GLAST Observatory Slew Rate and Pointing Knowledge Issues

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See http://lheawww.gsfc.nasa.gov/~ritz/docs/IRD_Pointing.pdf

Overview

- **Motivation: Why now?**
  - Next iteration of Interface Requirements Document (IRD) was done in time for spacecraft vendor studies. Also, instruments have been selected so more is known. Ready to make progress.
- **Must flow down requirements in SRD to more detailed observatory requirements. Requires some interpretation.**
- **Work is very preliminary – just first looks. Approach is to gather relevant requirements, look at representative components (wheels, star trackers, etc.) and see what drives what.**
- **Definitions of rates:**
  - **Slew rate:** (total angle through which observatory rotates)/(total time of the maneuver). A slew maneuver begins and ends at rest wrt a target (not a necessary assumption for GLAST – see later).
  - **Rotation rate:** magnitude of the instantaneous angular velocity.

Thus, for a particular maneuver, the slew rate is the average rotation rate. Units are *degrees/minute*.

Start with SRD

- **SRD states the following relevant requirements:**
  - 40 arcmin pointing accuracy
  - <10 arcsec pointing knowledge

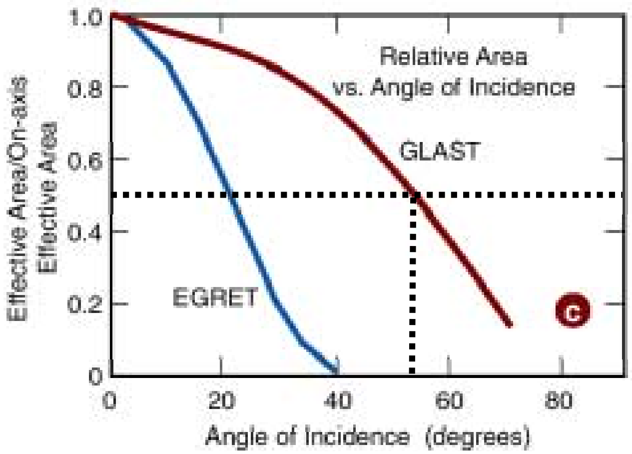
  These values are 1 σ diameter.

  - Rocking zenith pointing and steady target pointing observing modes.

- **MISSION GOALS:**
  - Targeting ability to point anywhere in the sky at any time
  - More than one target per orbit
  - Autonomous repointing in <5 minutes

What does “pointing” mean?

- **The LAT FOV is huge: FWHM is ~55 degrees:**



PSF also degrades off axis. At 55º, 68% containment radius is ~1.5 times larger than on-axis [95%/68% ratio is not significantly worse]. For science, this is likely more important than 50% changes in effective area. **Definition of pointing is evolving**.

Thus far, for these purposes, define pointing as the Z axis being within 55 degrees of the target. **This is just to set the slew time.**

- Conventional slew calculations assume a maneuver in which the bore sight begins and ends at rest wrt the target. A gentler required torque or faster response time is possible if we allow the instrument to be rotating relative to the target (though coming to rest) when the source enters the FOV. *Caveat: Attitude Control System must maintain pointing knowledge while the observatory is slewing.*

Slew Maneuvers

1. **Repointing** The largest single slew angle is 180-2*55=70 degrees.
   SRD goal is 5 minutes.
2. **All-sky Survey Rocking** The nominal zenith-pointed rocking is from +45 (35) degrees to –45 (35) degrees, or a 90 (70) degree slew. The project had been carrying a time of 6 minutes for this maneuver. Needs review.
3. **Multiple target mode** Two possibilities:
   - A. A single target plus a scan when the target is occulted
   - B. Two individual targets on opposite sides of the earth

   Requirements for option (A) are more modest. Option (B) again implies a 70 degree slew. Time is at a premium: target 1 will be occulted for ~35 minutes – if slew to/from target 2 takes much longer than 5 minutes, observing on target 2 will hardly be more efficient than a simple scan.

The three are surprisingly commensurate.

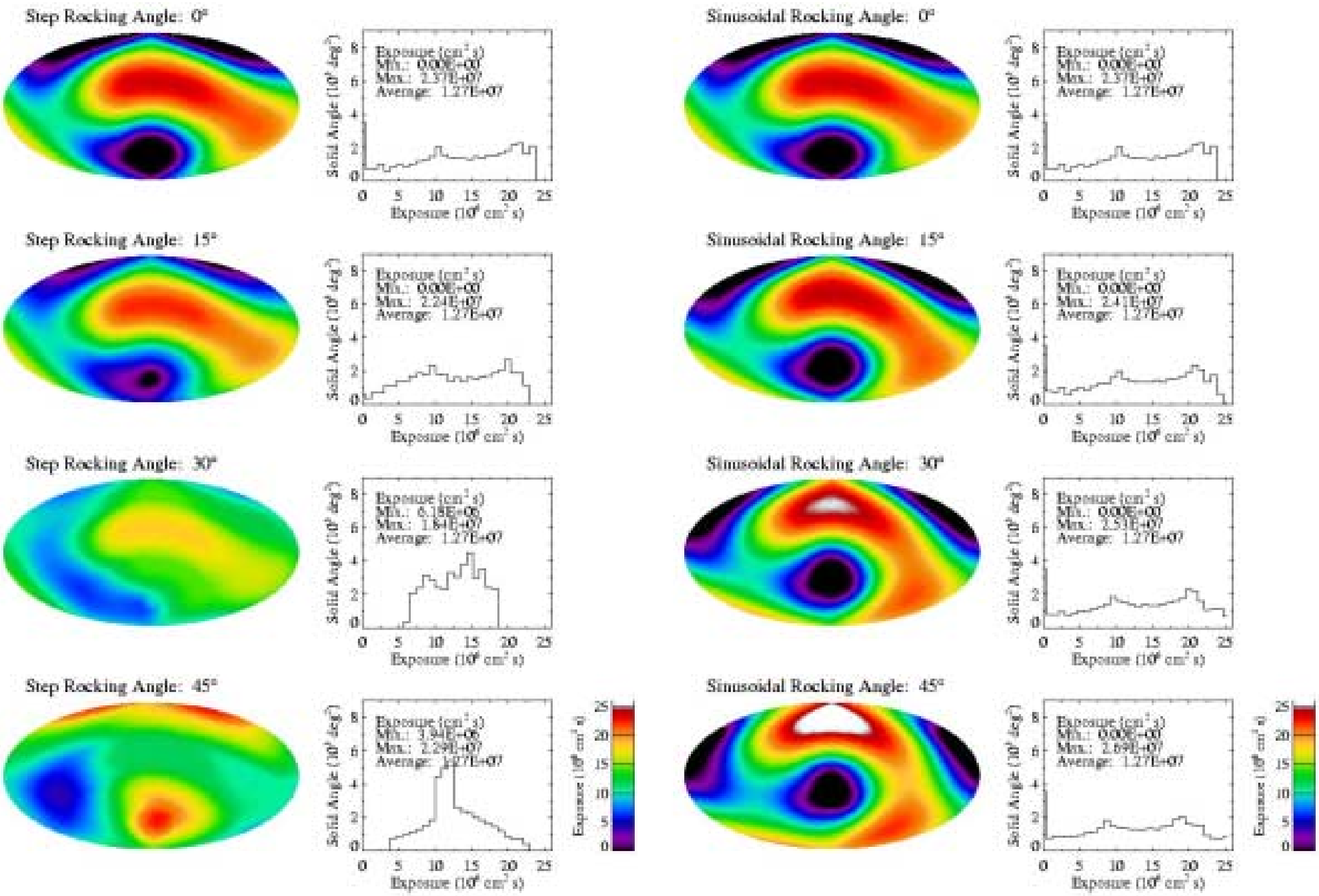
All-sky Scan Strategies

- Work done by Seth Digel. IDL scripts to simulate sinusoidal and square rocking patterns at different angles. SAA can be turned on/off.
- Best short-timescale coverage uniformity is obtained by square rocking with ~35 degree amplitude. Larger amplitudes overexpose poles. Finite slew time is not yet included in the simulation.
- Sinusoidal rocking over 1- and 2-orbit periods investigated (reduced requirements on reaction wheels). Over 2 orbits, coverage is far less uniform than for square rocking case. Over 55 days, orbital precession eventually smoothes coverage.

representative examples

- Also investigated relative advantages of lower-inclination orbits.

Exposures, two orbits



Slew Rate Calculations

Spreadsheet tool provided by GSFC GN&C group. Calculates profiles and momentum wheel parameters for a given slew maneuver. Calculation assumes:

- **Moment of inertia is 3363 kg m^2** (IMDC value)**. MUST CHECK.**
- **Maneuver starts and ends at rest (thus, parameters are somewhat overestimated for our purposes).**

Sample of results:

angle[deg], time[min]	***90, 6***	***90, 7***	***70, 5***	***180, 12***
Minimum torque [Nm]	0.16	0.12	0.18	0.08
momentum capacity [Nms] **(infinite torque case, minimum torque case x2 larger)**	14.7	12.6	13.7	14.7

Largest rotation rate in any maneuver listed is 30 degrees/minute.

Wheels

Example: Relevant Ithaco wheels:

Model	*TW-16**B**200*	*TW-19**B**300*	*TW-50**E**300*	*TW-26**E**300*
Torque[Nm]	>0.2	>0.3	>0.3	>0.3
Momentum capacity [Nms]	>16.6	>19.5	>50.0	>26.0
Peak power [W]	<250	<350	<280	<150
Mass (wheel+motor)[kg]	8.0	8.4	13.9	13.9

Typical costs for four wheels are $530k for the "**B**" wheels, and $1.4M for the "**E**" wheels. Note that the "**E**" wheels also have substantially lower peak power. **See next talk**.

First-look Slew Conclusions

The requirements on the reaction wheels from fast repointing, all-sky survey rocking, and multi-targeting are commensurate.

These requirements do not place unusually large demands on the system, but accommodating them with adequate margin might result in using the higher-end “E” wheels. These wheels cost more money, but also use substantially less power.

A compromise on the performance to save money would adversely affect all three goals of fast repointing, uniform daily sky coverage, and multi-targeting.

Pointing Knowledge

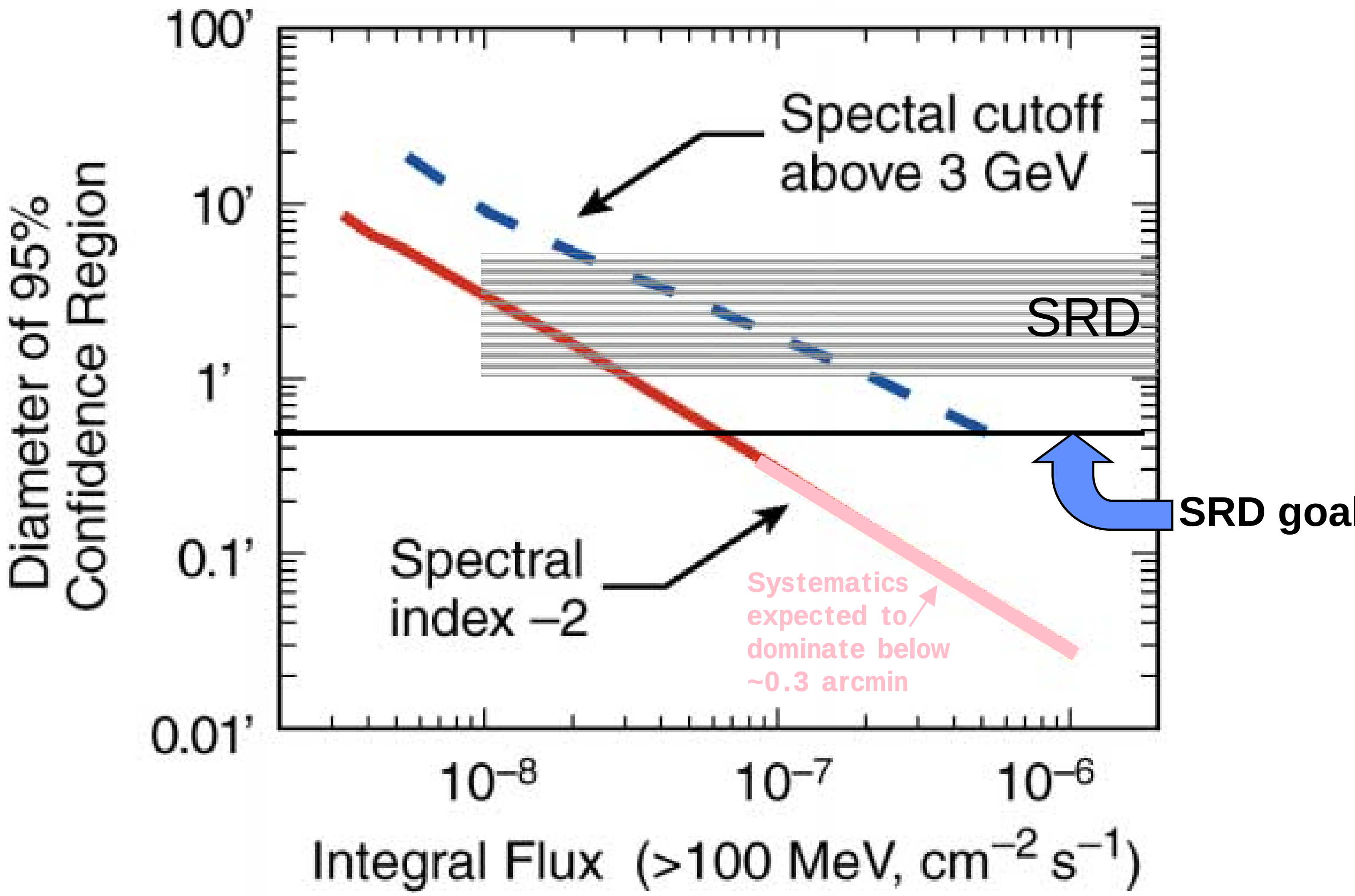
The SRD clearly specifies a < 10 arc second pointing knowledge.
Two main components to the pointing knowledge error budget:

1. **Star tracker resolution**. Static resolution straightforward (and apparently easily met); however, want to take data while slewing. Standard star tracker (*e.g.*, Ball CT-602) maintains maximum resolution for rotation rates of <18 degrees/minute. At faster rates the tracker loses lock. Revert to info from the gyros. In typical systems (*e.g.,* using the Litton SIRU gyro), the pointing knowledge may be maintained to better than 2 arc seconds for star tracker outage periods of 15 minutes or more.
=>Keep the same pointing knowledge requirement, while specifying the maximum rotation rate (30 degrees/minute).

2. **Relative alignment of the star tracker and the instrument.** Since we are planning to calibrate this alignment on orbit, the alignment error requirement effectively becomes a set of requirements on stability:

- alignment and stability on the ground
- stability during launch (and environmental testing)
- stability on orbit

LAT Localization Capabilities



Proposed Requirements

Slew Rate

- The observatory maximum rotation rate during slew shall be 30 degrees/minute.
- The observatory shall be capable of repointing, autonomously or by ground command, by slewing as much as 70(TBR) degrees in less than 5 minutes, as specified in the SRD.
- To accommodate the rocking zenith pointed mode, the observatory shall slew 90 degrees (+45 degrees to/from –45 degrees) in less than 7(TBR) minutes, once per orbit, as specified in the SRD and MRD.

Pointing Accuracy and Knowledge

- The observatory shall be capable of pointing in any direction at any time, autonomously or by ground command, to an *accuracy* of <40 arc minutes [1σ diameter], as specified in the SRD.
- The *knowledge* of the observatory pointing direction at any time, including during slew, shall be such that the total error is < 10 arc seconds [1σ diameter]. This error budget includes the intrinsic resolution of the star tracker and gyro system and the relative alignment of the star tracker system with the SI reference surface.

Proposed Requirements continued

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Mechanical Alignment and Stability

•The relative alignment of the star tracker system and the SI reference surface shall be surveyed on the ground and maintained to < 30(TBR) arc minutes [1σ diameter] during environmental testing and launch to orbit.

•The relative alignment of the star tracker system and the SI reference surface shall be calibrated once on orbit using celestial sources. Periodic alignment checkout observations shall be performed every TBD months.

•The stability of the relative alignment between the star tracker system and the SI reference surface, including all thermal-mechanical effects, shall be < 5 arc seconds [1σ diameter] throughout the mission.

Next talk by Jennifer Bracken: other ACS issues, details on component choices, orbit ACS power profiles.