GLAST Requirements Issues Update

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Requirements Issues

- ***Slew rate requirement with one failed wheel***
- ***#slews/orbit***
- ***Pointing knowledge***
- ***[implications for data downlink path change already discussed]***

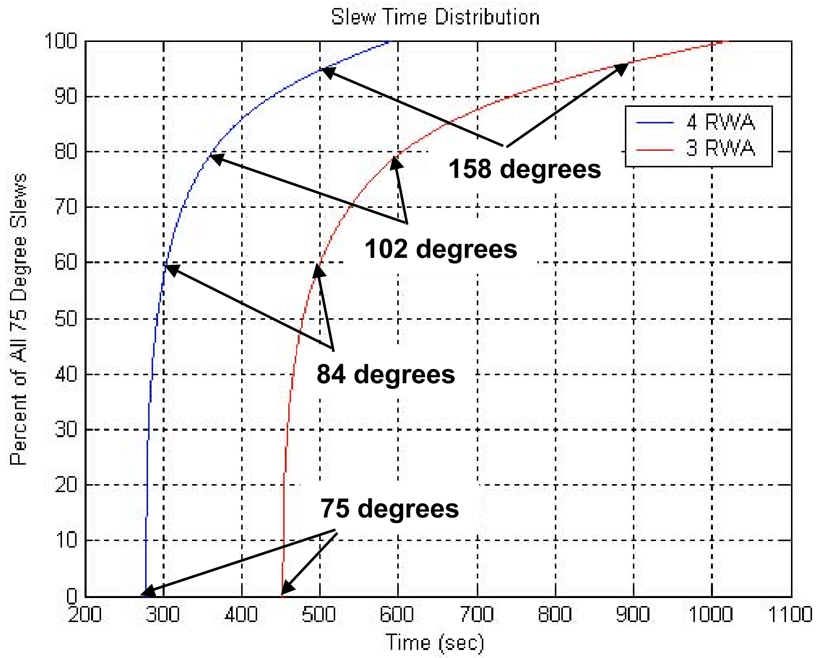
Slew rate requirements

- ***SRD specifies 75 deg slew in <10 mins (requirement; <5 mins goal). Mainly driven by repointed mode slews to follow GRBs. SRD also states 5-year lifetime, with <20% degradation.***
- ***Level I requirement specifies that no credible single point failure will cause the observatory not to meet requirements***
- ***Spectrum Astro design easily satisfies the requirement when all the wheels are functional (4-for-3 redundant). With a failed wheel the situation is more complicated:***
  - *Spectrum Astro has analyzed many realistic cases. Sometimes a 75-degree slew involves rotations through much larger angles, due to constraints (keep sun off LAT and S/C radiators, etc.) Naively, simple 75-degree slews are not a problem.*
  - *Estimate that requirement is met, even with one failed wheel, in ~79% of all cases.*
  - *Trades done for design modifications (e.g., more complex GN&C software, bigger wheels, allow more sun on LAT radiators). All are expensive and/or add risk. Not worthwhile. (79% is close to 80%!)*
  - Estimated probabilities of one of four wheels failing:
    - 3.15% @ 2 years; 7.70% @ 5 years; 14.81% @ 10 years

- ***=>Project plans to modify the requirement.***

Results of slew rate analysis

- ***Running many 75 deg slew cases (with different sun and s/c orientations), observatory meets requirement in 79% of all cases with one failed wheel):***



- ***Modification:*** Time for 75 deg slew, **to be met 100% of the time under 4 reaction wheel (RWA) control and 75% of the time under 3 RWA control (single RWA failure)**

Number of slews per orbit

- ***Spacecraft design allows for great observational flexibility. As design proceeds from PDR to CDR, checking all the limitations.***
- ***There is a thermal limitation on the frequency of "fast" slews.***
  - *Design comfortably supports 5 fast slews per orbit.*
- ***Obtaining a quantitative definition of "fast".***
  - *At present, "fast" slews include yaw flips, any nominal point-to-point slew, transitions from Sky Survey to Pointed (assuming the target is different from the current attitude).*
  - *Limb tracking (Earth avoidance) is not considered a fast slew.*
- ***Consider the possible impacts (see next slide).***

Representative examples

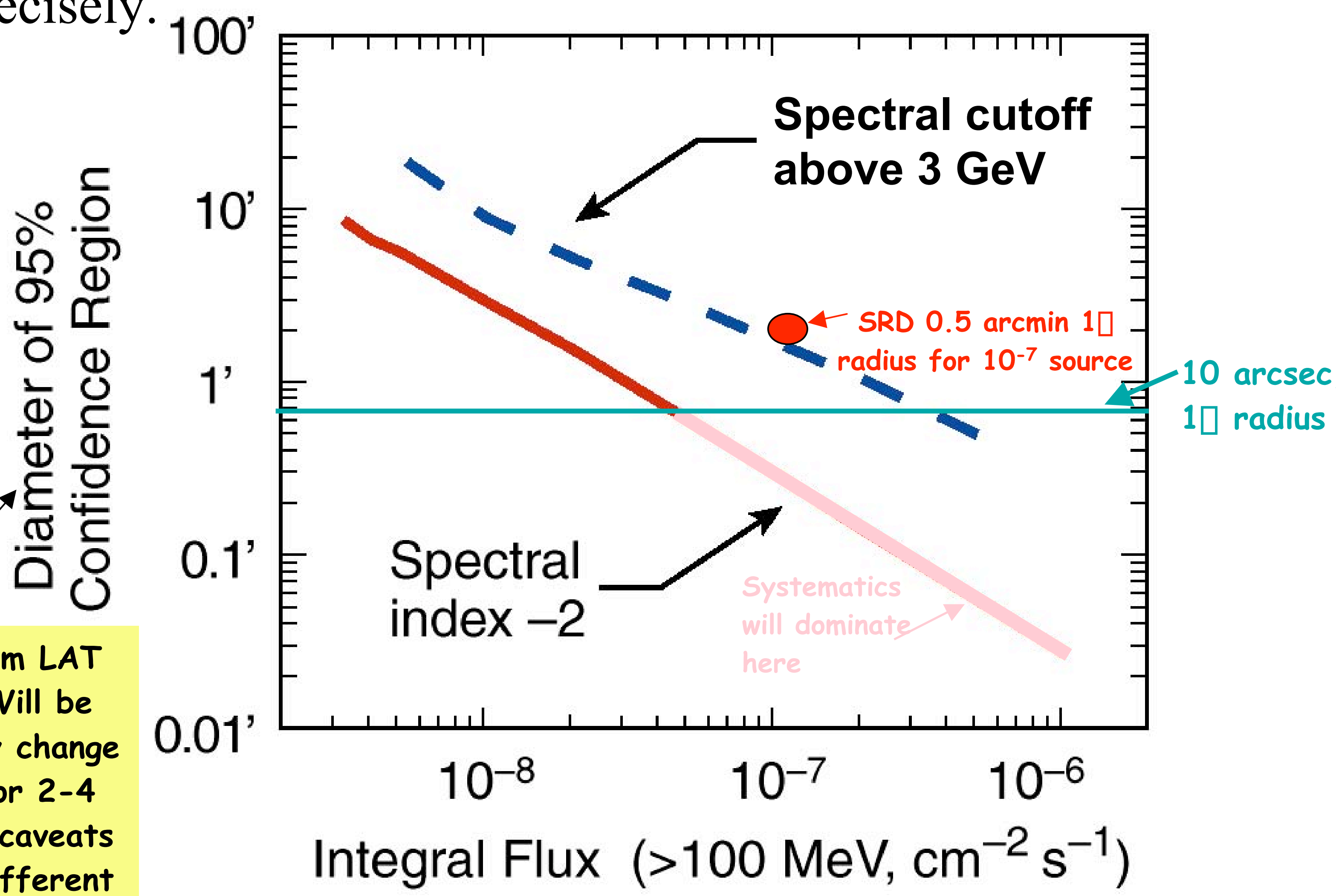
- ***The following scenarios are all possible within one orbit:***
  - *1) Start in Pointed Observation, transition to Sky Survey, perform a Yaw flip, remain in Sky survey and perform the second yaw flip, then transition to new Pointed mode. This would be 4 slews.*
  - *2) Perform 5 different (unocculted) pointed observations within one orbit. Do not transition to Sky survey in between Pointed observations. (5 slews)*
  - *3) Slew to a pointed observation that becomes occulted forcing a slew to a secondary target, then a slew to resume the primary target. (3 Slews)*
  - *4) Slew to a pointed observation that becomes occulted, track the earth's limb, then slew to sky survey and perform a yaw flip. (3 slews)*
- ***At first (and second) look, this appears to be fine.* Anyone see a problem?**
- ***Note: For science observing planning, it will be necessary to have the operational limitations carefully codified.***
  - *GLAST Mission SE: Spectrum has a CDRL delivery called the Observatory Operations Description Manual. This will document how to operate the observatory, including all constraints and restrictions.*

Localization and Pointing Knowledge

- ***Pointing knowledge (<10 arcsec) vs. pointing accuracy (<2°)***
- ***The uncertainty in the measured direction of a single photon by LAT is determined by:***
  - *single photon PSF*
  - *end-to-end pointing knowledge*
    - *GN&C uncertainties*
    - *mechanical/thermal uncertainties*
    - *alignment calibration uncertainties*
- ***LAT will measure many photons from a point source. The point source localization is determined by a combination of several factors:***
  - *Aeff, FOV, single photon direction errors, source characteristics (brightness, emission spectrum, sky region), and exposure*

LAT Source Localizations, Pointing Knowledge

In general, brighter, higher-energy sources are localized more precisely.



note!

figure is from LAT proposal. Will be updated. May change at the factor 2-4 level. A few caveats (comparing different quantities)!!

Pointing knowledge requirement

- ***History: as a result of early mission s/c studies, relaxed requirement a factor 2 to current value.***
- ***It takes significant work to design (and test) the system to meet (and verify) this requirement (LAT, S/C, observatory).***
  - *therefore reasonable to ask, if we were to relax the requirement further:*
    - *(a) what are the estimated savings to mission? mainly mech-thermal stability issue.*
    - *(b) what is the possible science loss?*
  - *to be quantitative, consider 20 arcsec and 40 arcsec*
- ***Notes:***
  - *mission mechanical engineers say: we would have to relax the requirement to ~100 arcsec to warrant reducing the current detailed mech/thermal analyses. No one wants to go here!*
  - *spending effort evaluating pointing knowledge is unavoidable. This is an astronomical instrument. Most of this work has to be done anyway. Worth checking if there is a break point in pain vs. gain, however.*
- ***So, ask SWG to consider (b) at most recent telecon.***
  - *understood that, as of now, designs all meet requirements. Issues might arise later, during testing. Be prepared; think through science arguments in advance.*

An approach

- ***Inputs from Tune Kamae, Martin Pohl, Kent Wood.***
- ***Not easy to estimate science loss for a mission for which discovery is a significant component.***
- ***Expectation: it is the bright + high-energy sources that are affected.***
  - *two obvious possibilities to consider:*
    - *brightest EGRET UNID sources. What is the expected localization of the brightest ones? Worth re-evaluating. One estimate:*
      - *3EG 1911-2000 (2-3x10^{-7} E>100 MeV, b=-13): ~20 arcsec, assuming no spacecraft errors, from LAT proposal. Full simulation by Seth Digel. (needs updating with new performance parameters). Again, results depend on high-energy behavior of source spectra (and region)!*
    - *new and/or flaring sources not currently known as bright*
      - *guidance from history. we don't necessarily know all the bright GLAST sources from EGRET.*

Input from Tune

Dear All,

*May I reiterate one more time that the issue is not what we write down as a requirement: rather how we do our best. Please refer to a memo I wrote sometime ago (I will search for it).   I have been raising this issue because 1) Engineers interpreted this 5(or 7) arc sec as a level 0 requirement and came down to require   1 arc sec measurement and an excessive FEM. 2) We all know that "alignment" on ground has little meaning at arc second level because of gravity   and thermal condition. 3) We also know charged cosmic rays can only give relative alignment in orbit. Absolute alignment   has to be derived from photon data. 4) Crab Nebula will be the brightest source above 5GeV but is extended over 30 arc sec. 5) Vela and PSR B1706-44 are on the steep slope of the Galactic Ridge and requires accurate model   of Ridge Emission to become calibration sources. Geminga may be a better calibration source. 6) We need >2 more calibration sources: preferably identified high latitude point sources bright in   E>5GeV. We will get 10k gammas (E>1GeV) a year from them and will allow us to calibrate   to 15-20 arc sec. 7) From accelerator experiments, we know localization limit with SSDs are typically 1/20 of the   pitch with charged non-electron tracks. This sets a limit of 12um for LAT, or   12um*sqrt(2) over 12trays*3cm/tray = 17um / 36cm = 5*10**(-5) = 10 arc sec 8) If zenith pointed, the telescope axis will move at a rate of 240 arc sec per second.   If the pointing   telescopes use off-shelf CCDs, we will be out of business: the gate width must be <10ms,   and the detection limit (magnitude) must be 12 or better (fov=0.5deg) for 10ms exposure, equiv.   for 1 sec exposure of magnitude=12+5. Combining all of above, we will be able to make 15-20 arc sec but not 10 arc sec. So I will propose to write down 20 arc sec.   This doesn't mean SpectrumAstro can relax it spect to 20 arc sec: they should give us pointing knowledge better than 10 arc sec at 10ms gating.   I hope they ar not planning to use off-shelf slow readout CCDs.   Tune Kamae*

Addresses more (a) savings/capabilities (note: not reviewed by LAT team) than (b) science loss due to capability.

Input from Martin

- ***The pointing knowledge is an uncertainty, that is probably systematic on short timescales, but is getting stochastic on timescales much larger than the orbit time. I think that any potential science impact would occur when analysing data on long timescales like weeks and months. We can therefore safely assume a stochastic uncertainty. I can see two potential trouble zones:***
  - ***Very bright sources****: As Tune pointed out, a Geminga-type source will give us more than 10^4 photons above 1 GeV, and a bright AGN may do 10^4 photons or less. The source localization can be done approximately with an uncertainty, that is the 68% psf width divided by the source significance.* ***A localization to 10 arcsec is not unrealistic, then****. What the limited pointing knowledge would do is to cause ghost images like we had around Vela in the EGRET analysis. I we understood the long-term average of the pointing error, we could modify the psf accordingly, but I doubt we will understand it except by measuring after many years. On the other hand, at these energies all photons come from the source and can be just counted.*
  - ***Blind pulsar searches****: the important case here is a periodicity search for the position of a x-ray source (or other suitable frequency). The limited pointing knowledge leads to an error in barycentrisation. This problem can be alleviated by observing at the "right" season, that is when the source in question is in opposition to the sun. Generally only for very fast pulsars we may have a serious limitation here, for the phase error scales inversely with the pulsar period (and linearly with the pointing knowledge or other position error). So we may have a small price to pay in the form of a slightly reduced capability to blindly find millisecond pulsars.*

Both problems do not appear to be very serious.

- ***If we would go to 40 arcsec pointing knowledge, another problem will arise. There will be unidentified sources, whose position can be determined to 30 arcsec or so on statistical grounds (think of 3EG J1835+5918). I wouldn't want to blow up the error box too much.***
- ***To summarize, I think we wouldn't loose much be going up a bit, but the price will significantly increase when the pointing knowledge gets worse than 20 arcsec.***

Let me know what you think.

Martin