GLAST Large Area Telescope

Instrument Flight Software
Flight Unit Design Review
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Event Filtering

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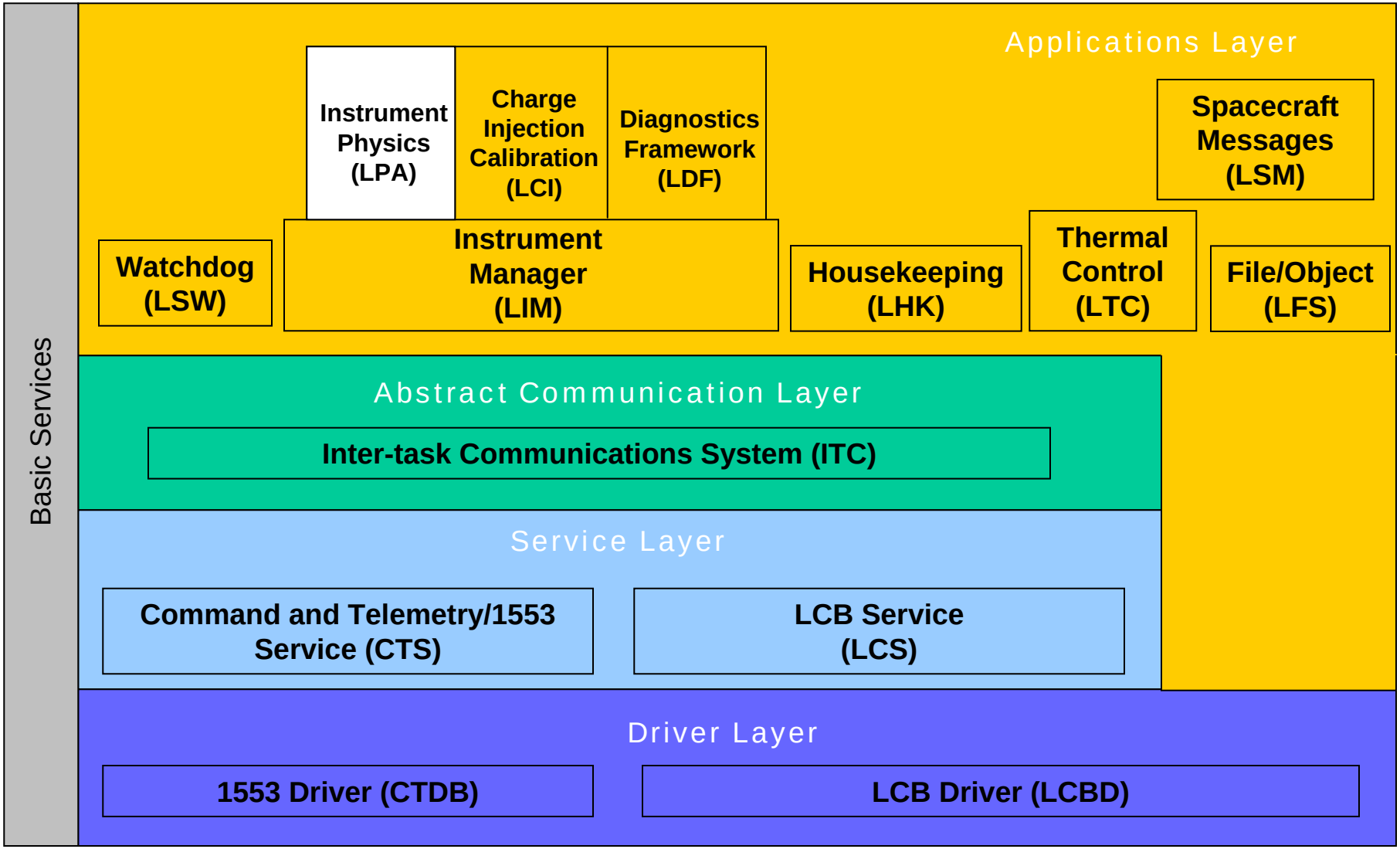
Event Filtering Requirements

- **FSW General Requirements:**
  - **5.3.9.1: The FSW shall filter the input stream of events accepted by the electronic trigger to an output stream commensurate with the spacecraft (SC) interface rate, up to 66 Mbps, and capacity of a maximum of 104 Gb in any given 24 hour period, keeping events meeting the science objectives.**
  - **5.3.9.2: The event filtering software shall be reprogrammable via the SIU.**
  - **5.3.9.3: The event filtering software shall be capable of passing a pre-scaled sample of unfiltered events for monitoring and analysis, upon request.**

FSW Layer Architecture



Event Filtering: Overview

- The LAT's downlink data rate allows only a small fraction (2-10 percent) of triggered events to be reported. Consequently, the vast majority of events must be discarded.
  - Fortunately, this can be done without damage to the scientific objectives of the instrument.
- The LAT will trigger on a variety of phenomena:
  - High-energy photons (i.e., Gamma rays)
  - Cosmic background radiation (e.g., protons, electrons, and positrons).
    - In fact, cosmic rays and other "noise" account for 99.8% of the detected events.
- The Event Filter's goal is to preserve analyzable gamma data:
  - First, identify and discard cosmics (relatively easy and fast)
  - Second, identify and retain analyzable gammas (harder)

Event Filter: ACD, TKR, CAL

- **The Event Filter uses ACD, TKR, and CAL data in distinct ways to sift events:**
  - **ACD data to reject cosmic rays**
  - **TKR data to detect tracks and reject trackless events**
    - **Correlates to ACD data to reject cosmics**
    - **Identifies classic tracks and shapes (e.g., the signature V-shaped, 2 track events)**
  - **CAL data to provide a rough energy classification:**
    - **Allows the Filter to correctly identify the likely topology of gamma ray events, shower shapes consistent with EM shower, and energy deposition consistent with cosmics**

Event Filter Tests

- At the highest expected data rate (10K events per second), the LAT computers have, on average, 100 microseconds (margin x2) to handle each event.
  - Consequently, "cheaper" tests are made before "expensive" ones.
- The Event Filter will perform three tests (in increasing order of expense):
  - Trigger discriminator tests
    - Fast, and eliminates 75% of candidate events
      - Primarily, checks if data is consistent with a cosmic
  - Energy-level tests
    - Require considerable compute time (about 10 times that of the trigger discriminator tests)
    - Use energy information from the CAL, which must be unpacked
    - Use TKR layer patterns (in essence, a more sophisticated version of the hardware trigger)
    - Nearly another 20% of candidates eliminated
  - Track-projection tests
    - Use fully-unpacked Tracker data to find X-Z and Y-Z projections
    - Very compute intensive (yet another factor of 5 above energy-level)
    - However, by this time, 95+% of candidates have been eliminated, so aggregate compute time isn't a big issue
- The filter and this general sequence of tests were developed "offline" and are being adapted by FSW for online use
  - A proven filtering process

Trigger Discriminator Tests

- These tests are very fast and quite effective (eliminating 75% of the candidate events). They use data from the GEM (Global Trigger), including anti-coincidence hit maps, which tracker towers had "3-in-a-row" triggers, and trigger information from the CAL (low- and high-energy) discriminators.
  - Essentially, a more sophisticated use of the trigger level information

- Veto tile response; no CAL LO
  - If any ACD tile near the top of the instrument ("veto tile") responds to the event and the CAL low-energy (CAL LO) trigger discriminators all read zero, the event is rejected (64.4%).
    - This test targets charged track events (e.g., incoming electrons or positrons) which miss the CAL, but produce a tower tracker "3-in-a-row" trigger.
    - Note: At energies which are too low to activate the CAL LO discriminators, Gamma-ray interactions in the CAL will not produce backsplash in the ACD veto tiles. Thus, this must be an incoming cosmic ray.

- ACD Splash Veto (pass 0)
  - If the ACD gets too many hits and the CAL high-energy (CAL HI) trigger discriminators all read zero, the event is rejected (10.2%).
  - This test targets events which enter from the bottom of the detector and interact in the CAL.

Energy-level Tests

- **These tests requires significant compute time (~10x that of the previous set). They use energy information from the CAL, which must be unpacked.**

- **Veto tile response; CAL energy < 350 MeV**
  - **If a veto tile responds to the event and the CAL detects energy of less than 350 MeV, the event is rejected (1.5%).**
  - **This test targets events (e.g., protons) which are composed only of minimum-ionizing tracks.**

- **Any ACD tile response; CAL energy < 10 MeV**
  - **If any ACD tile responds to the event and the CAL detects energy of less than 10 MeV, the event is rejected (3.0%).**
  - **This test targets cosmic-ray events and events where there is no potential for backsplash from the CAL to hit an ACD tile.**
  - **Note: This is a much more inclusive version of the initial test ("Veto tile response; no CAL LO"). At 10 MeV, no backslash can reach even the lowest ACD tiles, so all tiles can be included in the test.**

Energy-level Tests (cont'd)

- **ACD Splash Veto (pass 1)**
  - **If the CAL detects energy of less than 40 GeV (this is almost always the case) and the ACD gets too many hits, the event is rejected (0.4%).**
  - **This test targets events which enter from the bottom of the detector and interact in the CAL.**
  - **Note: Because we now know the energy of the event, we can apply the "ACD Splash Veto" test to more events.**

- **TKR tower match with ACD top or side tile**
  - **If a responding ACD top or side tile shadows a tower with the "3-in-a-row" tracker trigger, the event is rejected (2.7% for top, 2.0% for side).**
  - **This test targets charged particles (e.g., protons) which enter through the ACD. This is a slightly more sophisticated version of the hardware throttle.**
  - **Note: This test, coupled with the following test, refines the geometric resolution to a single tracker tower. A follow-on test ("TKR/ACD matching") will refine this to a single ACD tile.**

Energy-level Tests (cont'd)

- **No connection between CAL energy and TKR (pass 0)**
  - **If there is any CAL energy and no tracker tower has hits in more than four of its bottom six planes, the event is rejected (7.7%).**
  - **This is an inexpensive test for bottom- and side-entering showering tracks.**

- **CAL layer 0 energy < 1 percent of total**
  - **If the energy detected by layer 0 (the top later) of the CAL is less than 1% of the total energy, the event is rejected (1.0%).**
  - **This test looks for behavior that is inconsistent with electromagnetic showering.**

- **CAL layer 0 energy > 90 percent of total**
  - **If the energy detected by layer 0 of the CAL is more than 90% of the total energy, the event is rejected (0.6%).**
  - **This test looks for behavior that is inconsistent with electromagnetic showering.**

- **CAL crystal ratio**
  - **If the number of CAL crystals with less than 1% of the energy exceeds 20% of the total number of hit crystals, the event is rejected (0.25%, from recent work).**
  - **This test looks for behavior (e.g., a diffuse scattering) that is inconsistent with electromagnetic showering.**

Track Projection Tests

- These tests depend on finding X-Z and Y-Z projections, using the fully-unpacked tracker data. They are very compute-intensive, requiring perhaps 50x the processing time of the initial tests. Fortunately, we're down to a small fraction of the initial events, so the aggregate compute time isn't a big issue.

- No projections
  - If no projections are found, the event is rejected (TBD%).
  - This test targets two classes of events which are barren of tracks: false "3-in-a-row" triggers (generally caused by noise) and non-tracker (e.g., CAL LO) triggers.

- TKR/ACD matching
  - If a track projection points at a responding ACD tile, the event is rejected (1.7%).
  - This test targets charged particles which enter through the ACD. This is a very sophisticated version of the hardware throttle.
  - Note: Although the projection has much greater resolution, we can only compare against a single ACD tile. Because of the increased geometric correlation, noise is not a factor (so we can target more events).

Track Projection Tests (cont'd)

- **Track(s) project into skirt region**
  - **The "skirt region" lies between the CAL and the lower row of ACD tiles. Thus, it is outside of the area covered by the CAL, but inside the active area of the instrument. If a track projection points into this region, the event is rejected (0.5%).**
  - **This test targets charged-particle tracks that escape detection by the ACD and CAL, as well as Gamma rays which miss the CAL. (The rejected Gamma rays are nearly useless for analysis, because they lack energy information.)**

- **CAL energy < 350 MeV; fewer than two tracks**
  - **If the energy level detected by the CAL is less than 350 MeV and there is no evidence of two or more tracks, the event is rejected (3.0%).**
  - **This test targets events which are inconsistent with the topology expected from relatively low-energy Gamma rays. At this energy, one expects to see two separated tracks (from the initial electron-positron pair). At higher energies, the separation between the two tracks is insufficient for the tracker to resolve.**

Track Projection Tests (cont'd)

- **No connection between CAL energy and TKR (pass 1)**
  - **If there is any CAL energy and no projection points at that energy, the event is rejected (TBD%).**
  - **This is an expensive (but more precise) test for bottom- and side-entering showering tracks (e.g., caused by a particle interaction with the spacecraft).**

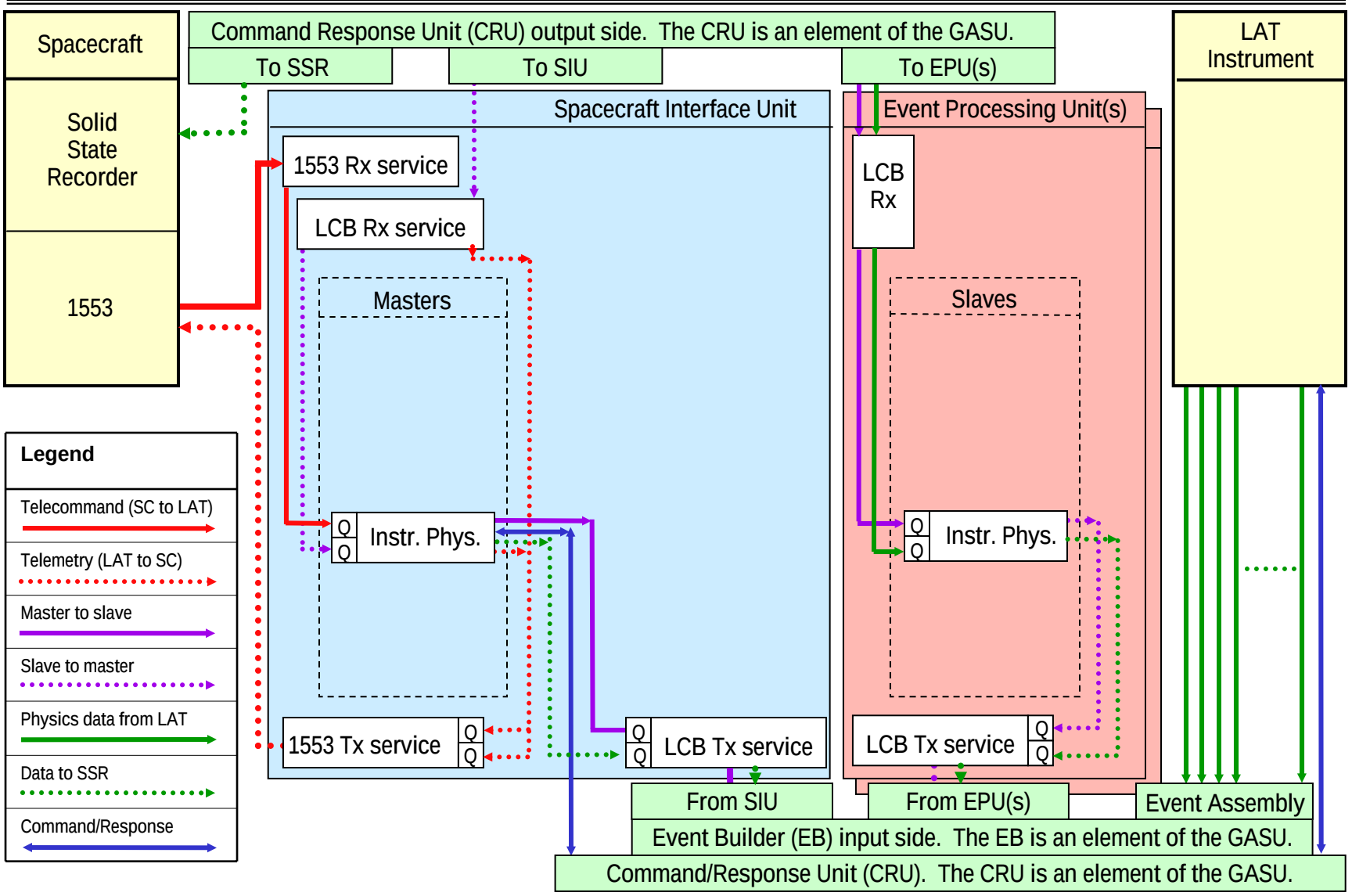
- **Albedo Gamma-ray rejection**
  - **Relatively expensive calculation in terms of infrastructure, so may or may not be implemented, depending on performance of an updated albedo model**
  - **If the track of the candidate event (now assumed to be a Gamma ray) is consistent with pointing at the Earth's limb, the event is rejected (TBD%, out of an absolute rate of 250-750 Hz).**
  - **Gamma rays coming from charged-particle interactions in the Earth's atmosphere are irrelevant to LAT's primary science mission. We may allow a certain percentage of these through, for calibration and monitoring purposes.**

Do These Tests Get Us the Desired Reduction?

- **Current estimates are into 300-400 Hz range without rejecting albedos**
  - **300 bytes/event (2400 bits)**
  - **Yields bandwidth usage of 0.72 to 0.96 Mbps**
    - **Allowed bandwidth 1.2 Mbps**

- **But, are the estimates of albedo rates correct?**
  - **If much higher, some will need to be eliminated**
  - **Again, albedo filtering is expensive, since absolute direction must be calculated from event data**

Event Filter Architecture (cont'd)



Event Filter Architecture

- The Event Filter operates as a set of separate tasks executing on multiple CPUs. A master task running on the SIU acts as a controller, coordinating execution of the slaves. Slave tasks operating on the EPUs perform the filtering.
- The Event Filter master task performs the following duties:
  - Processes commands from the ground and configures the operation of the slaves accordingly
  - Gathers summary statistics from the filter slaves
  - Packages the summary statistics for transmission to the ground
- The event filter slave tasks perform the following duties:
  - Filter event data using the trigger discriminator, energy-level, and track-projection tests

Filter Control and Reprogramming

- **A 32 bit mask is manipulated to veto individual filter tests**
  - **If no vetoes is applied, all filters used on event data stream**
  - **Allows prescaling:**
    - **The filter can be set to execute specific tests on a defined fraction of the event data that comes through during a cycle.**

Event Filter Telecommands and Telemetry

- **Telecommands**
  - **Bypass event filter**
  - **Set prescales**
  - **Set parameters (veto word – 32 bit mask)**
  - **Reprogram event filter:**
    - **By parameterization**
    - **By new code (filter ~ 25K, uncompressed)**

- **Telemetry**
  - **Event data, with events in each test category (statistics only)**

Forward Work

- **Coding is 70% complete**
- **Event filtering of data generated by a Front End Simulators and a full set of hardware is scheduled for January 2005**
- **Code and unit test complete 1/05/2005**

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Backup

LPA Configuration Management

- The Event Filtering function is part of the LPA package. However, the Filter component has no build-time dependencies on any other software:
  - Through use of build tags, the filter code can be compiled for use in different settings:
    - Into onboard FSW
    - Into offline code used for testing (including testing of the filter algorithms themselves)

- The dependency tree, constituent list, command and telemetry list, and other configuration management information related to LPA are published dynamically on the FSW Web site at http://www.slac.stanford.edu/exp/glast/flight/web/a_pnp/Pack_LPA.shtml