GROUND PROCESSING ALGORITHMS

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Agenda

- Requirements and Design Documentation
- Overview
- Algorithm Details
- Verification

Ground Processing Algorithm Requirements

Requirement	Reference	Required Value	Capability	Verification
False Alarm Probability	GLMNF5 (PORD75)	< 5%	<< 5%	Test
Processing Latency	GLMNF10 (PORD96)	≤9 seconds	< 9 seconds	Test
Detection Probability	GLMSS41 (PORD74)	> 70%	> 90%	Analysis
Lightning Flash Rejection	GLMNF3	< 1%	< 1%	Test
Navigation	GLMNF7 (PORD92)	Navigate each optical lightning event	Comply	Test
Geolocate lightning events	GLMNF9 (PORD276)	Geolocate	Comply	Test
Report each event	GLMSS91 (PORD97)	Report	Comply	Test
Radiant energy of each event	GLMSS94 (PORD99)	Provide	Comply	Test
Threshold for each event	GLMSS95 (PORD100)	Provide	Comply	Test

Ground Processing Algorithm Requirements

Requirement	Reference	Required Value	Capability	Verification
Background for each event	GLMSS96 (PORD101)	Provide	Comply	Test
Time tag each event	GLMSS92 (PORD98)	1 millisecond accuracy	Comply	Test
Detector element for each event	GLMSS97 (PORD102)	Provide	Comply	Test
Design, develop, implement and maintain a GLM GPDS	SOW395		Comply	Inspection
Use GPDS to demonstrate Ground Processing Algorithms	SOW396	Verify full performance and functionality within allocated latency	GPDS will be demonstrated under all instrument conditions (full operation, partial operation, data loss, redundant side selection) versus the algorithms	Test

False Alarm Rate Budget

Event Type	Expected number of false events (per second)	Expected number of events after filters applied (per second)	Requirement
Photon and Electronics Noise	600	< 0.05	N/A
Radiation	< 16	< 0.01	N/A
S/C motion (Jitter)	6,000	< 0.06	N/A
Solar Glint	< 100	< 0.01	N/A
Total	~ 6,716	< 0.13	< 1 per second
False Alarm Rate		< 1%	5 %

- False alarm rate calculation assumes a lightning flash rate averaged over 24 hours of 18 flashes per second.
- False alarm rate calculation assumes that every false event that is incorrectly identified as a real event will become a lightning flash in L2 processing.

(Note: RTEP and L1b algorithms provide adjustments enabling user tuning of both false event rates and false alarm rates)

Data Latency Budget

GLMPORD96 [ver. 2.2] → GLMSS90 Data Latency

The GLM shall contribute no more than 10 seconds to the total data latency from event detection through generation of Level 1b products.

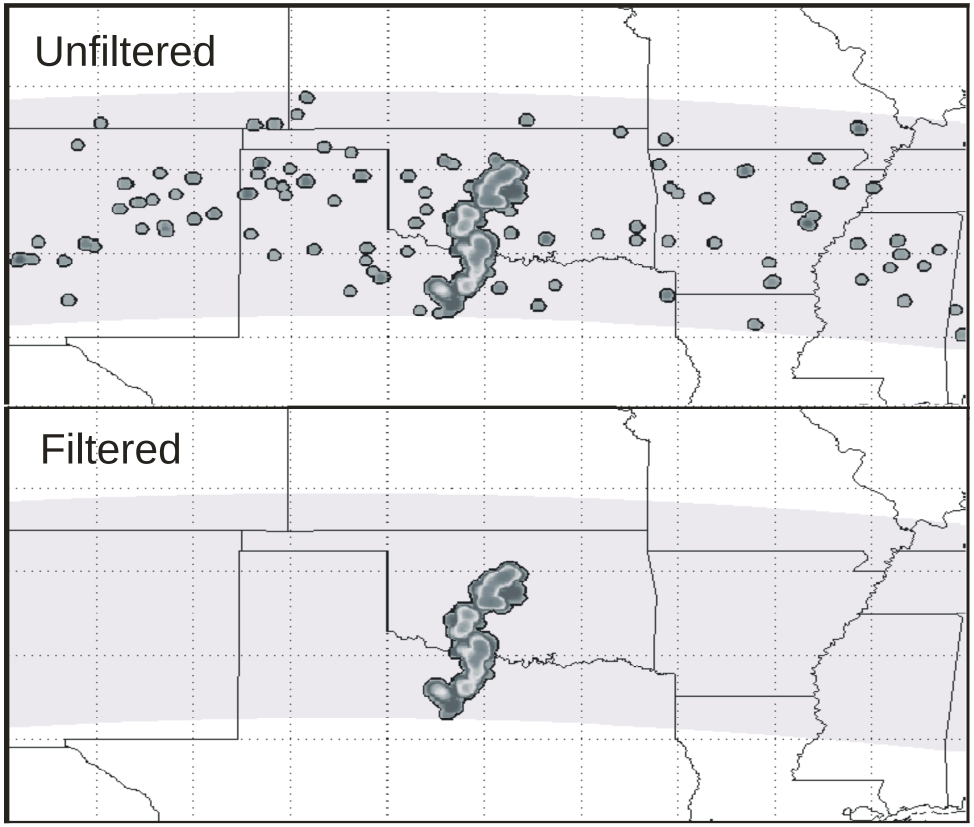
Document		Req. ID	Allocated To:	Requirement (sec)		Comment
GLM00244, Rev. -	GLMSS	GLMSS90				
GLM00606, Rev. -	GLM SU Spec	GLMSU633	CCD & ADC	<	0.004	500 Hz Readout
GLM00554, Rev. -	GLM EU Spec	GLMEU982	Ser/Des	<	0.001	Transfer SU to EU
GLM00554, Rev. -	GLM EU Spec	GLMEU415	RTEP	≤	0.25	Calculate background, extract events
GLM00554, Rev. -	GLM EU Spec	GLMEU812	Data Formatter	≤	0.25	Take data from 4 RTEPs, send to SpaceWire
GLM00435, Rev. A	GLM SW Spec	SRS235	SW/CCSDS & GRDDP	≤	0.25	Round-Robin extract of 14 FIFOs, reformatting into CCSDS/GRDDP packets
GLM00701, Rev. -	GLM NF Spec	GLMNF10	Ground Processing Algorithms	<	9.00	
			Total Allocated		9.755	
			Total		10.00	
			System Level Margin		0.245	

Relevant CDRLs

CDRL Number	GLM Document Number	Description
43	GLM00447	Flight Telemetry and Command Handbook
46	GLM00323	Navigation Design Document
80	GLM00477	Ground Processing Algorithm Document
81	GLM00478	Ground Processing Algorithm Test and Validation Plan
82	GLM00479	Ground Software Acceptance Plan Input
106	GLM00492	Trend Analysis Plan Trend Analysis Data Reports
120	GLM00502	Operations Handbook

Lightning Detection and False Alarms

- To maintain high detection efficiency, GLM has high sensitivity and sends ***all*** events to the ground, including false events
- False Alarm Probability Requirement flows directly to the detection algorithms
- False events are removed during ground processing to maintain a false alarm rate << 5%
- Unfiltered data show many false events (non-lightning)
  - Many are due to radiation
  - These events cannot be removed by amplitude thresholding alone - some are quite intense
- After filtering, lightning-only data shows coherency



GLM performance is optimized by making the detection thresholds as low as possible which results in many false events. The role of on-orbit processing is to detect as many lightning events as possible while maintaining compatibility between the total event rate and the telemetry bandwidth. The role of ground processing is to essentially remove all the false events while processing all the lightning events.

Ground Processing Algorithms Overview

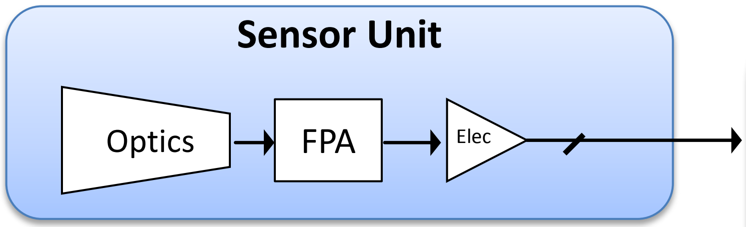
Emitted radiance → **Detect** photons; **Convert** to e⁻ → **Detect** events; **Acquire** bkgd → **Filter** events; **ID** flashes & bkgd

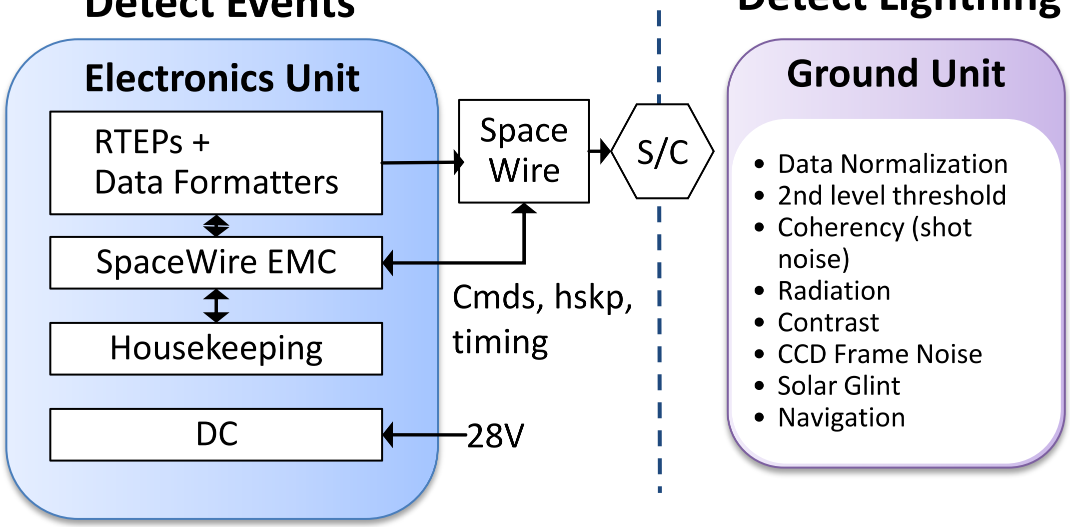
Photons → e⁻ → voltage → Voltage → numbers
Event & bkgd digitization → Geolocated, time tagged lightning flash & bkgnd image

Detect Photons

Detect Events

Detect Lightning





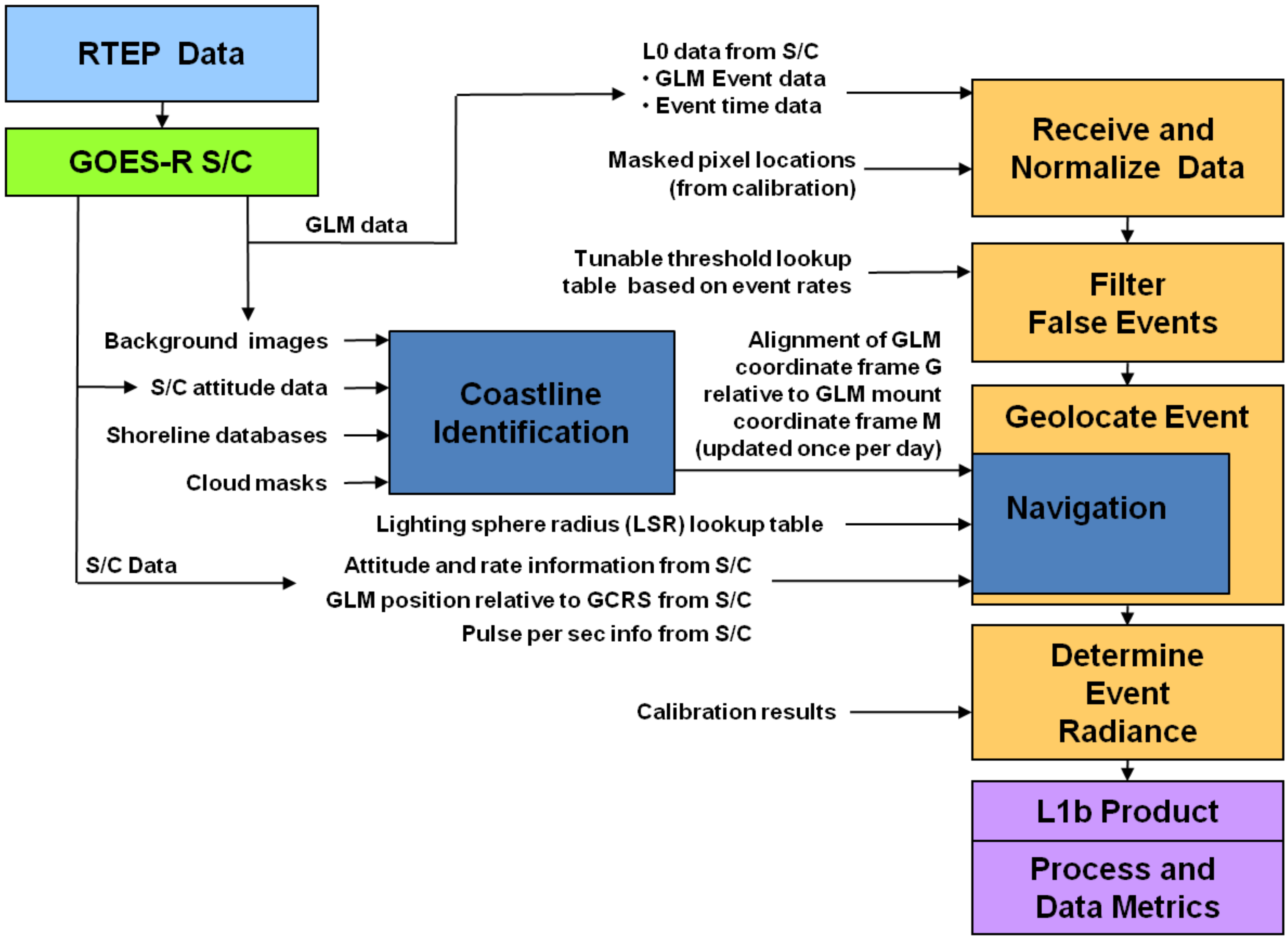
Event detection is performed on board by RTEPs. All events, including false events are sent to the ground for processing.

False events are filtered on the ground using level 1b detection algorithms. Detection algorithms allow high detection probability and low false alarm probability.

Deliverables:

GPDS	[GLMSOW§8.3]
Ground Processing Algorithms	[GLMSOW§3.1.3]
GPS	[GLMSOW§3.1.3]
CDRLs 080	[GLMCDRL848]
CDRL 081/082	

GLM GPA Functions and Interfaces



Ground Processing Algorithm Block Diagram

Note: Event to group to flash conversion is processed at Level 2

On-Orbit Data Acquisition

1. Background scene tracking & removal
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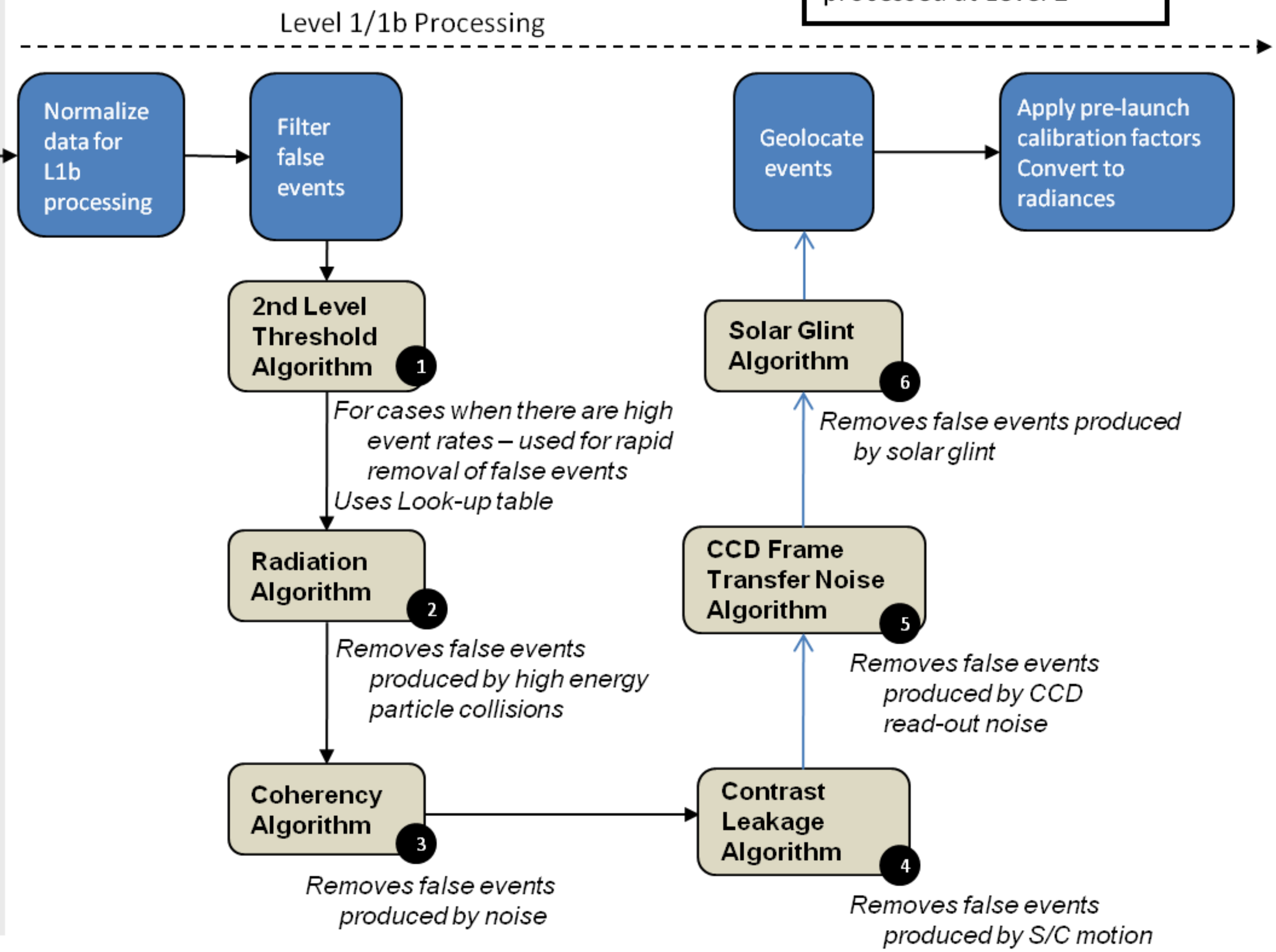
- Event detected



Ground Processing Algorithm Required Inputs

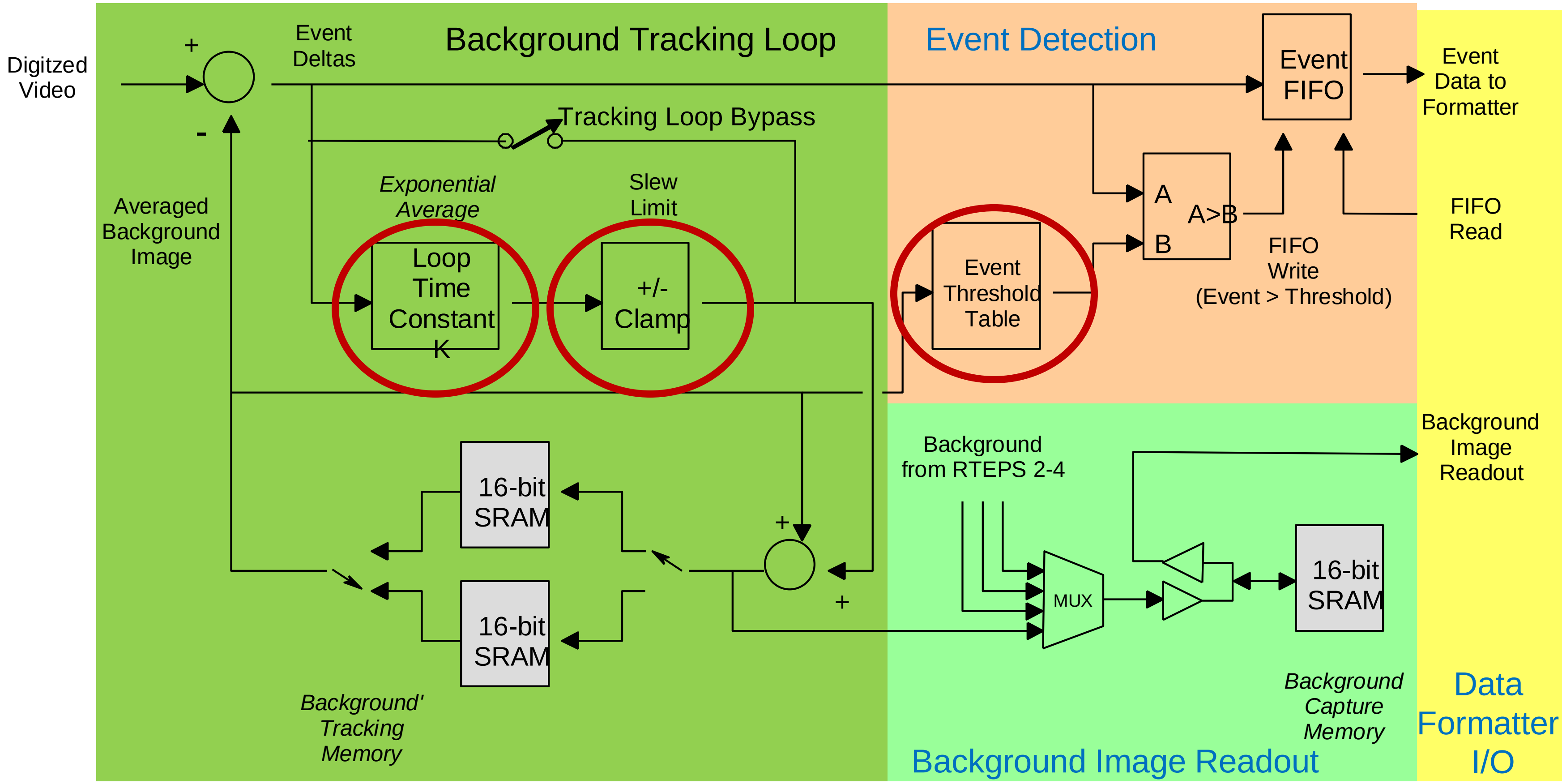
Data Required	Use	Location of Data	Frequency
GLM L0 Event & Time data	Event Filters	Provided to Ground Segment by Spacecraft	Each event
Calibration Table (Event)	Event Filters	Provided to Ground Segment by GLM prior to launch	Not updated
Gain Table	Event Filters	Provided to Ground Segment by GLM prior to launch	Not updated
Various lookup tables (see next chart)	Both	Provided to Ground Segment by GLM prior to launch	As required
RTEP settings	Event Filters	Provided to Ground Segment by GLM prior to launch	As required
GLM L0 Background data	INR	Provided to Ground Segment by Spacecraft	Every 2.5 min
Spacecraft Data (PPS, position, attitude, rate)	INR	Provided to Ground Segment by Spacecraft	1 Hz or 100Hz
Cloud Masks	INR	Provided to Ground Segment	Every 2.5 min
Shoreline Databases	INR	WVS and GSHHS databases	Not updated

GLM GPA Lookup Tables

Look Up Tables Provided By GLM at Flight Unit Delivery	Use
Masked pixel region	Event Filters
2^{nd} level threshold tables	Event Filters
Look up tables for coherency filter	Event Filters
Contrast leakage filter parameters	Event Filters
Solar glint (specular reflection) rejection region size	Event Filters
Lens Distortion and Calibration Factors	INR
Lightning Sphere Look Up Table	INR

- Lookup tables and stored parameters used during L1B processing to reduce latency time
- Values for parameters are modified as required based on results from calibration and performance testing

Event Detection: RTEP Block Diagram



(32K x 16-bit wide SRAMs are external to FPGA)

Refer to “RTEP Data Flow Logic Diagram” in GLM00736 for more detail

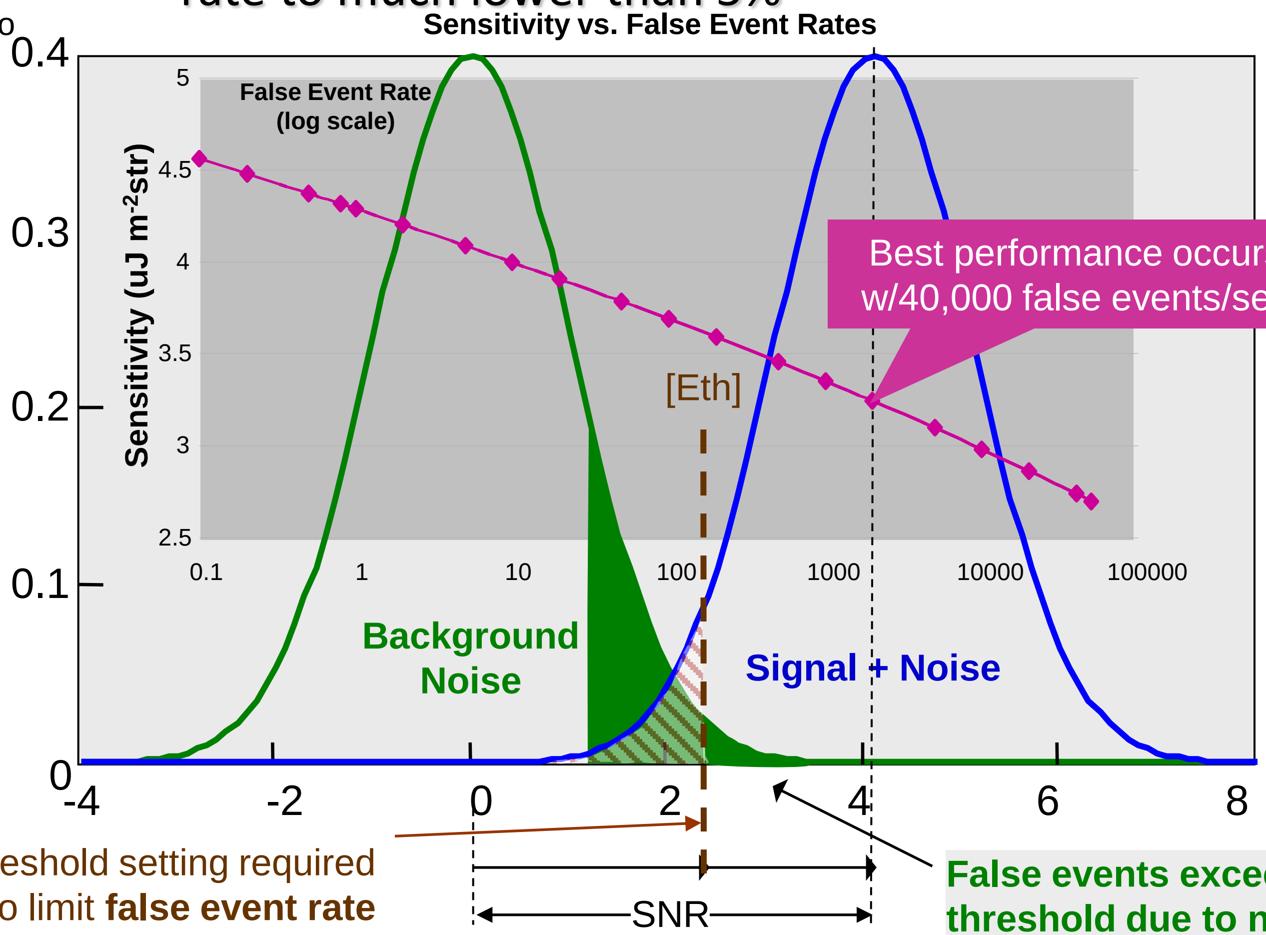
RTEP Controls

- RTEP and GPA work together to optimize GLM performance
- Each system has adjustable parameters that affect sensitivity and false events rates
- RTEP on-orbit adjustable controls include:
  - Loop time constant – determines the number of frames averaged in the background scene. The more frames, the lower the system noise but the slower the response to a changing background scene (jitter)
  - Clamp – limits slew rate. Limits the size of the difference signal that is used to update the background scene. A large, lightning event can contaminate the background, thus decreasing the system sensitivity to lightning detection. Too low a clamp setting, reduces the system's ability to track changes in the background scene, particularly, jitter produced changes.
  - Event Threshold Table – a 32 level background driven lookup table that sets the system's ability to detect weak lightning events. The brighter the background, the higher the threshold, thus enabling near uniform false event rates, independent of the background intensity.
- For optimum lightning detection efficiency, it is desirable to set the loop time constant high and the slew limit clamp low, but this may not be compatible with instrument jitter.
- Settings will be determined once we have a quantified estimate of GLM jitter response and calibration derived GLM performance measurements

Low threshold levels allow large numbers of lightning and false events; this large number of total events drives false alarm rate to much lower than 5%

SNR = Signal to Noise Ratio

Normalized Gaussian Distribution STD=1

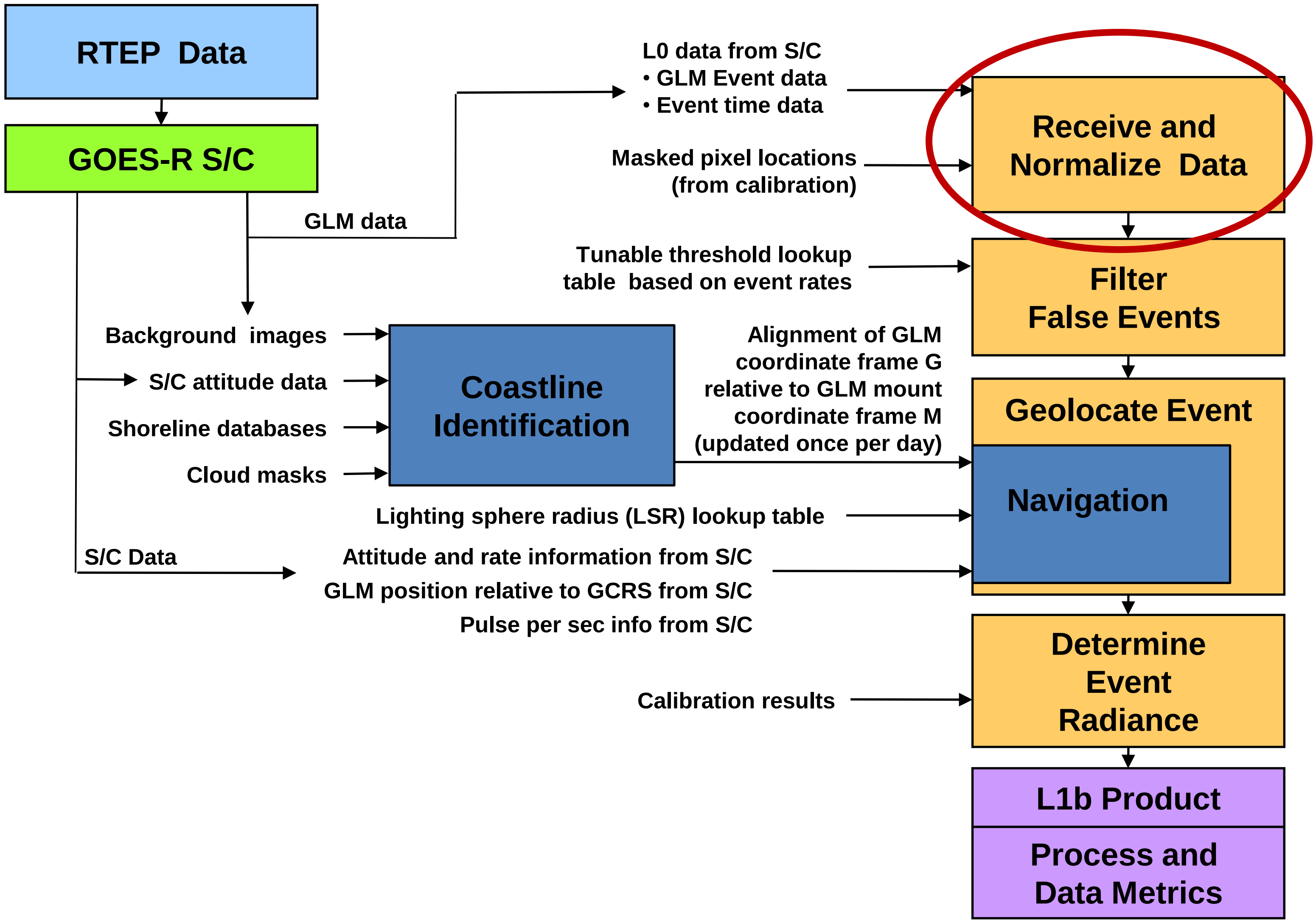


Threshold setting required to limit **false event rate**

False events exceeding threshold due to noise

As threshold (Eth) is lowered, the false event rate increases and more lightning signal is detected; false events are removed by robust algorithms in level 1b

GLM GPA Functions and Interfaces



Ground Processing Algorithm Block Diagram

On-Orbit Data Acquisition

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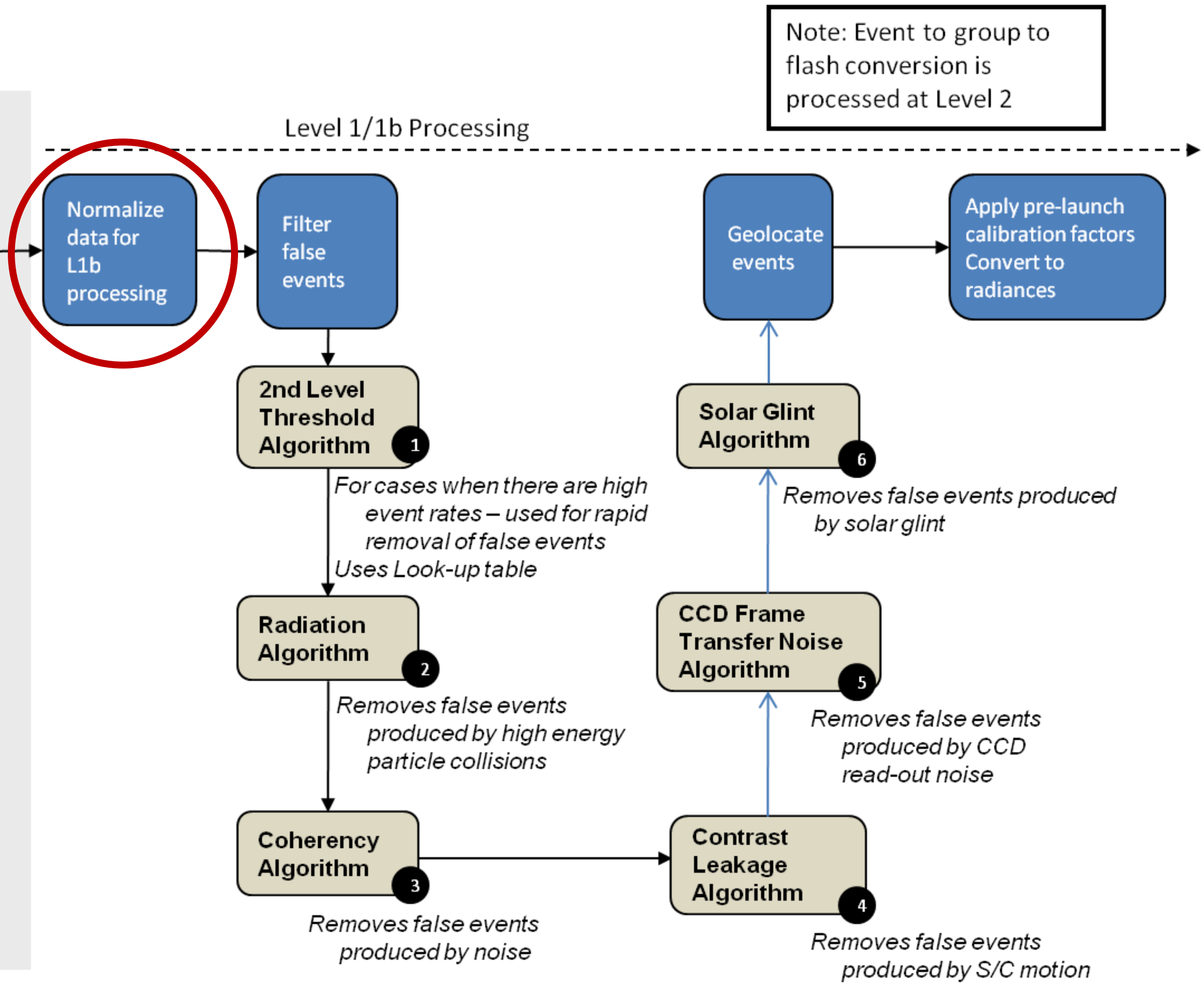
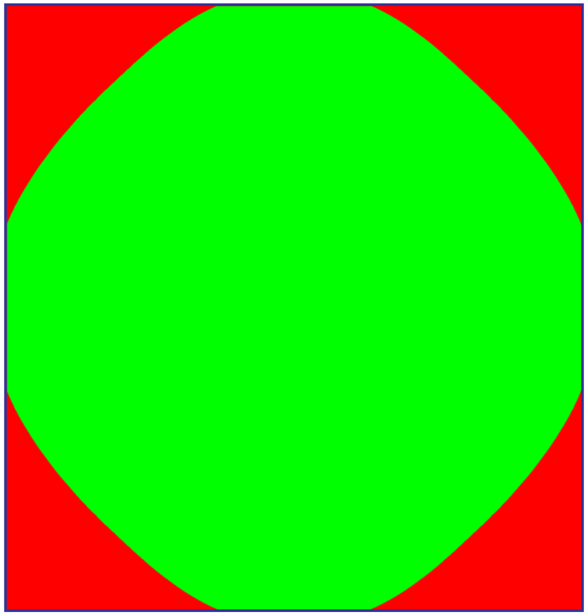


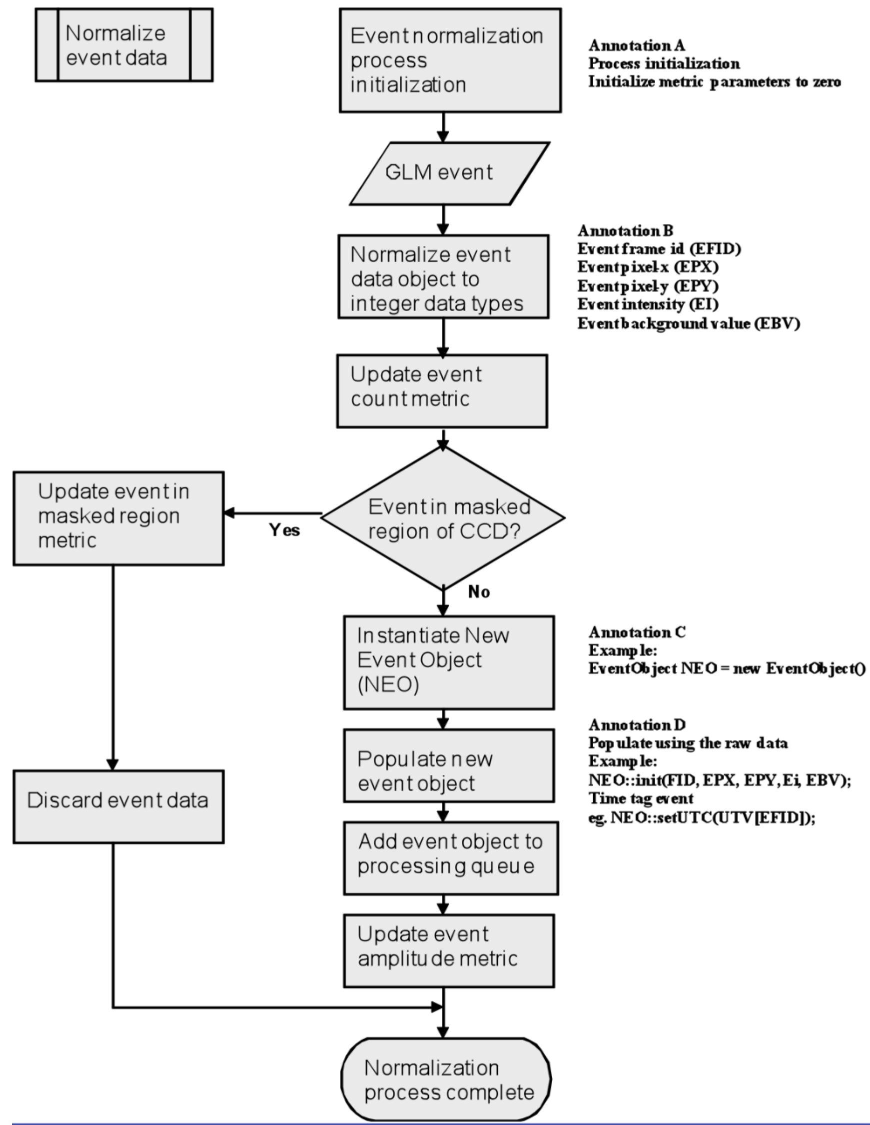
Overview of Event Data Normalization

- When event packets are available, each event is extracted from the packet and stored as a member of a newly instantiated event object in unsigned integer format
- Calculated fl_RADIANCE ENERGY value is in microjoules/steradians
- fl_LATITUDE value is in degrees with a range of 0 to 90 for the northern hemisphere and 0 to -90 for the southern hemisphere
- fl_LONGITUDE value is in degrees with a range of 0 to 180 for location s east of the prime meridian and a range of 0 to -180 for locations west of the prime meridian
- dbl_UTC contains the Coordinated Universal Time (UTC) and represent the number of seconds since the Epoch, (00:00:00 UTC, January 1, 1970)
- Event frame id is used as the index to extract the event time data
  - Time data is converted to a double precision number representing the event time in Coordinated Universal Time (UTC) format and stored in the event object
- Event amplitudes metric are incremented
- Event amplitudes metric are a measure of all events having the same amplitude
- Apply CCD Masked Pixel Filter Algorithm

CCD Masked Pixel Filter Algorithm

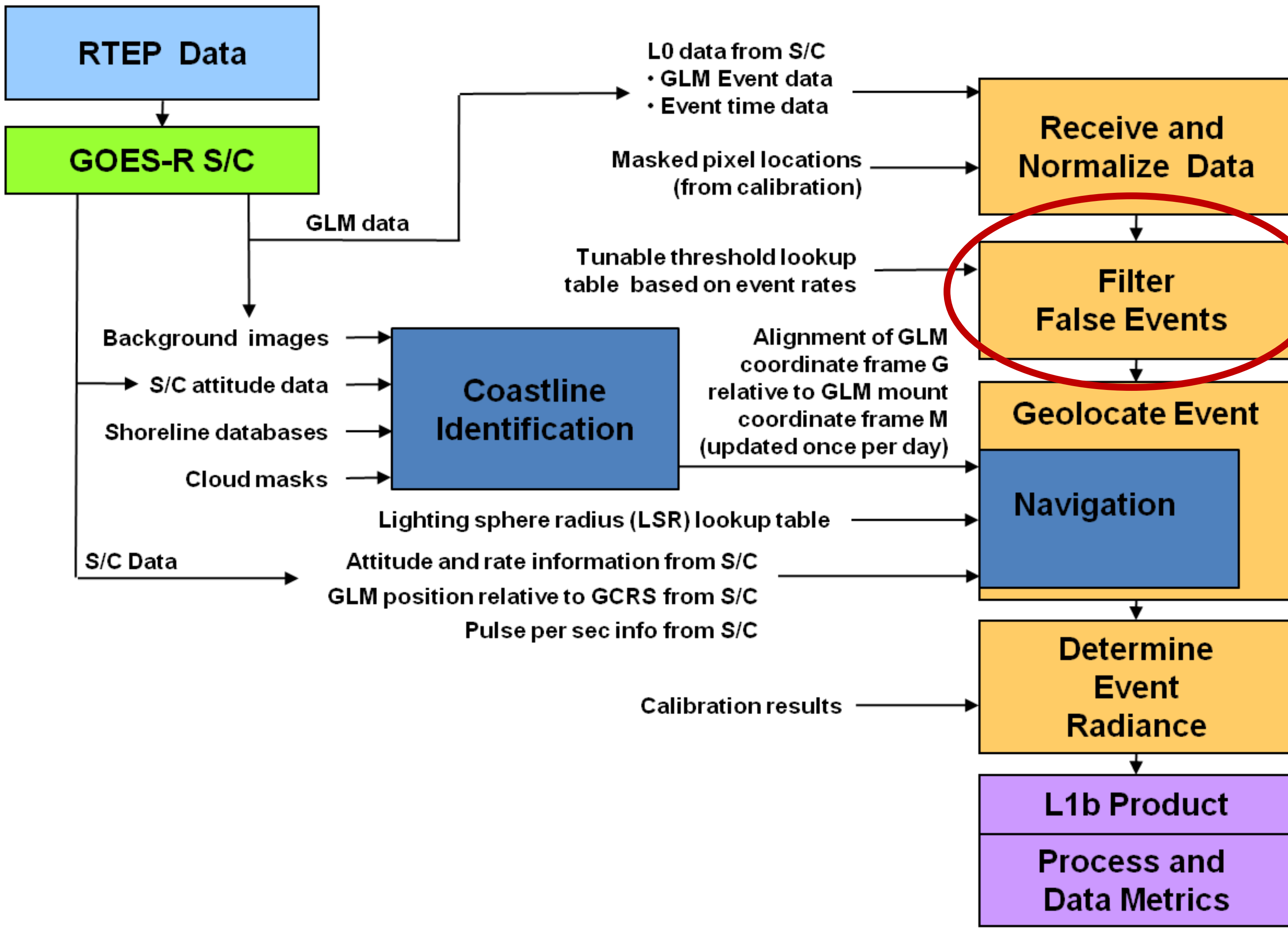


1300 x 1372 CCD (masked pixel region in red)



Events with pixel locations in the masked region of the CCD will be rejected during event data normalization. A lookup table will be utilized for this purpose. The masked pixel locations will be determined during instrument calibration. These masked pixel locations will be used to construct the masked region lookup table.

GLM GPA Functions and Interfaces



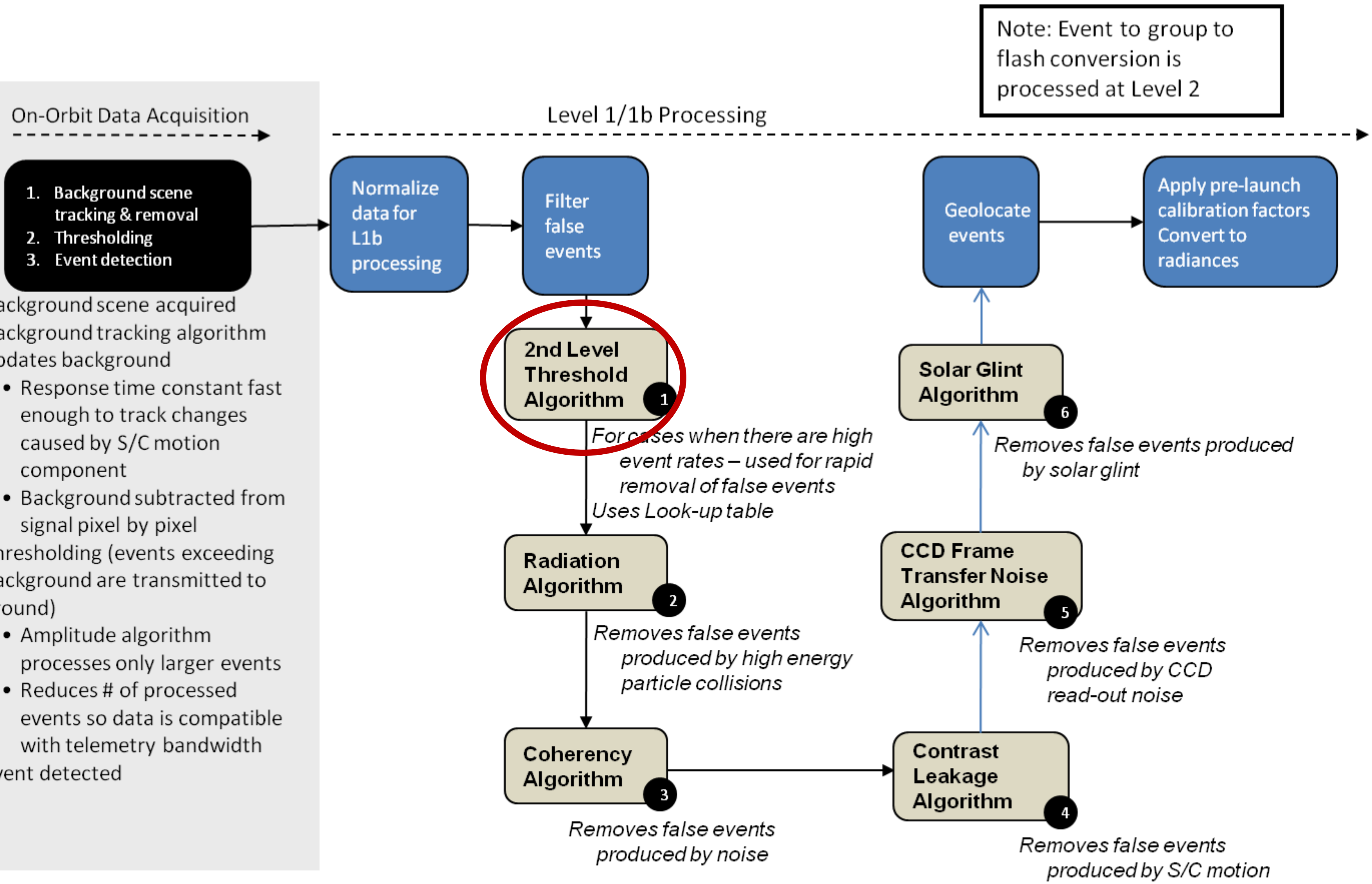
False event Removal Filters

In order of application, these filters are:

- 2nd level threshold algorithm
  - Pixel by pixel threshold optimization
- Radiation algorithm
  - Remove FEs caused by low angle of incidence high energy particles
- CCD frame transfer noise algorithm
  - Remove FEs caused by strong lightning occurring during frame transfer periods
- Coherency algorithm
  - Remove statistically random FEs
- Contrast leakage algorithm
  - Remove FEs caused by sharp cloud boundaries and S/C jitter
- Solar glint algorithm
  - Remove FEs produced by specular reflection of the sun off water (solar glint)

(After all false events are removed, the lightning events are geolocated and the amplitudes are converted to radiance values using the prelaunch calibration.)

Ground Processing Algorithm Block Diagram



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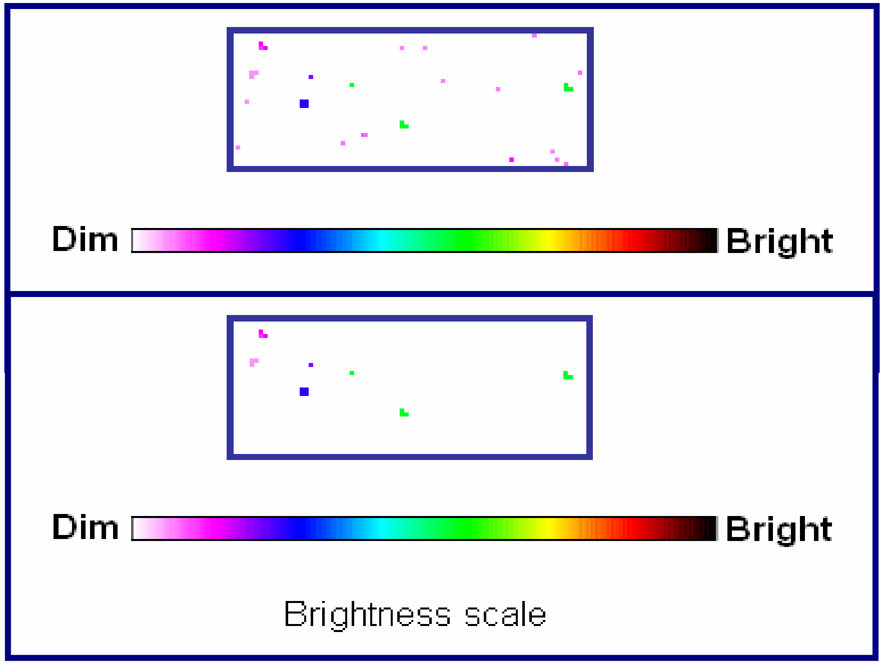
Overview of Second Level Threshold

- During periods of high event rates, a 2nd level threshold function may be necessary
- Filter thresholds allow for pixel specific low amplitude event rejection
- A tunable threshold lookup table is used
  - Event pixel x-y location is used as the index to the threshold for the event
  - The lookup table is created or updated by specifying pixel x-y locations and the threshold value
  - Initial values are determined during instrument calibration and updated during on-orbit check out
- Filter is useful for excess events associated with "hot" pixels



LIS events after 2nd level filter algorithm

Top figure: A frame of data from the LIS instrument with high events rates. This frame has many low amplitude single pixel event detections.

Bottom figure: Pixels remaining after amplitude thresholding

Expected Performance of Second Level Threshold

- Second level threshold compensates for anomalous pixels and is not expected to remove false events under normal operations

- Output
  - Saved metric for number of events rejected by this filter
  - Event data packets that pass the filter

Ground Processing Algorithm Block Diagram

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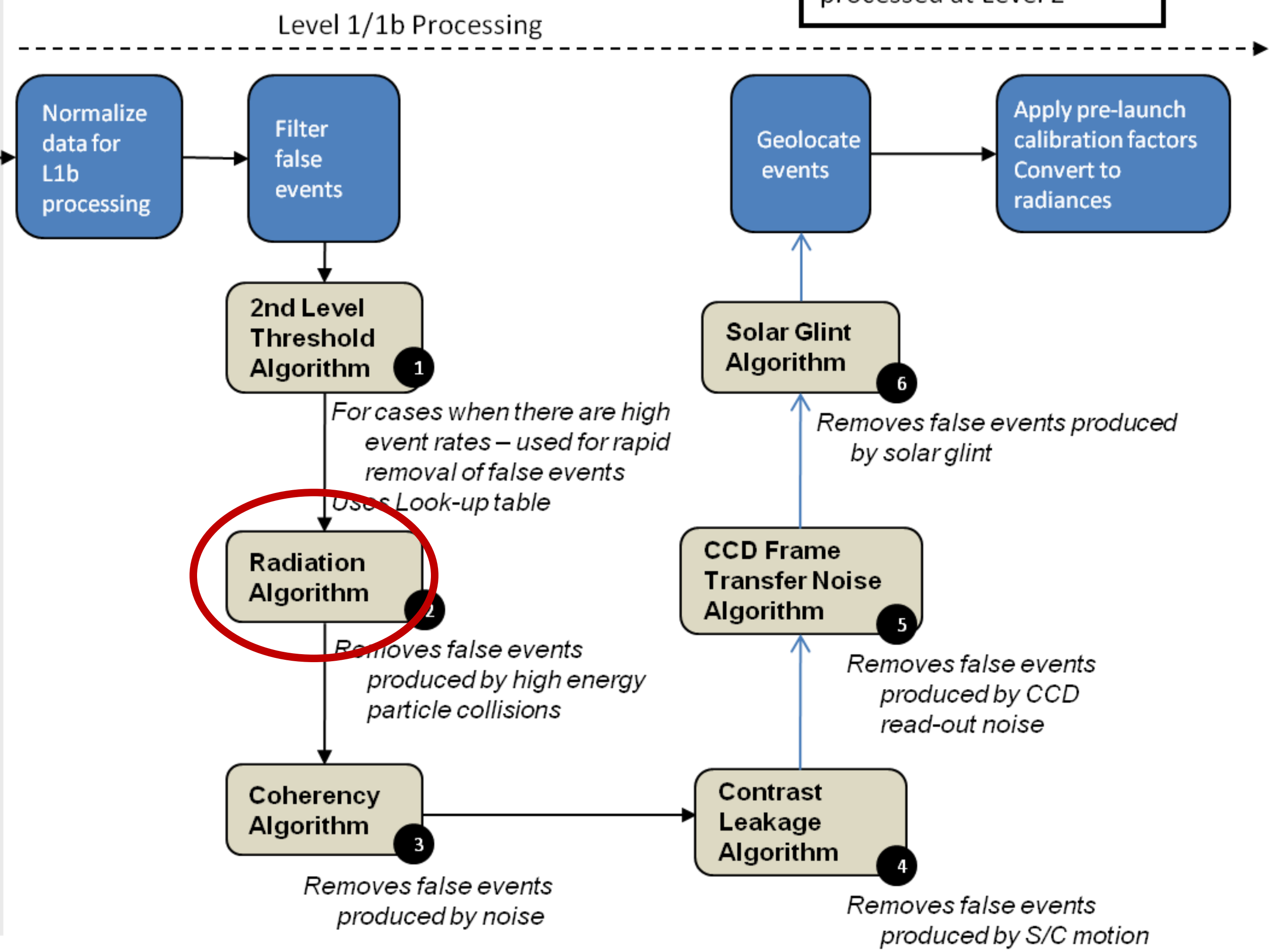
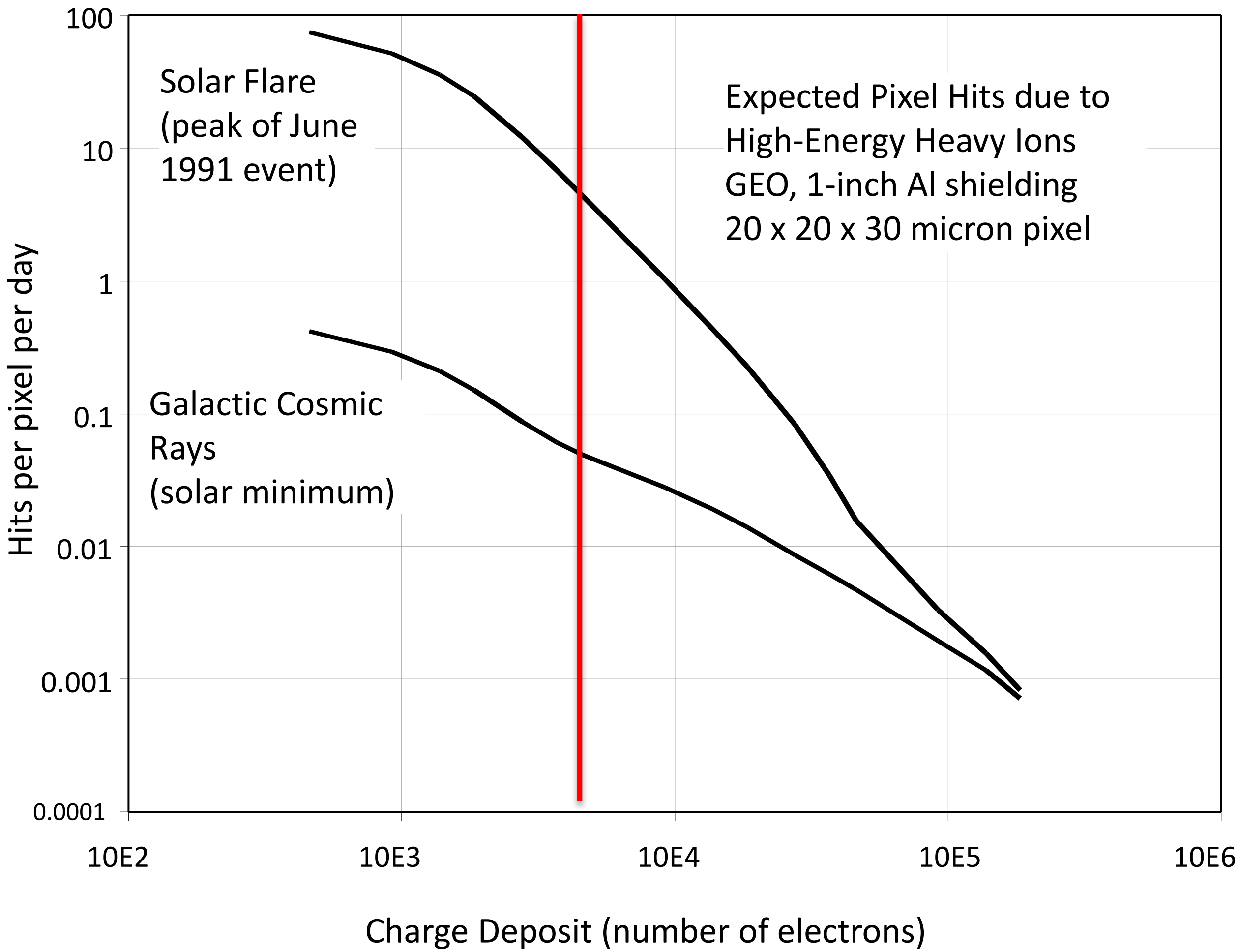


Overview of Radiation Filter Algorithm

When high energy ions strike the CCD or the background memory large false events are often produced

- High energy particle impacts can produce large numbers of electrons - cannot remove via amplitude thresholding
- Effect is the same for any silicon based focal plane (CCD, CMOS, etc)
- Events produced by high incident angle hits are removed via radiation track filter (streaks)
- Events produced by low angle of incidence hits (single pixel or single group) are removed using coherency (same as for shot noise)
- Hits on background memory can upset errors in the background estimate resulting in false events in successive frames until background tracking is reestablished
  – Characterized by decreasing event amplitudes in successive frames

Pixel Hit Rate from High Energy Ions



The GLM CCD will have at least 2 inches of shielding, thus reducing the hit rate to <5 hit per pixel per day

Expected Performance of Radiation Track Filter Algorithm

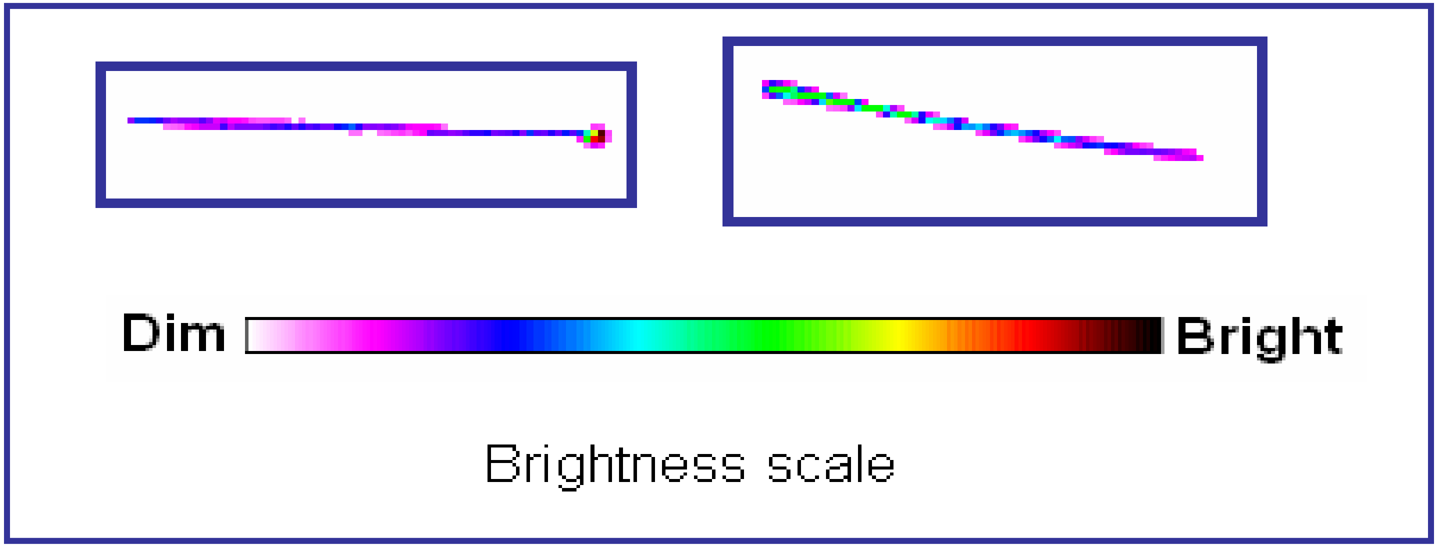
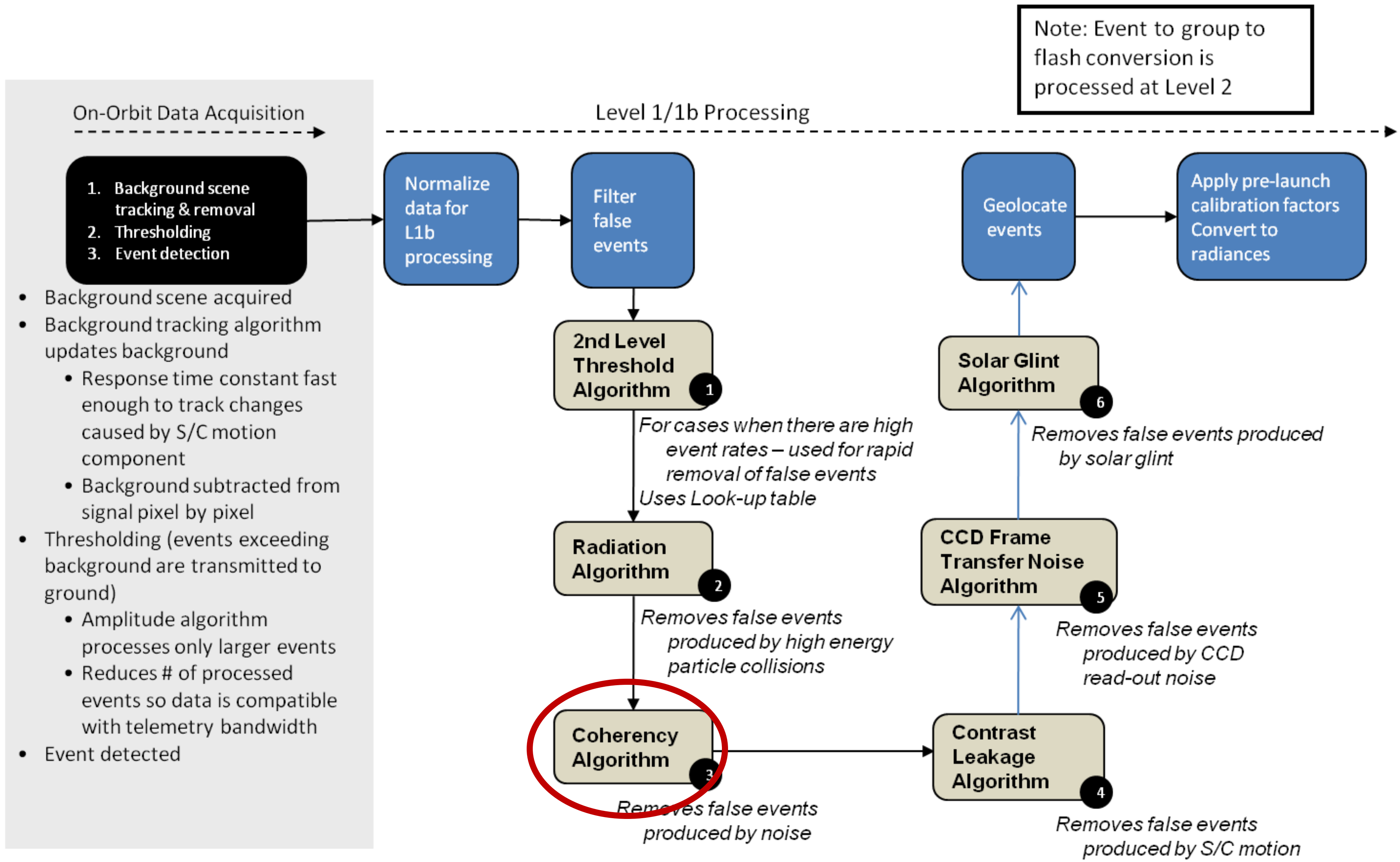


Figure Particle tracks

- Due to excellent overall CCD shielding, the total number of radiation particle hit is expected to be < 5/pixel/day
- Less than 20% of the hits will produce streaks of 3 pixels or more, for a total of less than 10 streaks per second
- Streaks produce a unique signature – 100% removal efficiency is expected
- Radiation events that do not produce a track of 3 pixels or more are removed by the coherency filter

Ground Processing Algorithm Block Diagram



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Overview of Coherency

- Coherency Filter removes false events caused by shot noise and radiation
- Noise-produced false events are characterized by low amplitudes and random occurrences in time and location, whereas lightning events are characterized by high coherency in time and space (multiple pixels are illuminated in a single frame and the same pixels continue to be illuminated over the duration of the lightning flash)
  - Shot noise is characterized by a Gaussian distribution
  - Thresholding is used to control the false event rate – the higher the threshold (the larger the event amplitude), the lower the event rate
  - Assuming a Gaussian distribution, statistical techniques can be used to calculate false event rates for a given background intensity and threshold setting
  - Statistics are also used to calculate the probability that a given event is false and the probability that successive events are false.

- When successive events occur at the same or adjacent pixel locations but exceed a statistically derived programmable time interval the first event is rejected and removed from the processing queue
    - The length of the time interval is dynamic and is a function of the event amplitude and background intensity of both events

- An "active region" table is used to determine the events spatial and temporal compliance

Coherency Test

- For an event to be labeled “lightning”, a second event must occur in the same or an adjacent pixel within a coherency period, that is, two different frames must contain an event
- The coherency test processes every event as an independent occurrence
- It uses the event amplitude and background intensity to estimate the probability that the event is false
  - The larger the event, the more likely that it is real (except for radiation events)
  - The brighter the background, the greater the likelihood for a FE occurrence
- PFE is calculated (via lookup table) using the amplitude and background as variables and loaded into the active pixel table
- When a second event occurs, PFE is again calculated.
- The product of the two PFEs is then calculated and this number is multiplied by the total number of pixels processed during the coherency interval t (500*t*#of active pixels)
  - If the result is greater than a used selectable value, say 1%, then both the events are false

- This is a test to determine whether both events are false

Coherency Test

- To pass the coherency test, one or both of the events must be real
- Upon passing, only the later event is passed to the output queue (time sequencing and latency)
- Example of coherency test:
  - Event1 – amp=5,550 electrons (4.7uJ/m^{2}um), background=708,000 (80% albedo)
    - $P_{FE1} = 8.11*10^{-9}$
  - Event2 - amp=4130 electrons (3.5uJ/m^{2}um), background=708,000 (80% albedo)
    - $P_{FE1} = 1.32*10^{-5}$
  - $P_{FE1}*P_{FE2}*500*1{,}408{,}000*t = 7.5*10^{-4}t$
    - If t=10 sec., Test = $7.5*10^{-3}$ - one or more of the events is real
- Case 2
  - Event1 – amp=4130 electrons (3.5uJ/m^{2}um), background=708,000 (80% albedo)
    - $P_{FE1} = 1.32*10^{-5}$
  - Event2 - amp=4130 electrons (3.5uJ/m^{2}um), background=708,000 (80% albedo)
    - $P_{FE1} = 1.32*10^{-5}$
  - $P_{FE1}*P_{FE2}*500*1{,}408{,}000*t = 1.2t$
    - Test fails for any time interval> 80 milliseconds

Expected Performance of Coherency Algorithm

Description	Equation to Estimate	Estimate with SNR = 5
Probability of false event in one pixel in one frame	ERFC(SNR/√2)	5.7×10^{-7}
Probability of two false events in the same pixel within 1 second	$(\text{ERFC}(\text{SNR}/\sqrt{2}))^2$ * Frame Rate	1.54×10^{-10}
Number of False Events per second not removed by this filter	$(\text{ERFC}(\text{SNR}/\sqrt{2}))^2$ * Frame Rate * Pixels per Frame	0.1 false alarms per second = 0.5 %

- The coherency filter can be set to provide higher or lower false alarm rate at the expense or benefit of the detection efficiency

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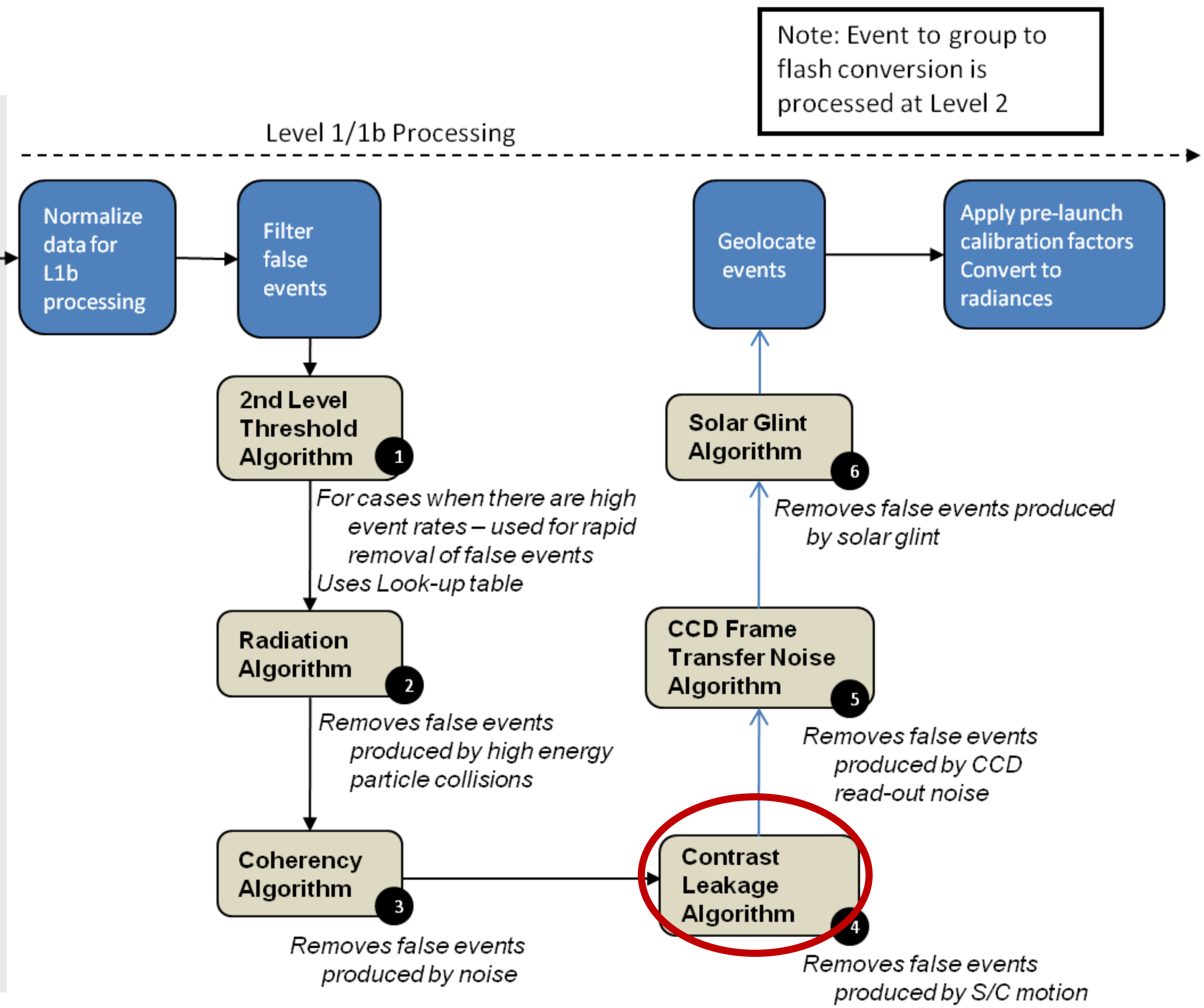
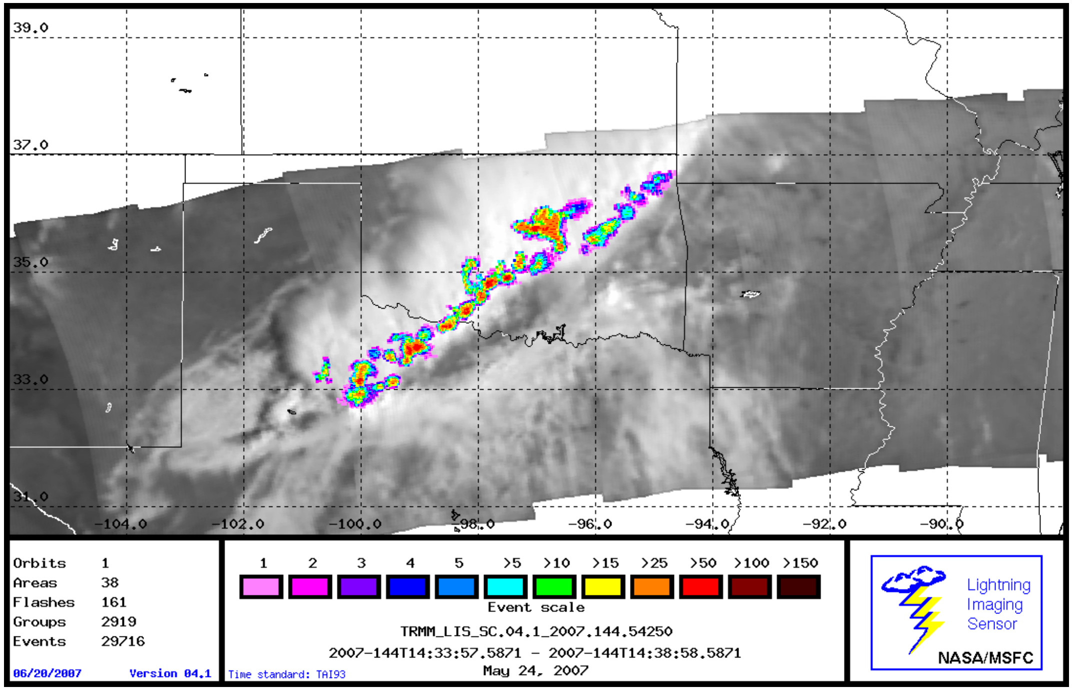


Overview of Contrast Leakage



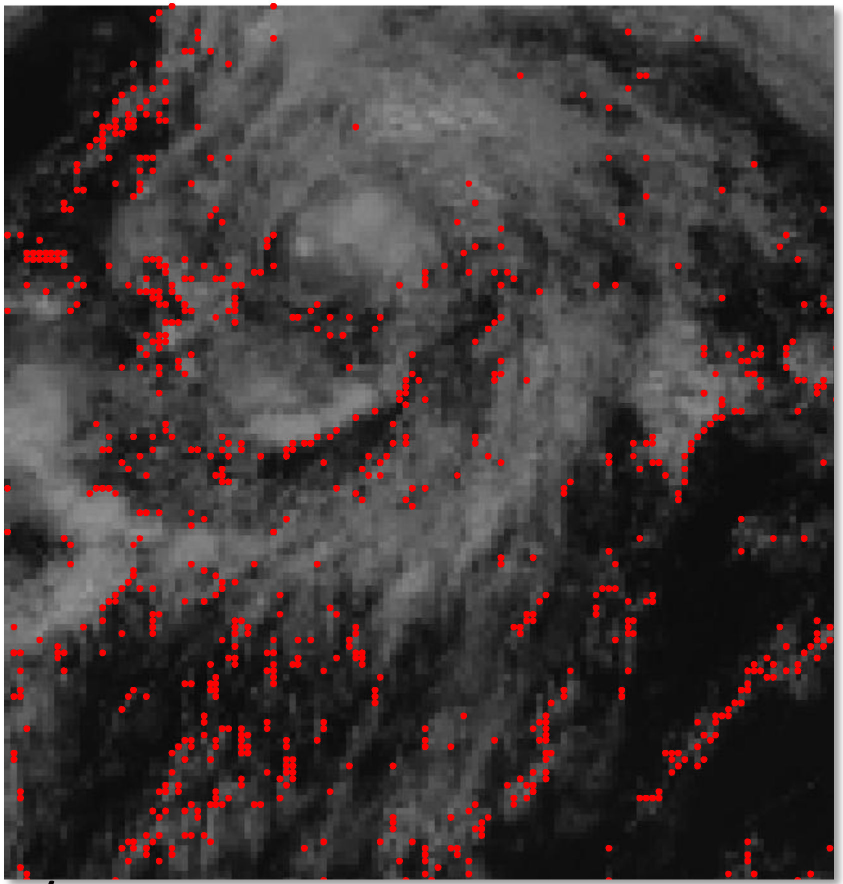
- Near the regions of cloud edges, coastlines, snowfields, or other bright/dark regions on the surface of the earth, contrast leakage FEs are possible due to spacecraft motion. The GLM instrument design and geo-stationary orbit will strongly suppress these types of FEs.
- The coherency filter will also be very effective in rejecting false events that fall in this category. Spatial filtering and background gradient tests provide removal of any surviving FEs from the processing queue.

Jitter Events on GLM

- The contrast leakage filter removes false events caused by jitter in the GLM line of sight due to S/C disturbances at the cold plate and the GLM mounting deck
- Full current jitter analysis details can be found in the instrument performance section
- Following jitter analysis is based on GIRD requirements for S/C disturbances
  - The contrast leakage filter performance is dependent on designing the filter to match the characteristics of the false events caused by jitter
  - Contrast Leakage algorithm filter is updated once detailed information on the expected S/C disturbances are available

Characteristics of Jitter for GLM

- Jitter events occur on high-contrast boundaries
  - Typically, sun-lit clouds
  - No night-time jitter events
- Jitter is "fast"
  - Tens of Hz
  - Contrast with STOP analysis << 1 Hz
- Jitter events can be taken out by ground processing
  - Jitter events are downlinked, eating into the telemetry budget of 50,000 events per second



  - Jitter FER budget: 35,000 events/sec
  - System level margin: 3300 events/sec

Contrast Leakage Filter

The purpose of this filter is to remove false events caused by spacecraft jitter and bright cloud boundaries. The filter works by looking for relatively weak events that occur in pixels with low backgrounds that are adjacent to pixels with bright backgrounds. The filter parameters represent initial “good guest” values. They will be updated with higher fidelity data as quantitative spacecraft jitter characteristics become available.

Input assumptions:

- Worst case jitter movement is 1 urad in 1 frame
- Brightest pixel = 800,000 electrons
- Dull pixel = 100,000 electrons
- Then, 1 frame leakage = 700,000/224 = 3000 electrons

Ground Processing Algorithms: Contrast Leakage

- Underlying Assumption: lightning occurs in thunderstorms that tend to be tall and bright and the vast majority of the activity tends to be in the active "core" regions, not the cloud edges.
- The contrast leakage filter tests for sharp gradients on the background intensity of adjacent pixels. When events occur in low background pixels, they are removed.
- As jitter characteristics are better characterized, additional features such as successive frame event removal will be implemented

Expected Performance of Contrast Leakage

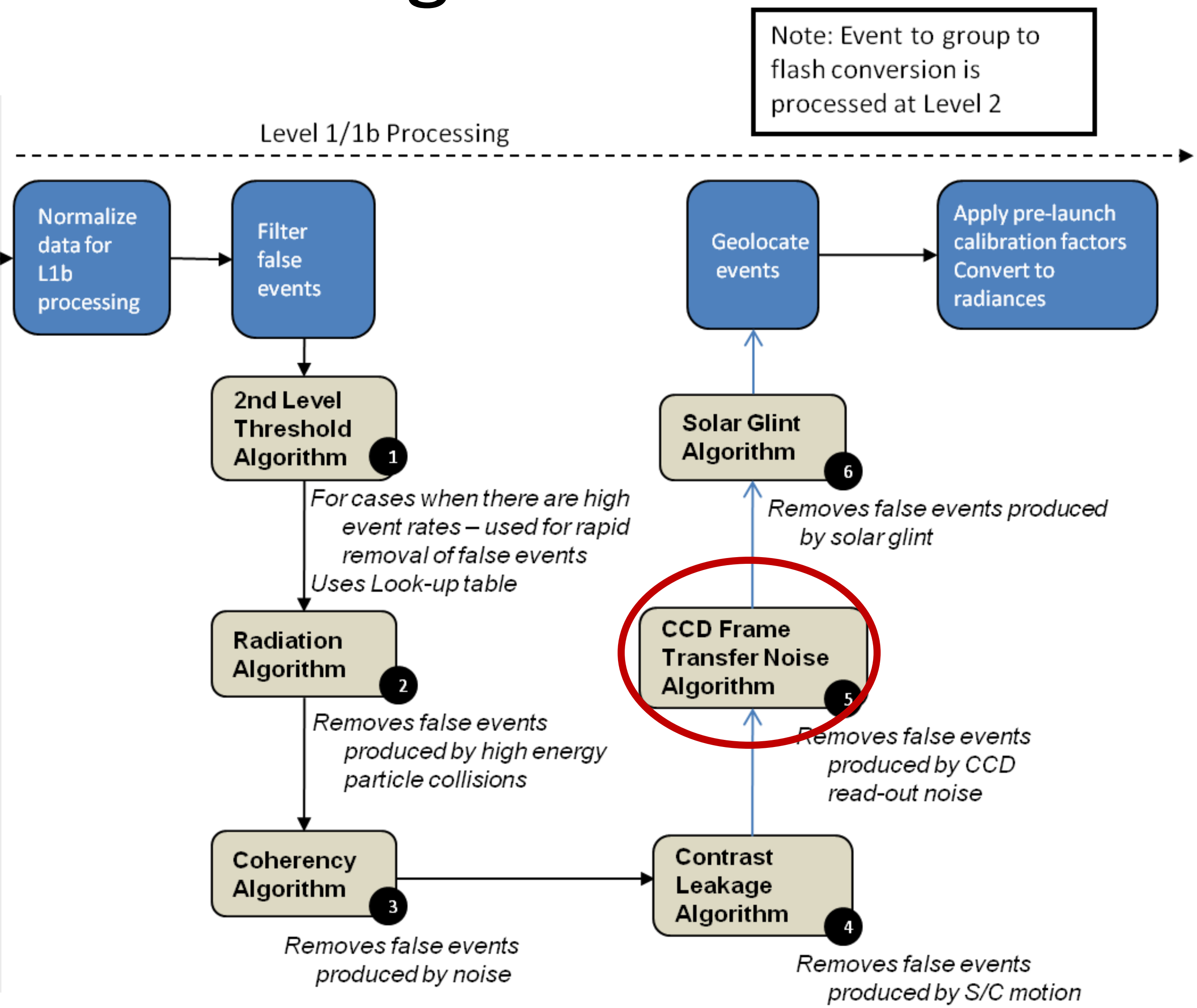
- If all jitter events are produced in dark pixels on boundaries then all jitter events will be removed by this algorithm
- If this assumption is incorrect, then an updated filter would be required
  - In order to write this update, detailed knowledge of the characteristics of these false events based on the S/C disturbances is required, which is not expected until at least S/C PDR (Jan 2011)

Ground Processing Algorithm Block Diagram

On-Orbit Data Acquisition

1. Background scene tracking & removal
2. Thresholding
3. Event detection

- Background scene acquired
- Background tracking algorithm updates background
  - Response time constant fast enough to track changes caused by S/C motion component
  - Background subtracted from signal pixel by pixel
- Thresholding (events exceeding background are transmitted to ground)
  - Amplitude algorithm processes only larger events
  - Reduces # of processed events so data is compatible with telemetry bandwidth
- Event detected



Overview of CCD Frame Transfer Noise

- When a very bright optical lightning pulse occurs during the CCD readout phase, portions of the light appears to be deposited in trailing pixels forming the handle of a "lollypop"

- These are lightning produced events that are mis-located and are easily corrected because of their spatial characteristics

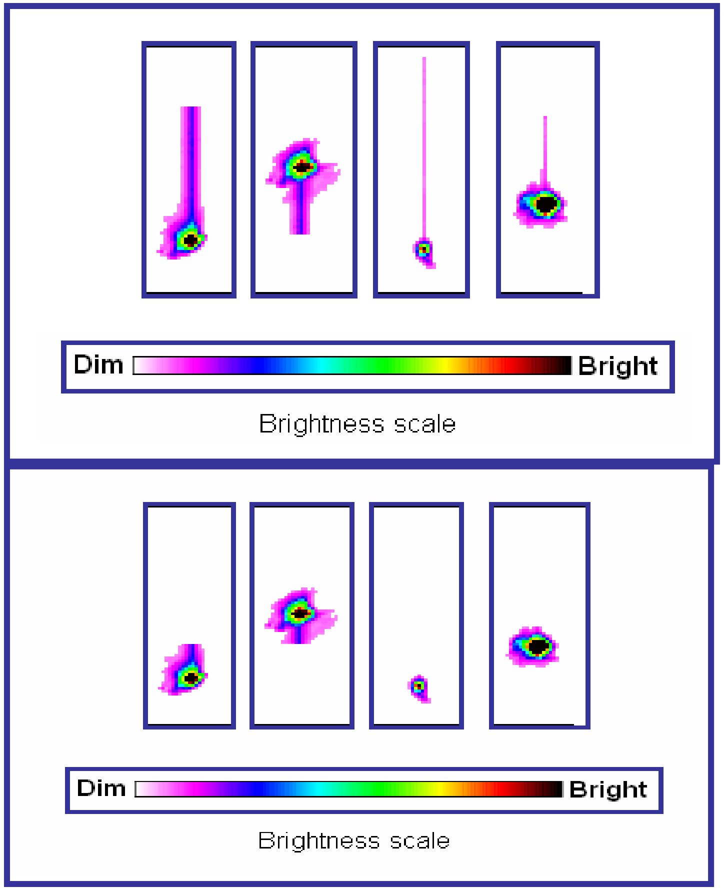
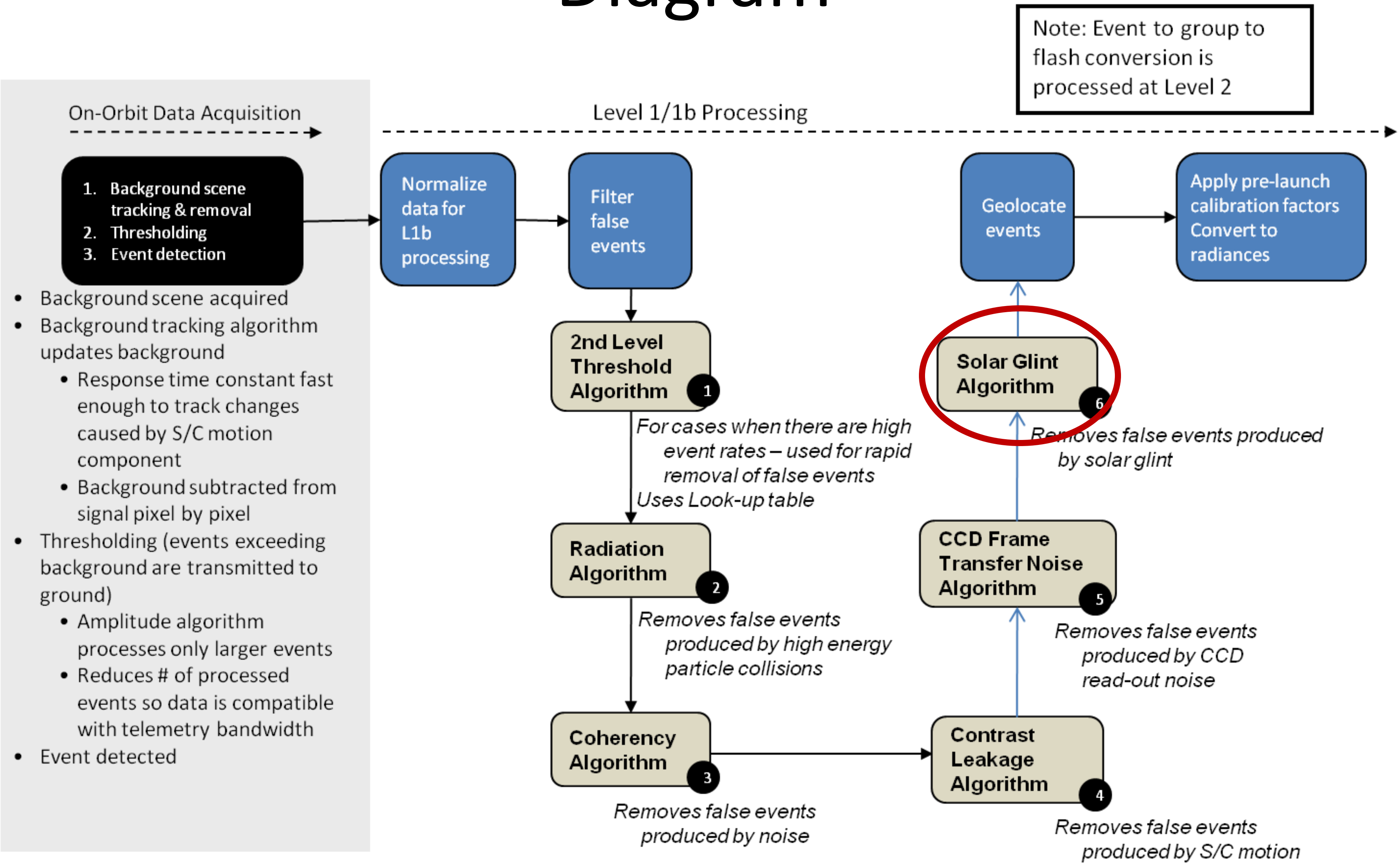


Figure LIS event cluster after readout FEs removal

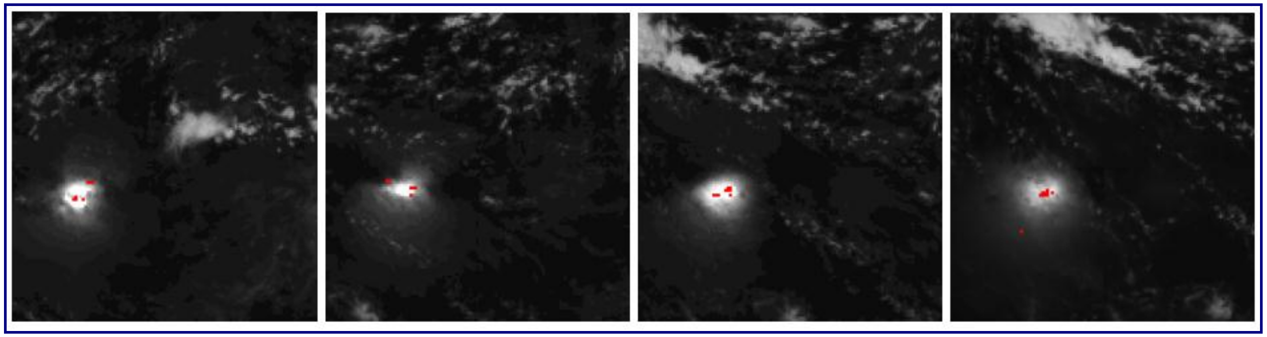
Ground Processing Algorithm Block Diagram



Overview of Solar Glint

The Solar Glint Filter removes solar glint induced false events

1. Potential glint regions are identified by the solar angle relative to the S/C
2. A spatial filter is applied only to these regions within the rejection zone (size is optimized during initial S/C checkout)
3. Background level is then checked; any events within rejection cone and exceeding an albedo of 1 are removed



Example from LIS of solar glint produced events

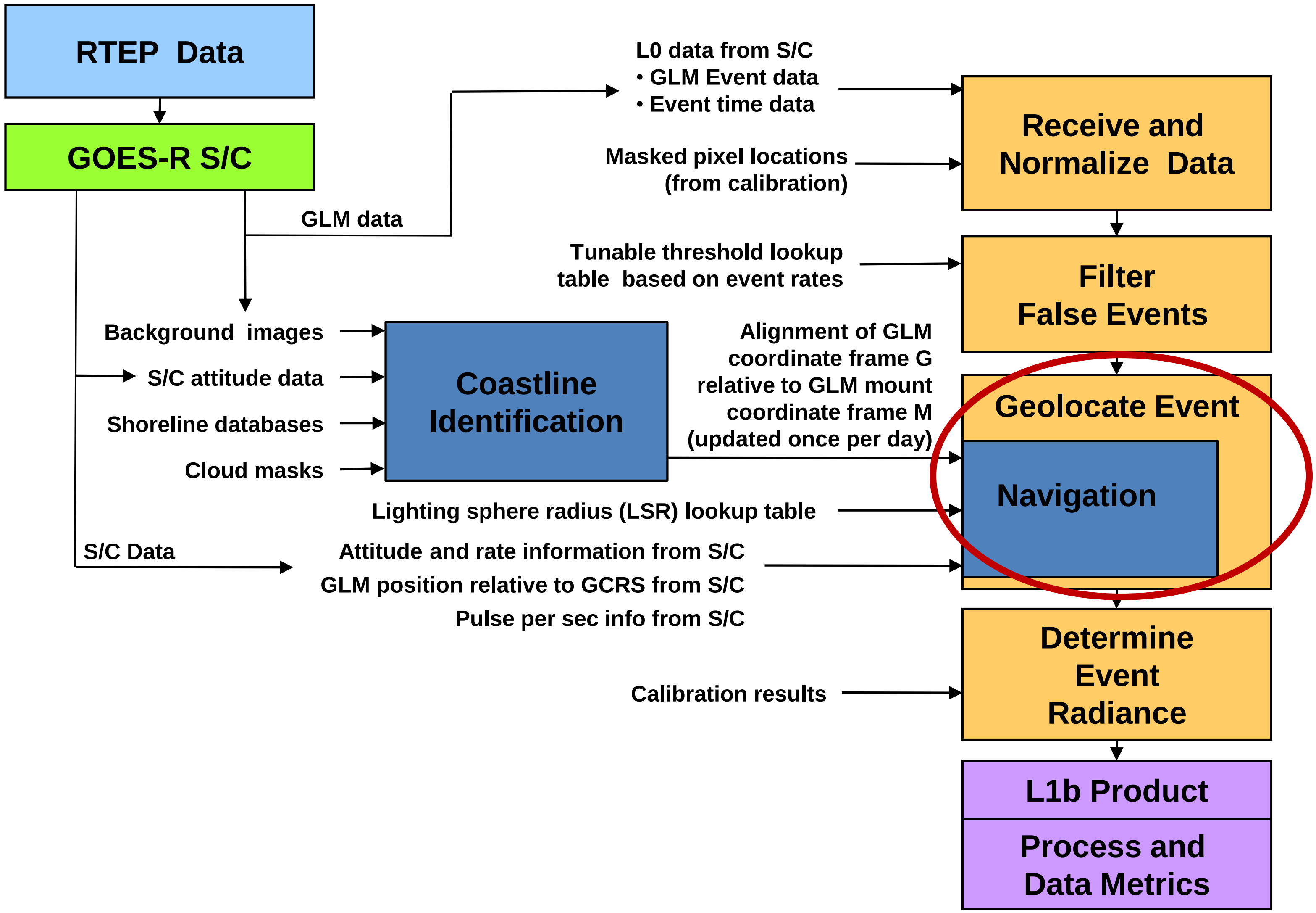
Ground Processing Algorithms: Solar Glint Filter

- Approach: Day of year and time of day are used to calculate the solar nadir point on the Earth, which together with the GLM nadir point and orbital position, is used to determine the centroid of the solar glint on the Earth's on the surface.
- An ellipse is drawn about this point, identifying the glint region.
  - Ratio of major to minor axis of ellipse is a function of solar angle
- Any events in this regions with background intensity/cos (solar angle) exceeding 1 are removed

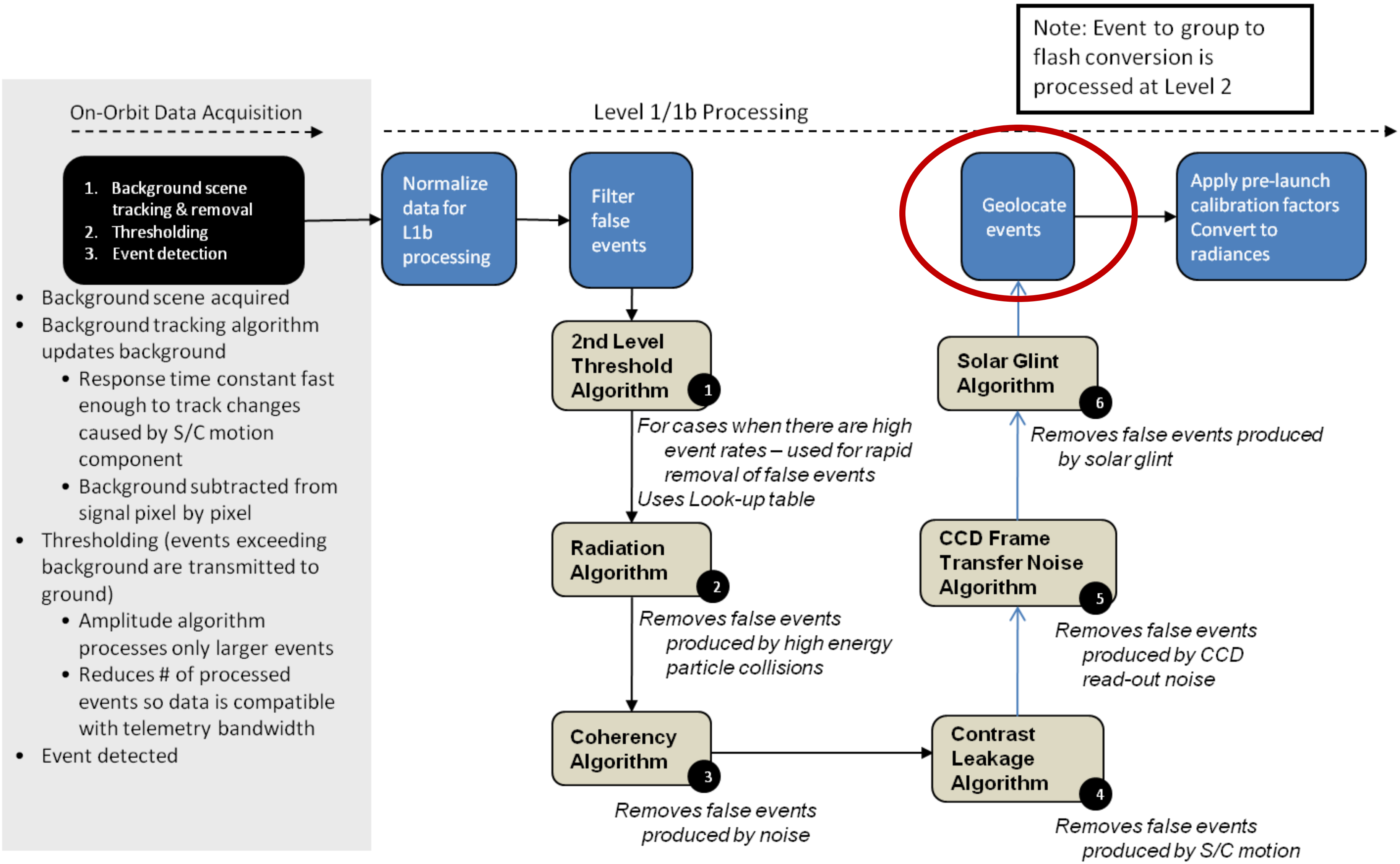
Expected Performance of Solar Glint

- The rate of solar glint produced false events is expected to be much lower for GLM than LIS because of the quasi-stationary orbit of GOES relative to TRMM in LEO
  - S/C motion modulated the bright glint scene causing events
  - However GLM will receive glint from lower incident angles, producing brighter glint
    - Waves and cloud boundaries will modulate the glint, causing events
  - LIS used a 100% exclusion zone around glint resulting in a 100% glint event removal efficiency.
  - GLM will use less restrictive criteria in order to detect lightning that may occur within the glint exclusion zone
    - These criteria will be tuned using both calibration and initial on-orbit observations

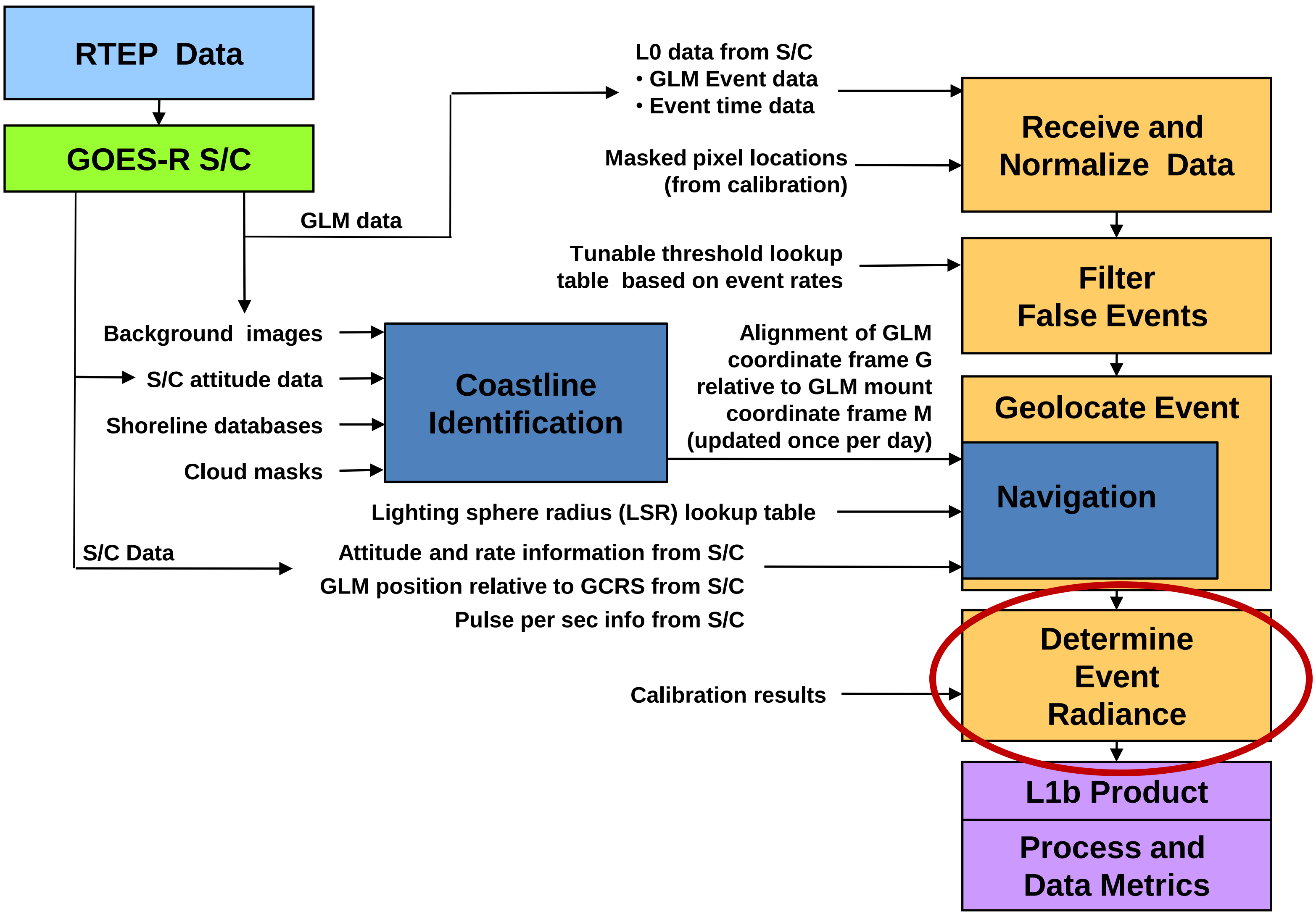
GLM GPA Functions and Interfaces



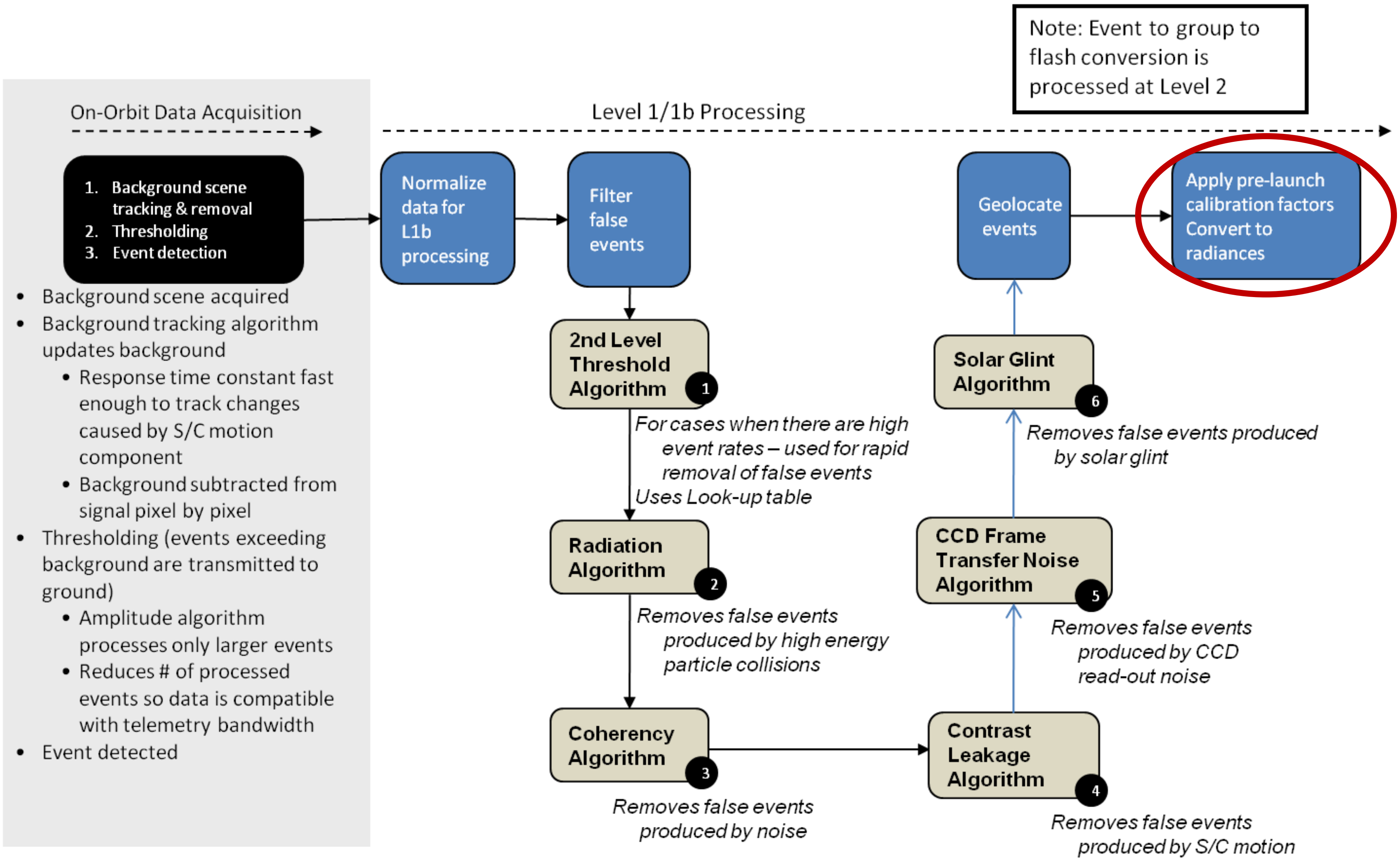
Ground Processing Algorithm Block Diagram



GLM GPA Functions and Interfaces



Ground Processing Algorithm Block Diagram



Event Radiant Energy

- Event amplitude count is converted to a calibrated event radiant energy an equation derived from instrument calibration
  - Calibrated radiance is stored as a member of the event data object in single precision
- Specific equation available after instrument calibration

Finalize Process and L1B Event Queue

- Event data objects remaining in the processing queue after all filters have been applied are removed from the processing queue and added to the L1B product queue

ALGORITHM VERIFICATION

Dr. Hugh Christian
Project Scientist

Verification of Detection Algorithms

- Detection algorithms are verified via test
- Simulated lightning and noise data (based on LIS and simulated noise) is used to evaluate the GPDS

- Optical calibration system, light and optical pulses stimulate the GLM & GPDS providing end-to-end performance testing

Ground Processing Demonstration System

- The GPDS demonstrates the effectiveness of the L1B processing algorithms and establishes that they satisfy the data latency requirement
- GLM pseudo data, derived from Lightning Imaging Sensor (LIS) data, is used during the initial algorithm tests
  - LIS uses similar lightning detection concepts as GLM but from a low earth orbit
    - Smaller field of view, shorter view time, lower sensitivity, and approximately twice the GLM's spatial resolution
    - Differences accounted for during generation of a test data set
- Once L1B algorithms are encoded, pseudo data is used to send repeating data sets for functional testing and timing verification prior to accepting any new release. These tests include:
  - worse than the worst-case on-orbit (maximum rate of false events)
  - "perfect" lightning set (no events should be discarded)
  - no lightning (all events are false) and background data only (no events)
  - no data packets (instrument powered off or communications failure)
  - nominal data-rate sets (with some/all types of defects)

Verification of False Alarm Rate

- Coherency Filter – multiple tests will be performed during calibration in order to fully characterize GLM performance (instrument + GPA)
  - Radiometric calibration- determines both radiometric performance, shot noise induced FE rates as a function of background intensity and the effectiveness of the coherency filter
    - GLM is fully illuminated, intensity is stepped through all 32 threshold levels with threshold settings varied at each step
      - Each RTEP is individually stressed to fully characterize false event rates as a function of background
      - The coherency filter is fine tuned
  - Event Calibration – determines event detection performance as a function of event and background intensity
    - An integrating sphere is used to generate a background scene with superimposed "lightning events"
      - Coherency filter tested on passing lightning events while removing false events

Verification of Event Detection Algorithms

- Contract Leakage Filter (CLF)
  - Light from the small integration sphere is scanned across the GLM FOV at precise rates
    - CLF effectiveness on FE removal is quantified
      - Both RTEP and CLF parameters are tuned to maximize performance and quantify affects

- Glint Filter
  - Output from the small sphere provides a background while the LED provides a smaller glint signature
    - LED output varied to well above one albedo and weakly modulated to simulate clouds and waves
    - Filter parameters are tuned to quantify and maximize performance

- CCD Frame Transfer Noise Filter
  - Output of the LED is set to high and pulse to occur during frame transfer intervals

Verification of GPA

- The combination of simulated data (background scenes and lightning events) and optical stimulation provides end-to-end testing of instrument and GPA performance
  - Verifies that the algorithms are coded properly
  - Verifies that GLM system performance requirements are met
    - Algorithms perform as designed

Process and Data Metrics

Relevant GLM data and GPDS processing metrics are created, during the processing of a segment of data, nominally a 1 second segment. These metrics include:

- GLM input data latency
- Count of events received
- Count of events in L1B output product
- L1B product Latency
- Count of timing values received
- Count of S/C attitude data vectors sets
- Count of invalid events received, (invalid or incomplete parameter specification)
- Count of events in the masked region of the CCD
- Count of events rejected by 2nd level threshold filter
- Count of events rejected by CCD radiation track filter
- Count of events rejected by RTEP background memory filter
- Count of events rejected by Coherency filter
- Count of events rejected by contrast filter
- Count of events rejected by CCD read noise filter