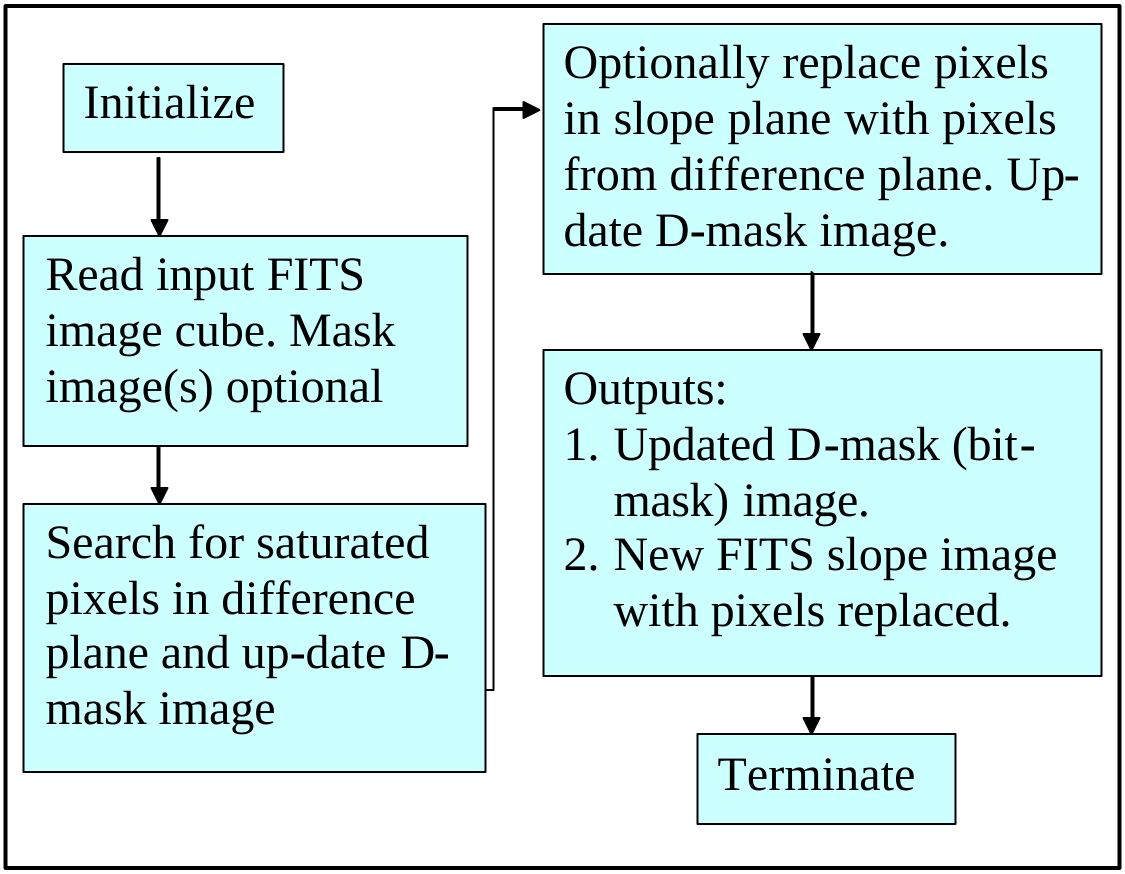

Figure 1. SATMASK data and processing flow

4.1.2. FITS-Image Input

The input image is read and stored in memory. This is a 2-plane (SUR-mode) FITS cube. The optional PMask and/or DMask images are read in as well, if specified.

4.1.3. Saturation Flagging

Software on board the telescope will only return data for pixels in the *difference plane* if they are suspected to saturate, otherwise, the difference values are set to zero. This however only provides a first cut at guessing whether a pixel is saturated and the algorithm described below is a refinement to flagging such pixels and reporting their occurrence in a bit-mask image for use in downstream software.

Saturated pixels are detected by thresholding pixel values in the difference plane (plane 2) of the input image via the user-specified namelist/command-line parameter Diff_Sat_Threshold. This input parameter pertains to a 30 sec exposure so that prior to thresholding, it is re-scaled according to the actual exposure time of the input image (header keyword "EXPTIME"):

$$\text{Diff\_Sat\_Threshold} = \text{Diff\_Sat\_Threshold} * \frac{31.46}{\text{EXPTIME}},$$

where the EXPTIME value is in "real" seconds.

The method of detecting and reporting saturated pixels in the SUR-mode uses a simple thresholding algorithm in the difference-image plane. Let us define a pixel in the difference plane as having the value d and in the slope plane with the value s. The d value is defined as the difference between the first and second reads in a "sample-up-the-ramp". Pixels are considered saturated if *either* of the following two cases are true:

1. If $d \geq$ Diff_Sat_Threshold (Input threshold in the difference after expsosure-time re-scaling – see above), or,

2. If $d = 0$ and $s = 0$. In other words, if any initial "sample reads" are ignored in a set of "sample-up-the-ramp" data and all ramp-data thereafter happens to be saturated, then the first (non-ignored) read (as well as the second etc...) will be pegged to the saturated value "Diff_Sat_Threshold" and d will be zero. Consequently, a slope fit to this horizontal line will yield $s = 0$.

Figure 2 below illustrates these cases showing a set of "sample-up-the-ramp" data that goes into saturation immediately after the first read. The blue line is the slope fit (s). The d value is the difference between the first and second reads and satisfies condition 1 above. If by any chance the first sample read is ignored in Fig.2, then $d = 0$ and $s = 0$ and condition 2 above will apply.

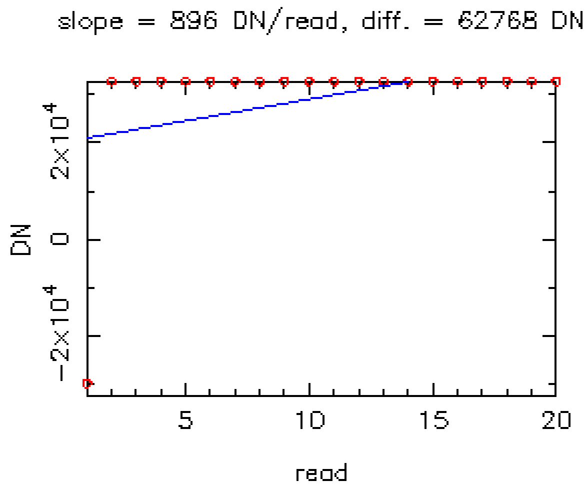

Figure 2. "Sample-up-the-ramp" data that goes into saturation

If any saturated pixels are detected according to the above algorithm, a relevant D-Mask bit is set to indicate this has occured. See section 5.2 for bit mask definitions.

4.1.4. Pixel Replacement (Optional)

This is an optional feature of the SATMASK software which produces as output a new FITS image with slope pixels considered unreliable due to saturation and/or cosmic ray-hit effects replaced with those from the difference plane. Pixel replacement is only attempted if the output filename (namelist parameter FITS_Out_Filename) of the new image is specified on input. Replacement is only performed if the saturation d-mask bit (value specified by DMask_sat) was set in the thresholding step of the software. If no saturation d-mask bit was set, input slope pixels are copied directly to the output image.

4.1.5. FITS-Image Output

The processing statistics are given in the standard output and log file. The primary output of SATMASK is an up-dated D-Mask image with appropriate bit values set to indicate saturated pixels and, an optional new slope image containing pixel replacements.

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4.1.6 Termination

Summary output is appended to the log file (the log file is created if previously non-existent), which includes diagnostic reports for the Q/A Subsystem and the appropriate exit code issued to be picked up by the pipeline executive. A detailed list of log file contents is given in Section 6.1.2.

5. Algorithm

5.1. Algorithm Description

The simple algorithm employed in this software has been adequately described in the previous section. Furthermore, at each pixel location, the "fatal" PMask and DMask bit data-words (Namelist/command-line input parameters PMaskFatal, DMaskFatal) are AND'd with the associated input PMask image value. If the result is greater than zero, then that pixel can be (optionally) set as a NaN and not used in processing.

The user can specify whether NaNs should be propagated to the output pixel-replaced slope image through the namelist parameter Replace_with_NaNs (command line option: –r). If the user does not want an output image, it is advised that they set this parameter to "Yes" since processing will be more robust. In this case, all fatal pixels (e.g. hot pixels) will be skipped in the saturation flagging stage. All NaN input/output pixels are counted and written to stdout or the log file.

The only keyword required in the FITS-header of the input slope-image is "EXPTIME" – the total exposure time whose value is in seconds. If this is not specified, an error message is written to standard output and the program aborts.

5.2. Default Parameters and Bit-Mask Settings

Default values for the difference value threshold (Sat_Threshold) and DMask bits are defined in Table 1. DMask_sat is a user specified value for which bit to set in the DMask if a saturated pixel is found (i.e. predicted to saturate in the ramp). Currently, this has the default DMask_sat = 8192 (bit 13).

6. Output

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6.1. SATMASK Output

SATMASK is capable of generating the following output:

A.) Standard-output processing and status messages.

B.) An up-dated D-mask image reporting saturated pixels.

C.) An optional 32-bit FITS image containing slope pixels and replacements with difference plane pixels for saturated cases. This new image is only generated if an "output" image filename is specified in the namelist or command-line.

D.) A log file containing processing statistics and status messages.

All SATMASK disk output is written to the pathnames that are specified with the output filenames in the command-line or namelist inputs.

6.1.1 SATMASK FITS Output

SATMASK uses the FITSIO library routines to create FITS-formatted output data files. The routines used are: fits_read_key_lng, fits_insert_key_lng, fits_create_file, fits_open_file, fits_copy_hdu, fits_flush_file, fits_write_key, fits_update_key, fits_write_date, fits_write_key_str, fits_write_key_fixflt, fits_write_img, fits_get_hdrspace, fits_read_record, fits_write_record, and fits_close_file.

6.1.2 SATMASK Log-File Output

The information stored in the log file at the output of this program includes: program name and version number, values of all namelist and/or command-line inputs, a message indicating the type of calculation performed, status code, processing time, date and time, and a message indicating program termination.

7. Testing

SATMASK has been successfully unit-tested as a stand-alone program for a variety of different input cases. The tests were designed to check SATMASK robustness and capability of generating corrected results.

Here is a summary of the unit tests that were conducted:

1. Executed SATMASK with inputs read from and output written to directories different from where the program was run. Both namelist and command-line input mechanisms were exercised.
2. Executed SATMASK with input SUR-mode images simulated from RAW-mode data containing rad-hits.
3. Executed SATMASK with input SUR-mode images simulated from RAW-mode data containing rad-hits, saturated pixels and combinations thereof.
4. Executed SATMASK for all combinations of input parameters, in order to test that they function properly.
5. Executed SATMASK with various combinations of input PMask and DMask image and associated unusable (fatal) mask-bit values.

8. Usage Examples

Using a namelist file with verbose (-v) output re-directed to a file “out.log”:

```
SATMASK –n satmask.nl -v | & tee out.log
```

Without using a namelist file:

```
SATMASK –i1 input.fits –ip pmask.fits –id dmask.fits -v -a
../ancpath –o output.fits –s 4000  –fp 24576 –ff 16384 –fs
8192
-r 0
```

9. Glossary

DCE Data Collection Event

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DN	Data Number
IOC	In-Orbit Checkout
SDS	Subsystem Design Specification
SIS	Software Interface Specification
TBD	To Be Determined
TBR	To Be Resolved