Far Ultraviolet Spectroscopic Explorer

FUSE One-wheel Operations Status and Update: The Adventure Continues

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FOAC Meeting, Nov. 3, 2006

Outline/Themes

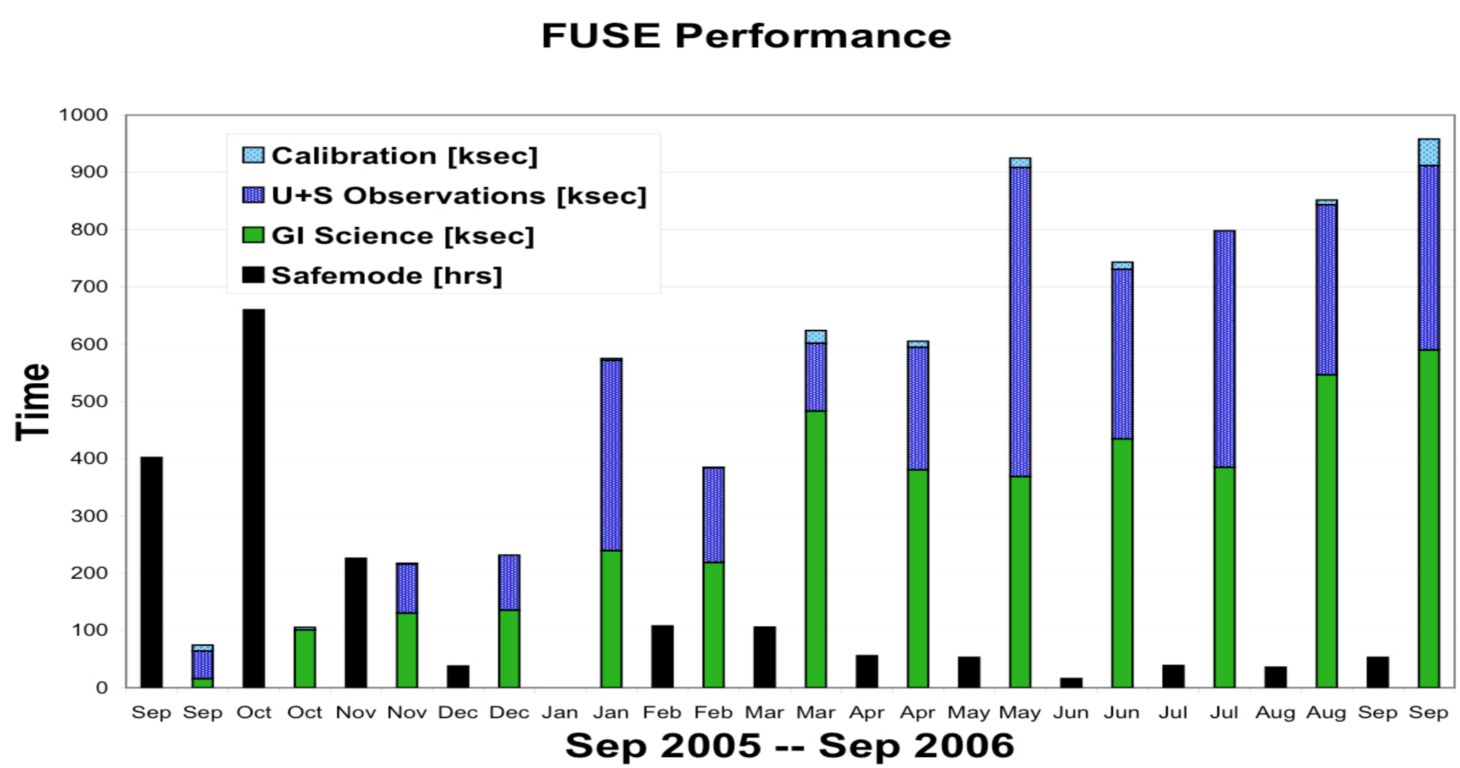

FUSE at KSC, May 1999.

- Since the last FOAC, the FUSE team has undertaken a process of continuous improvements in operational and planning techniques that have elevated the one-wheel mode to exceptional levels of performance.
- I will highlight some of these changes/improvements as I review recent performance of the satellite and the system.
- Review of CalFUSE/MAST Status (Dixon) and Reprocessing

Mission Status/Overview
(Since last FOAC meeting)

- We have just completed ONE YEAR in One-wheel mode.
  - Science Ops officially restarted Nov. 1, 2005.
- FES-B performance continues to be nominal.
  - Occasional timing glitches develop, causing acqs to fail, but easily addressed.
- No change in status of gyros.
- UPRM Ground station performance has been steady.
- Much improved momentum prediction/behavior.
  - Many fewer momentum interventions needed.
  - Many fewer trips to LVLH (Safemode).
- Semi-automated hemisphere crossing slew procedure.
- Long Range Planning tool improvements.
- Still completing CalFUSE 3.2, but full reprocessing still on track to be completed well before EOM.

Operations Improvements

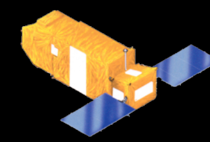


(M. Kaiser, A. Berman)

Staffing Changes

- MOT/Control center staffing at 6 (one below projected).
  - ***SCC Staffing is at 16/5 level since early September.***
- We have hired Thomas Civeit (previous French representative) into a staff position. (MP/software dev.)
- Our French partners have provided another operations person, Benjamin Ooghe-Tabanau, through Aug. 2007.
- One mission planner, Mark Kochte, has just accepted a new position at JHU/APL (Messenger project).
  - Project is looking at options for replacement.
- Several partial FTEs are being shared with STScI to support SM4 preparations.
  - Currently 25 people providing ~22 FTE of effort.
  - This model shrinks FTEs to ~20, but maintains the expertise level within the project.

One-Wheel Ops
A Primer



- Attitude Control System (ACS) is the S/C software that controls pointing.
- Only Wheel remaining is the Skew Reaction Wheel.
  - +/- 6500 rpm top speed (+/-21 Nms).
  - Higher wheel speeds mean more gyroscopic torques when slewing.
  - We plan so as to keep this below +/-14 Nms.
- Three Magnetic Torquer Bars (MTBs) mounted on the body axes of the satellite, need to share duty between control and momentum unloading for the wheel.
- Three-axis Magnetometers (TAMs) provide attitude knowledge to +/-2 degrees.
- Fine Error Sensor (controlled by the Instrument Data System computer) provides Fine Pointing Data (FPDs) to the ACS.

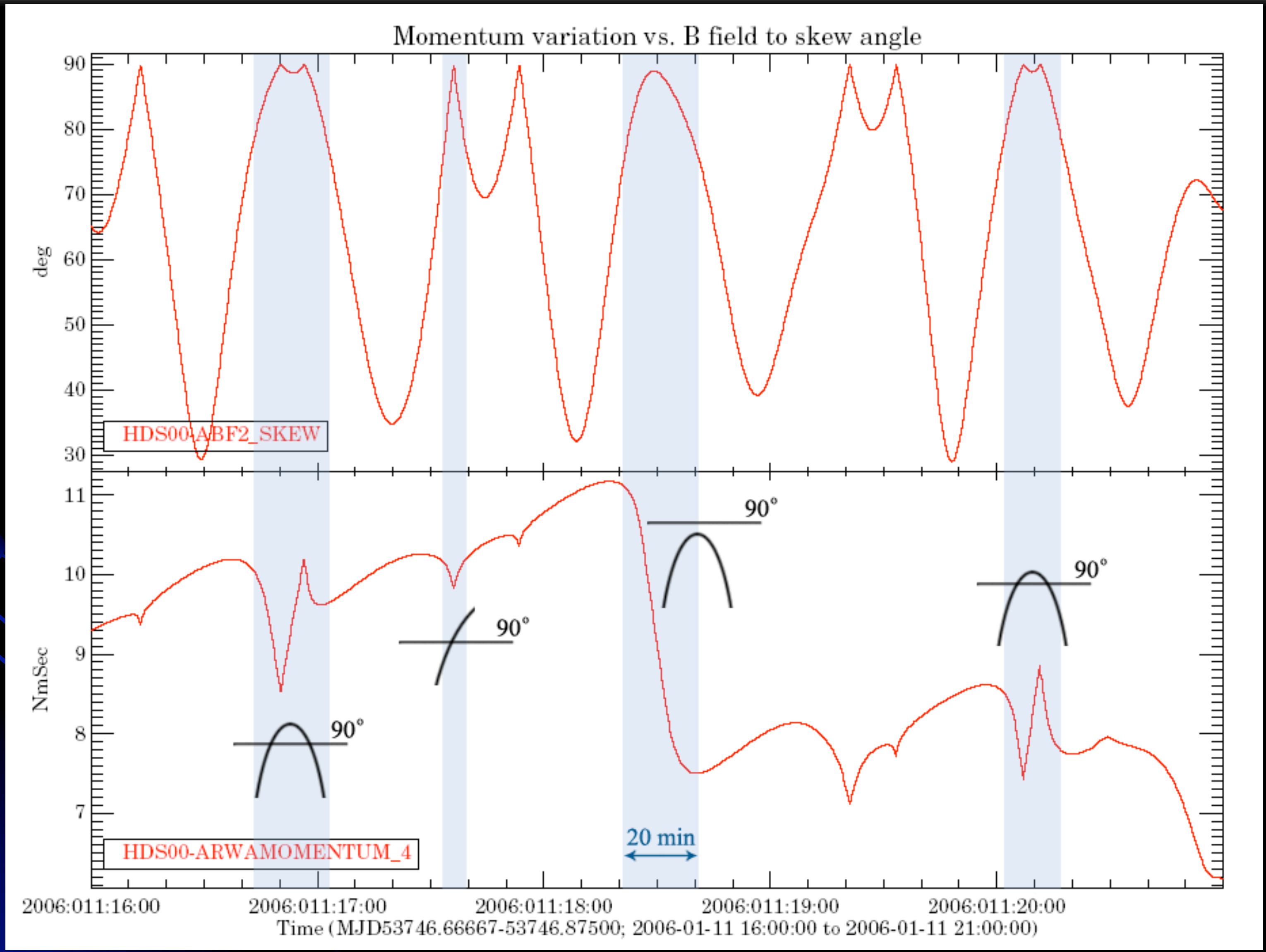
ACS E33 / IDS v3.02

- New ACS flight s/w and new IDS s/w and scripts were loaded to FUSE just prior to last FOAC.
- Has provided much improved attitude information sharing between ACS and IDS.
  - Fewer instances of bad FPDs corrupting ACS controller and causing loss of attitude.
- Revised Torque Distribution Algorithm at ***B***-to-***S*** angles near 90 degrees.
  - Fewer large and/or unexpected jumps in momentum compared with predicted behavior >> fewer momentum interventions needed.
- Medium gain controller--better slew and acquisition behavior.
- Improved LVLH “FB” recovery slews (from safemode) have been robust.
  - Continue to be calculated ahead so available if/when needed.

Momentum Management

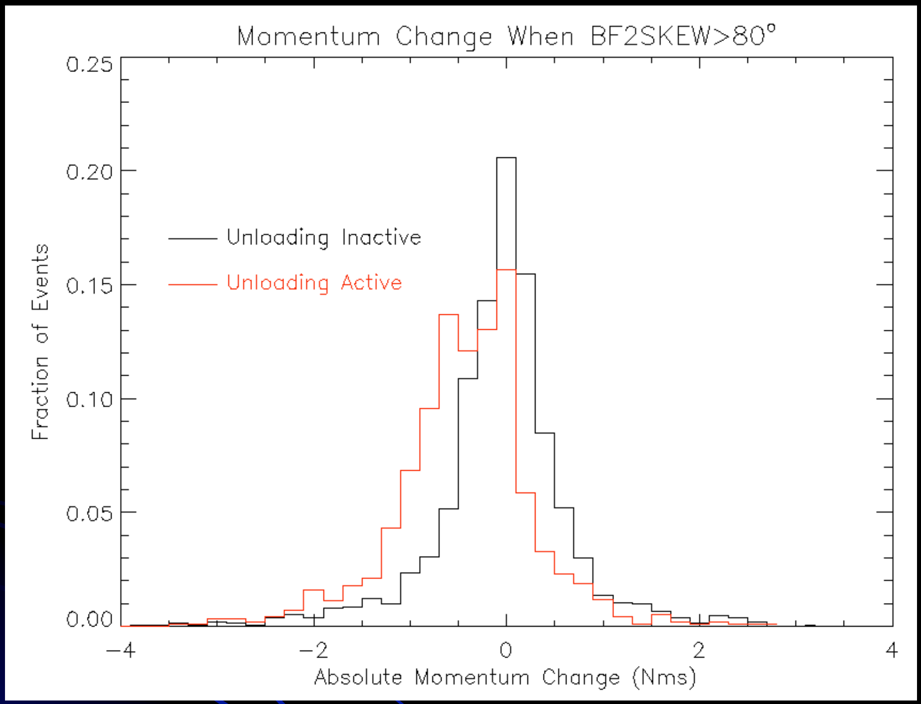
- With one reaction wheel, careful management of momentum is critical to operations.
  - Everywhere we point either spins the wheel UP or DOWN.
  - Momentum is managed primarily by selection of pointing direction as a function of time.
  - The higher the wheel speed is, the harder it is to slew.
  - Unpredictability of momentum behavior can make operations difficult. (The case as of the last FOAC meeting.)
  - Since MTBs are needed for control, their usefulness for momentum management has been limited.
- The new ACS E33 improvements and empirical unloading tests have now improved momentum behavior and management techniques and thus improved operations.

B-field-to-Skew angle Sensitivity



(T. Civeit)

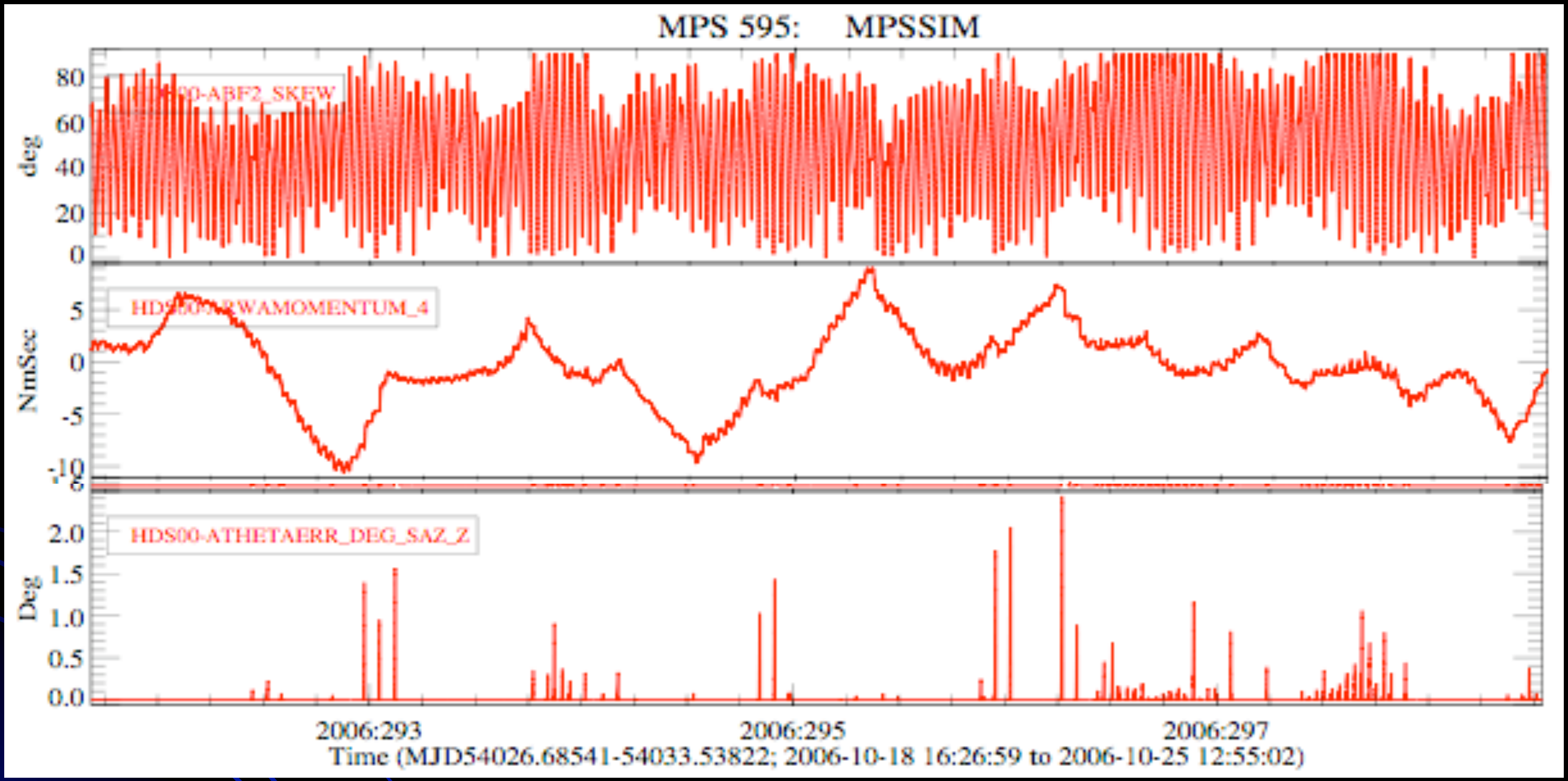
Aggressive Unloading



- No unloading: typical high BF2S passes have +/-2 Nms impact on the wheel.
- Aggressive unloading: whenever BF2S angle is above threshold, dump momentum.
  - Each high BF2S pass has a small impact on reducing wheel momentum.
  - Collectively, many such passes can actually have a significant impact on managing momentum!

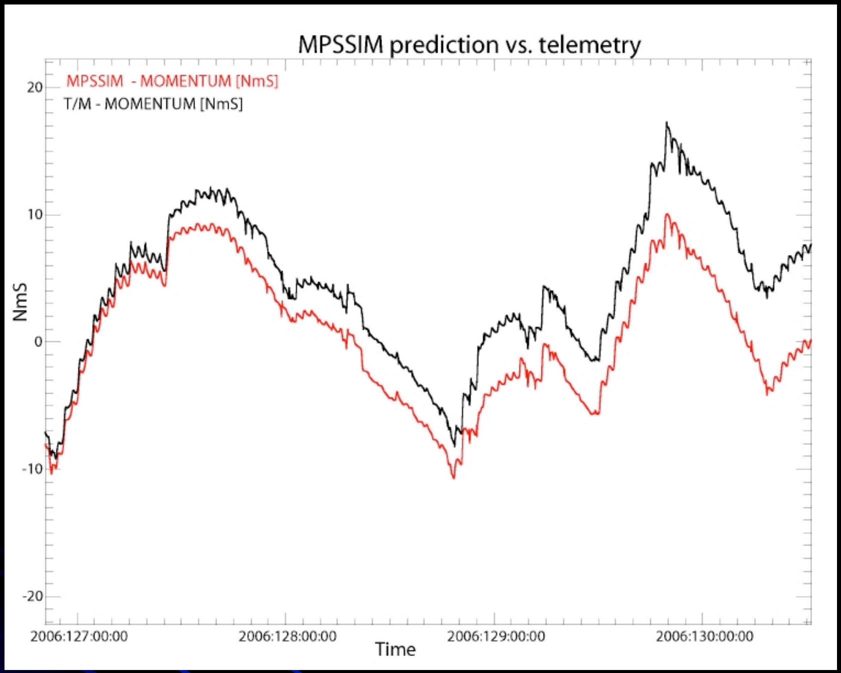
- Testing has shown that aggressive unloading ***<u>does not</u>*** add significant periods of bad pointing but does (collectively) help reduce the wheel momentum!

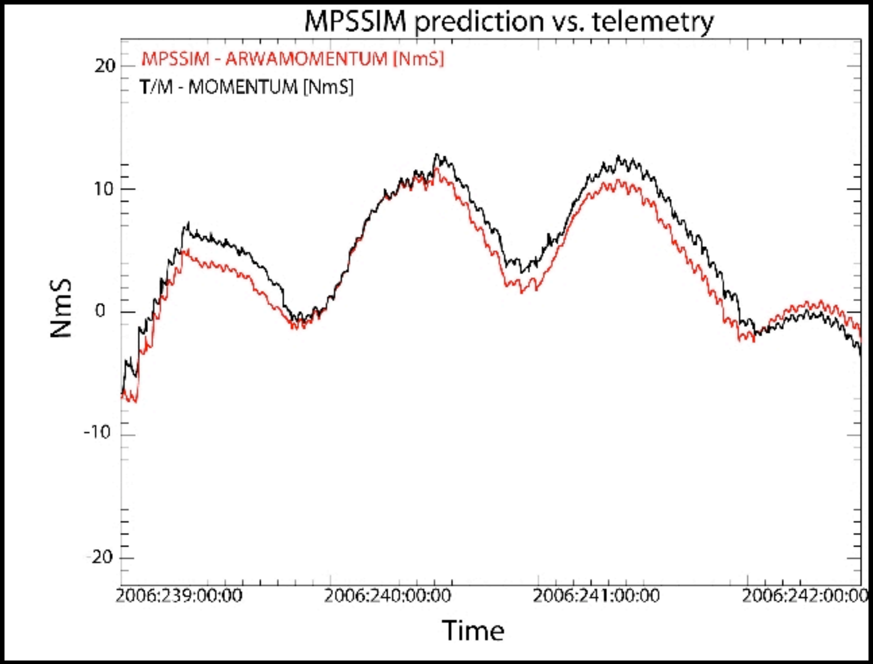
Typical current timeline



- Aggressive unloading is now left “on” as the default and is helping significantly in keeping wheel momentum in bounds.

Momentum Mgmt. Improvements





April 2006 **August 2006**

Fewer excursions from predicted behavior; lower overall momentum on the wheel:

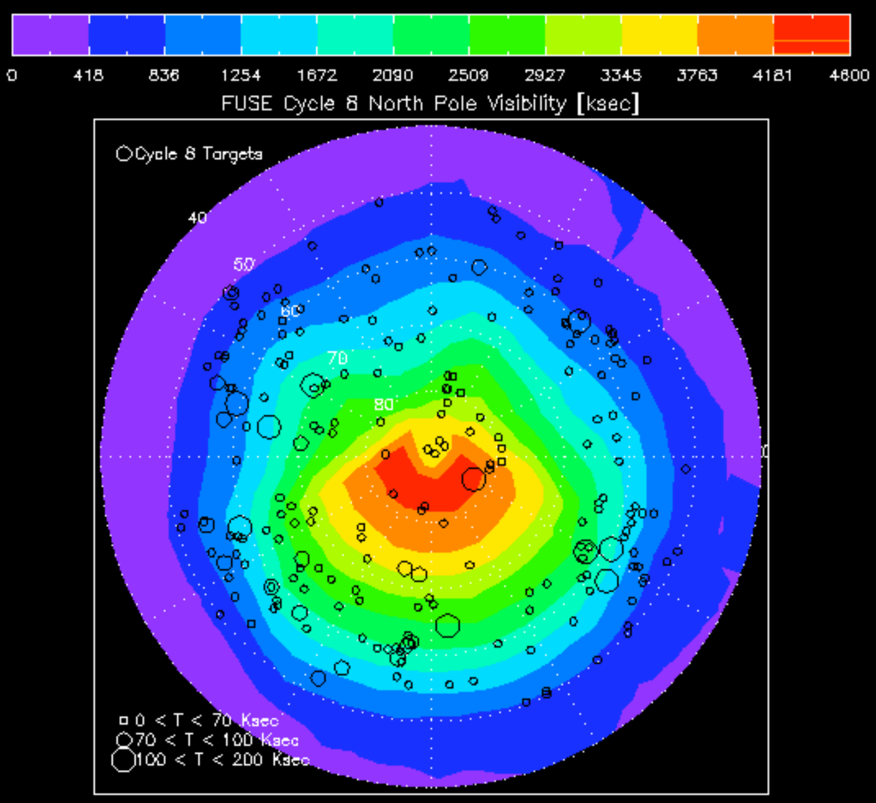
1. **Fewer momentum interventions**
2. **Fewer trips into Attitude-hold or safemode**
3. **Improved scheduling flexibility and performance**

MP Tool Improvement-LRP

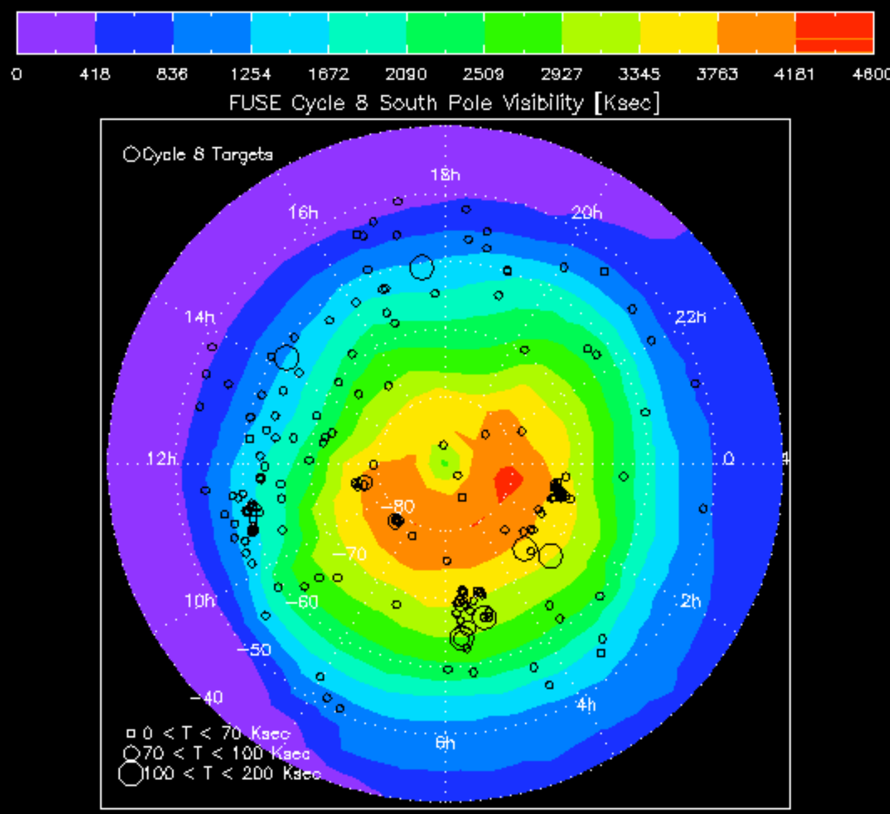
Spike/Long Range Planning Tool has been upgraded.

- Still performs the “year” view, but provides improved control and insight into first 4 weekly bins.
  - Effectively provides an “intermediate planning” capability, where the first four bins can be treated in more detail, and with different constraints.
  - Provides more insight to the MPers as they create MPSs.
- Improved procedures: Run separate LRPs for “science” targets and for S/U (“filler”) programs.
  - “Guarantees” the filler programs cannot impact scheduling of science, but keeps full information at MPers fingertips.
- Future improvements: feeding better “windows” information to Spike, especially of long observations and problem targets.

Cy8 Proposed Targets and Visibility

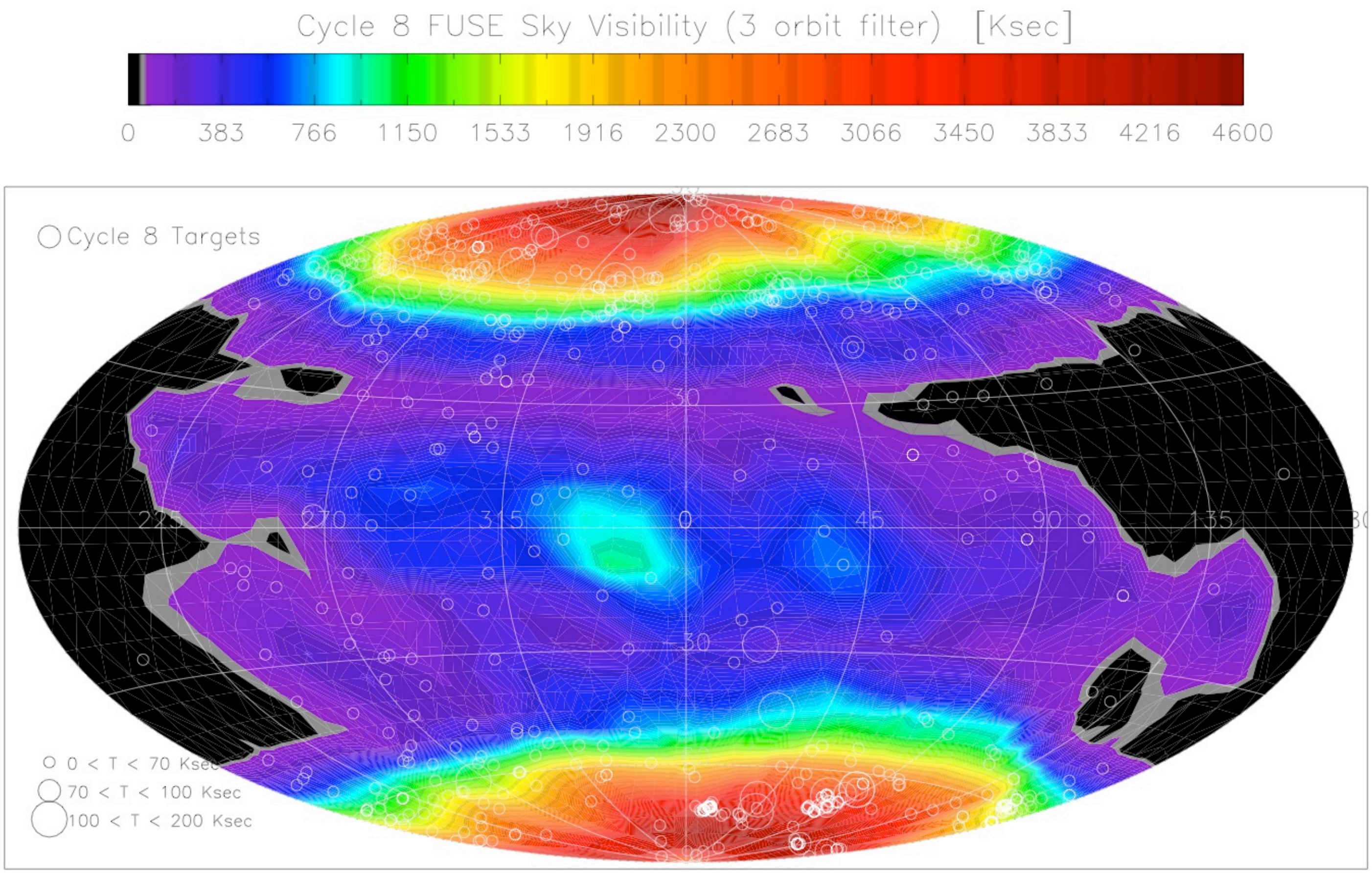


Northern Cap

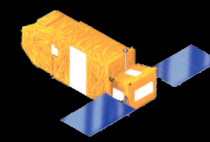


Southern Cap

Cy8 Sky Coverage w/Targets

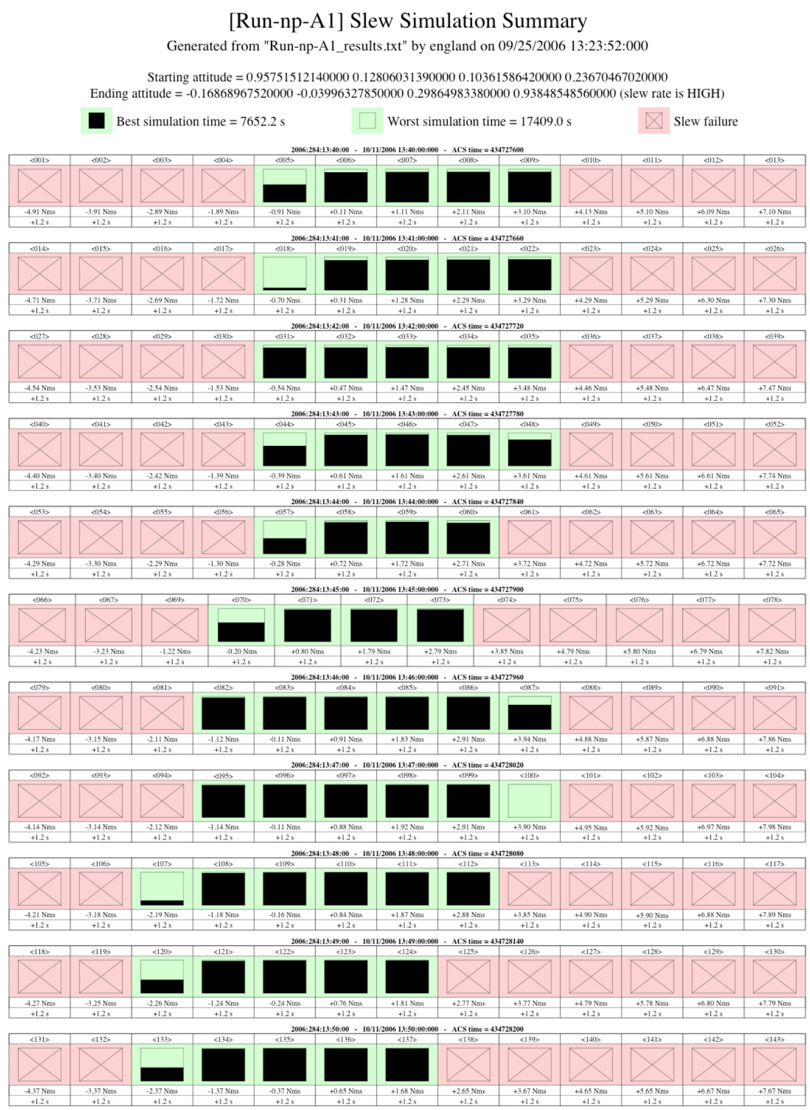


MP Tool Improvements

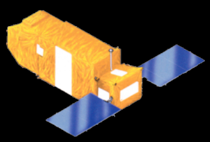


Hemisphere Crossing Slews

- Use <u>safeslew</u> (quick look tool) to identify times when conditions look promising.
- Use HDS (higher fidelity s/c simulator) to verify quick look assessment.
- Calculate matrix of slews around the nominal good slew case to establish allowed range of parameters that will work.
    - Actual conditions at the start of the slew cannot be predicted with complete accuracy.
    - Grid allows real-time decisions to be made effectively at the time of the slew.



MP Tool Improvements, con't.



Short Term Scheduling

- Our current short term scheduling methodology has adapted to numerous changes.
- STSing is still a complicated, hybrid process, involving many variables and significant manual effort.
  - In particular, ordering of targets and timing of slews is largely a manual process.
- Development/testing of a new STSing tool: SOVA
  - (Scott Heatwole, NASA Wallops)
  - Can sort through and try many options, optimize ordering, etc. (Solves "traveling salesman" problem.)
  - If it can be trained to handle the numerous FUSE constraints properly, could significantly reduce effort to produce MPSs.

Opening Sky Coverage

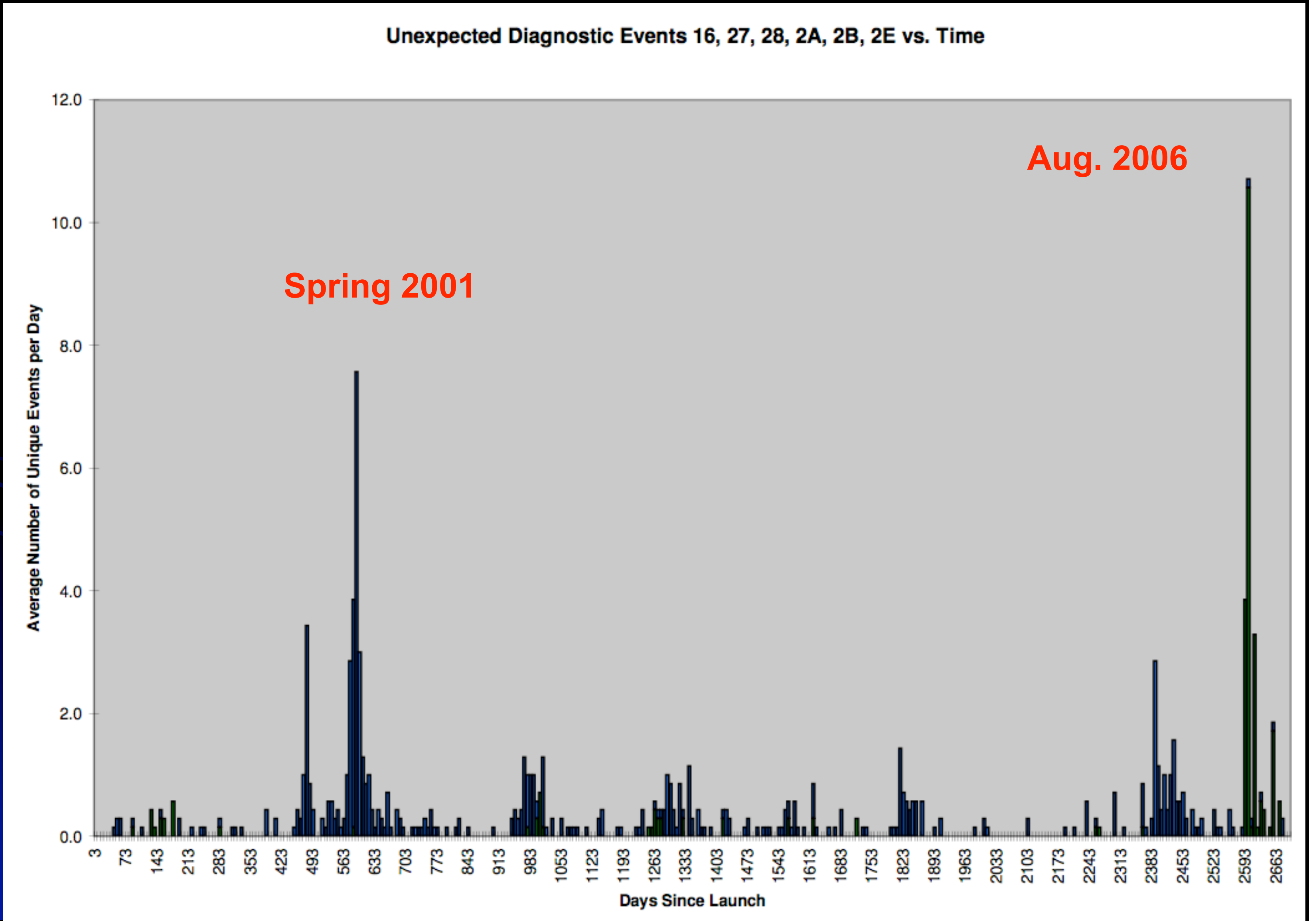
- <u>Primary requirement</u>: demonstrate we can slew to (and from) lower declination regions which have predicted (temporary!) stability and still have enough time to make an observation.
- At present, can perform simulations (as with hemisphere-crossing slews) to assess expected performance and range of allowed parameters.
- Currently performing a case study to set the stage for an actual test of this capability.
- One last version of ACS s/w (E34) will contain several alternate slew algorithms that MAY provide improved performance on these specialized slews.
  - [aside] Will also provide a safer method for proactively placing the satellite into LVLH.

Detector HV Mgmt Improvements

- FUSE detectors are tricky beasts to manage.
  - Galex and COS detectors are similar.
  - “Crackles” and “mini-crackles” happen sporadically over the lifetime of the mission.
  - Crackles cause temporary shutdown of a given detector, which is then brought back up with manual intervention.
- Detector 2[A] has been particularly sensitive.
  - Quit raising HV on detector 2 in 2001 (so no gain sag control).
  - August 2006: had a significant (but temporary) event where we had difficulty for about 7-10 days in getting HV back up.
  - This segment has continued to be somewhat noisy compared with the historical average, although has been in full use since that time.

Detector Crackles vs. time

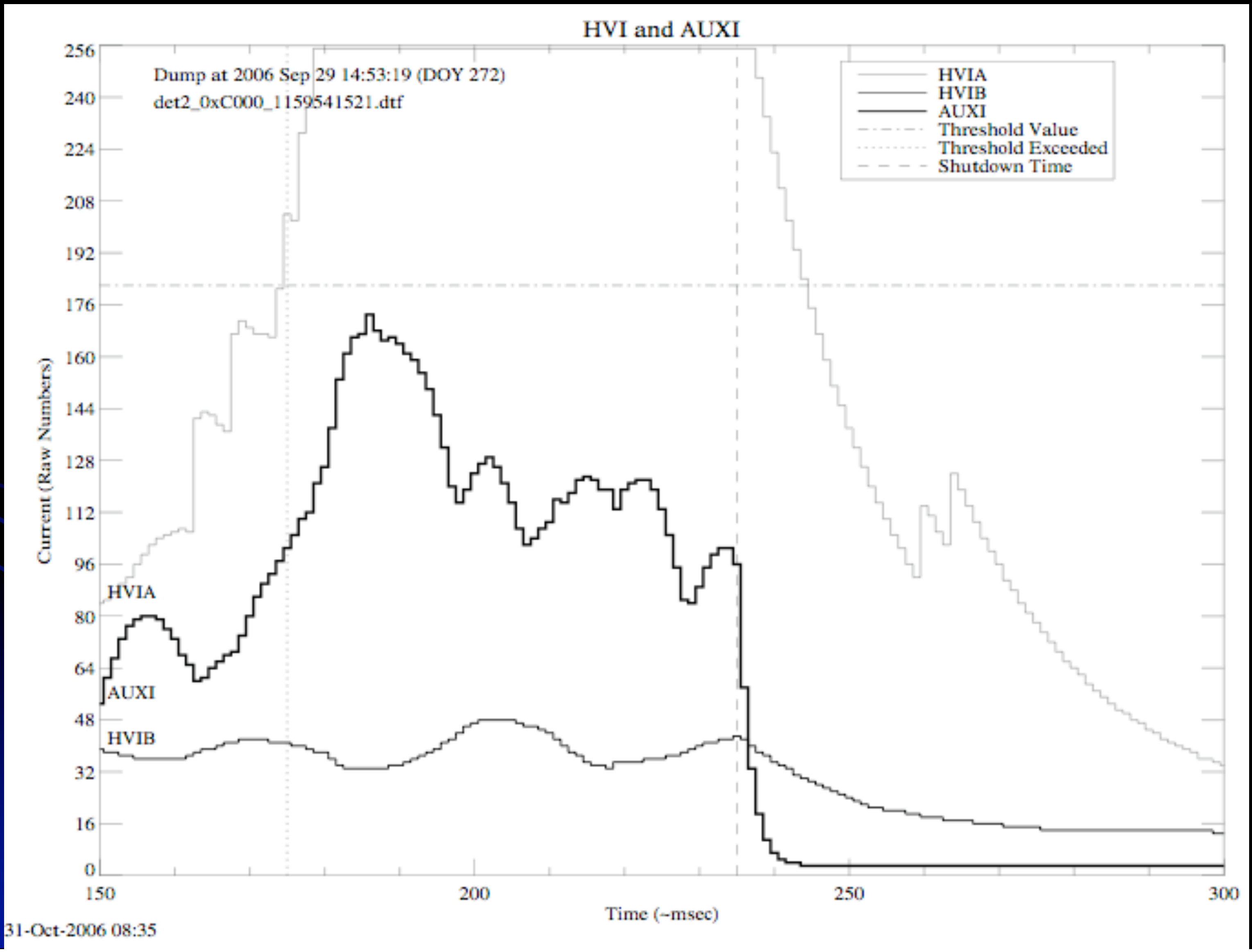
(includes mini-crackles)



Detector 2 HV mgmt.

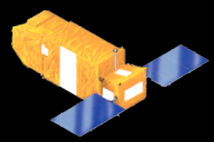
- With reduced staffing, detector shutdowns have more significant impacts than in the past.
  - Weekend shutdowns can cause loss of 2-3 days of data on detector 2. (Since we guide on side 2, this can be significant.)
- Have taken two tangible steps to reduce impacts.
  - Modified detector code to provide longer persistence times.
    - Decrease the number of unnecessary shutdowns.
    - (Involves a memory poke to existing detector code. Testing and verification took better part of two months.)
  - Implementing scripts to enable and monitor auto-HV ramp-up.
    - Decrease the DOWNTIME from any shutdowns that do occur.
    - Partially developed earlier in the mission, but never fully implemented.
    - In final testing and should be in place soon.

Short Persistence example



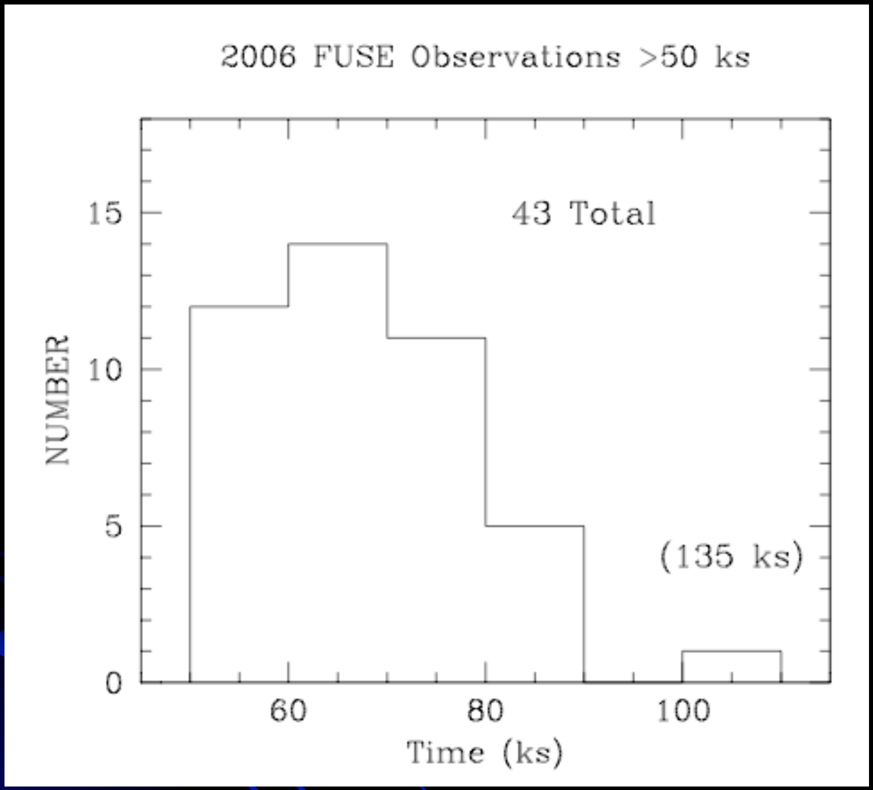
(Dave Sahnow)

Extended Operations?



- Ongoing development is being done to improve operations for the *<u>remainder of the approved mission.</u>*
- However, it has an undercurrent of application for potential post-2008 operations as well.
- ACS E34 Development
  - Several new slew algorithms (add flexibility to scheduling).
  - Safer LVLH entry slews (for parking satellite safely).
- More automated Mission Planning Schedule generation.
  - SOVA -- to permit short term scheduling with less effort and fewer personnel
- Long Observation Scheduling
  - If science to be done is driven by this, we need to understand what can be done.

2006 Observations >50 ks



- So far in 2006, FUSE has obtained 43 observations in excess of 50 ks.
  - 25 primary science, 18 S/U
- Many of these were scheduled for momentum management reasons rather than observer request.
- On the other hand, neither were long observations being forced into the schedule.

Long observations CAN be scheduled with FUSE.

The keys are 1) target distribution, and 2) prioritization.

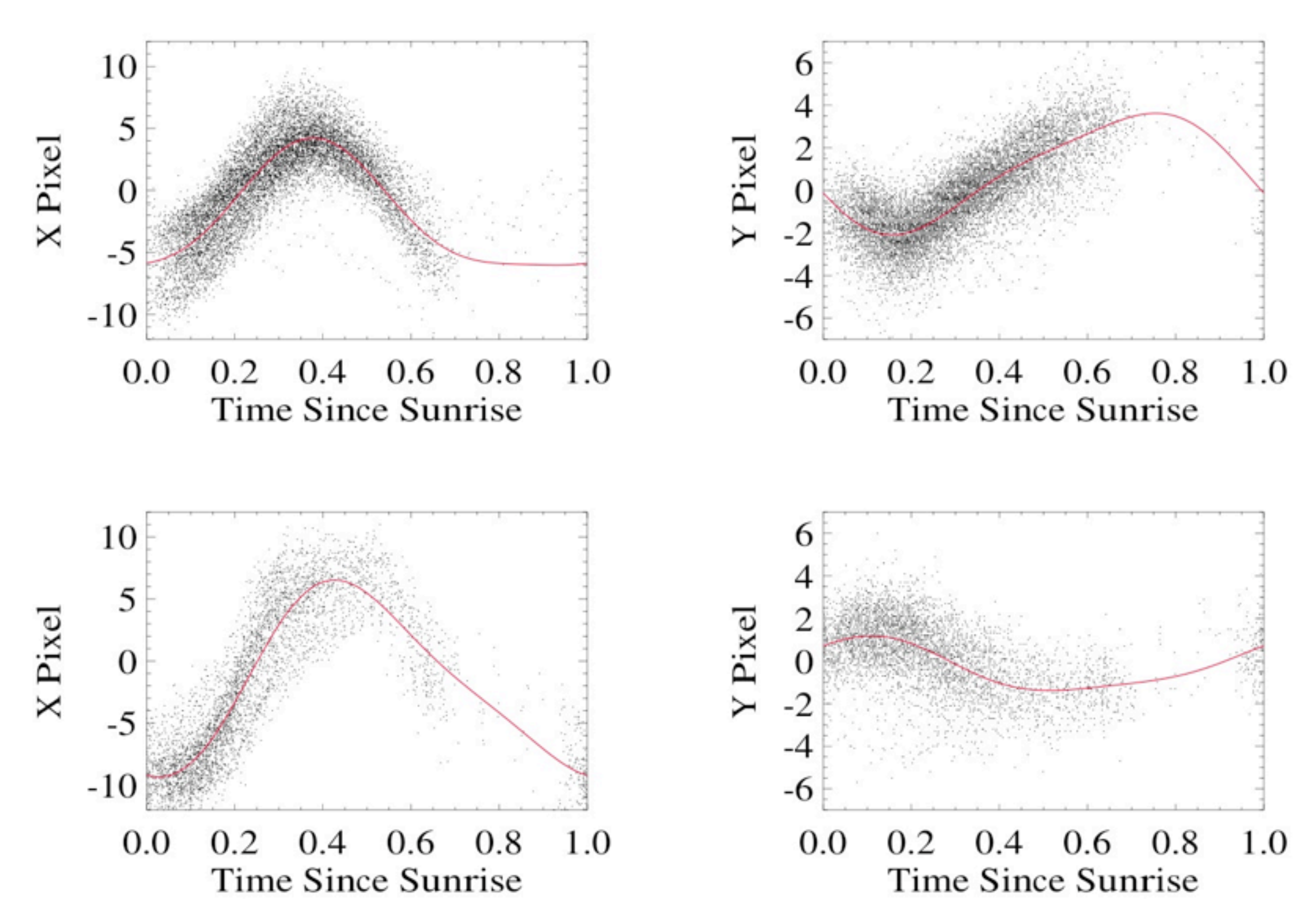
Odds and Ends

- Channel Alignment
  - We spend much more time at high beta (antisun) angles now, where the channel alignment is poorly behaved/characterized.
  - Improved alignment “scan” procedure implemented that works better in one-wheel mode.
  - Try to schedule an alignment activity on each (weekly) MPS.
  - Working on a revised alignment model to improve predictive mirror motions.
- HDS slew study to determine whether hard criteria on allowed slew torque margins can be relaxed.
  - Currently require 100% positive torque for planned slews.
  - This study implies a relaxation to 85% is tolerable.
  - Will provide improved flexibility in target selection and ordering by MPers.

CalFUSE 3.2 Status

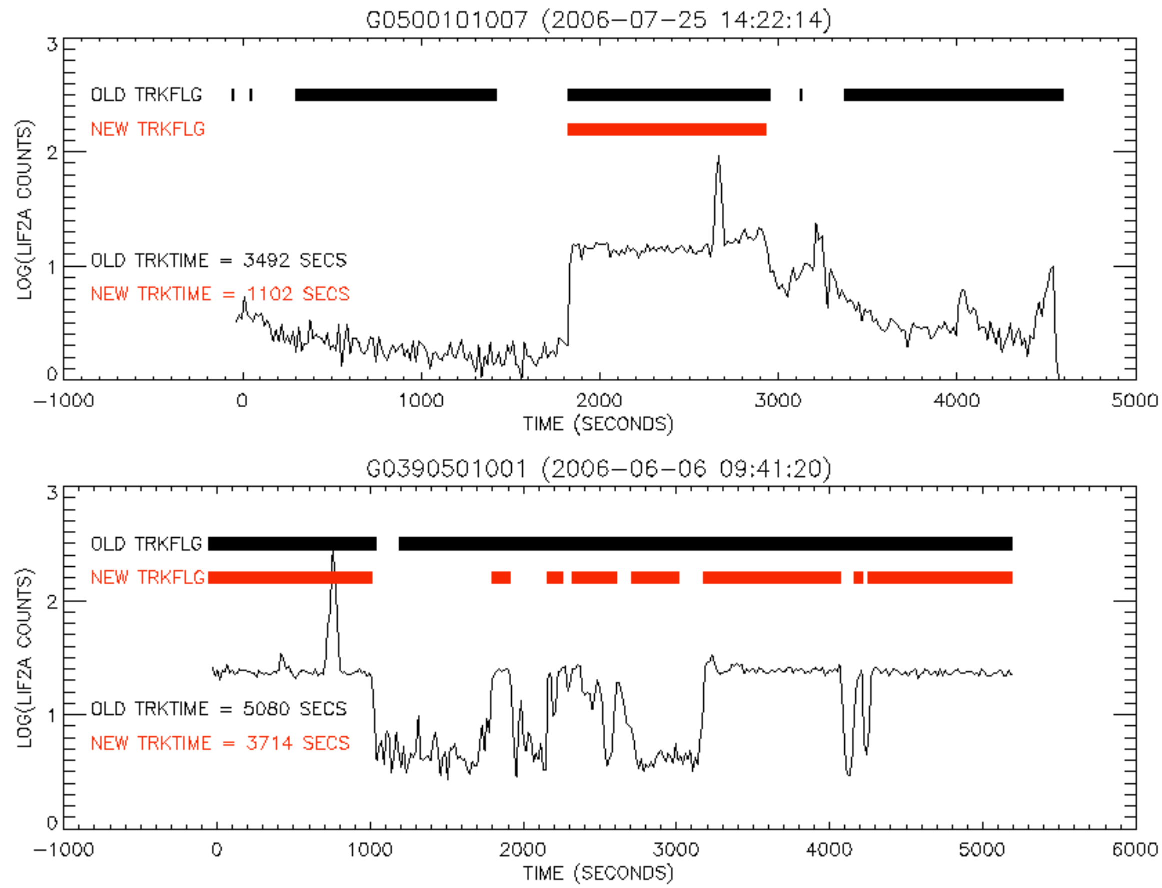
- Release of CalFUSE v3.2 has been delayed due to several factors.
  - New grating-motion calibration files: will significantly improve the zero-point stability of the wavelength scale. (Next page.)
  - A new pipeline module corrects for time-dependent changes in the detector X and Y scales (important early in the mission).
  - New algorithms for constructing and interpreting the jitter files will improve the spectral resolution and photometric accuracy of FUSE spectra. (2 pages forward.)
- CalFUSE PASP paper was submitted and received a positive review, but finalization and re-submission awaits final changes above.

Grating Motion Systematics
(for two beta-pole-roll combos)



(Dave Sahnow)

Good Time Selections



(Tom Ake)

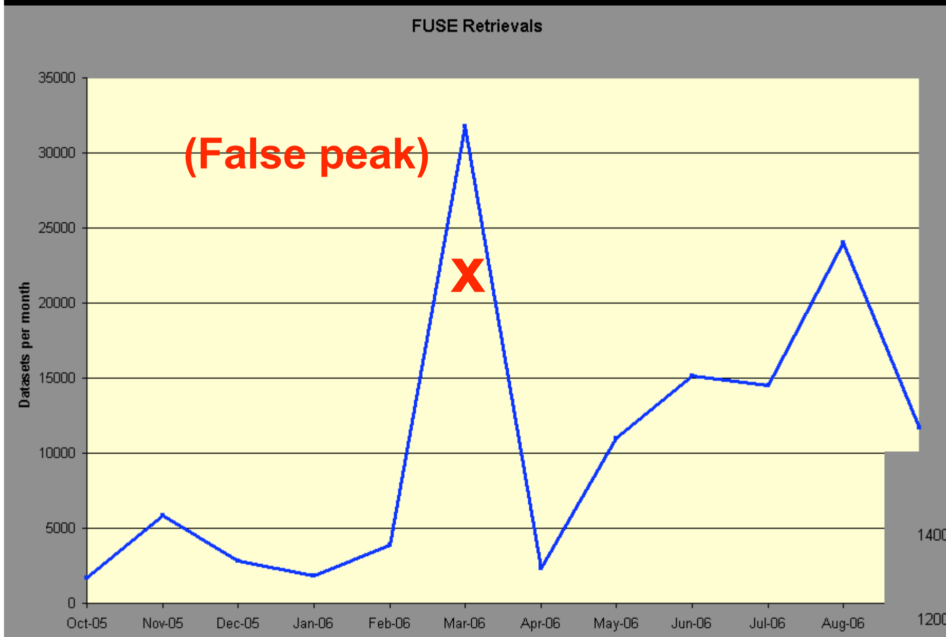
CalFUSE 3.2, con't.

- On-line documentation of the pipeline has been completely rewritten. The new web pages will be installed once the pipeline is released.
- Schedule for completion:
  - Nov. 2006: finalizecoding and test changes.
  - Dec. 2006: Move into operational area and test.
  - Jan. 2007: Release CalFUSE 3.2 to public; begin bulk reprocessing of all FUSE data with CalFUSE 3.2.
  - Complete reprocessing by end of calendar 2007.

MAST Data Status

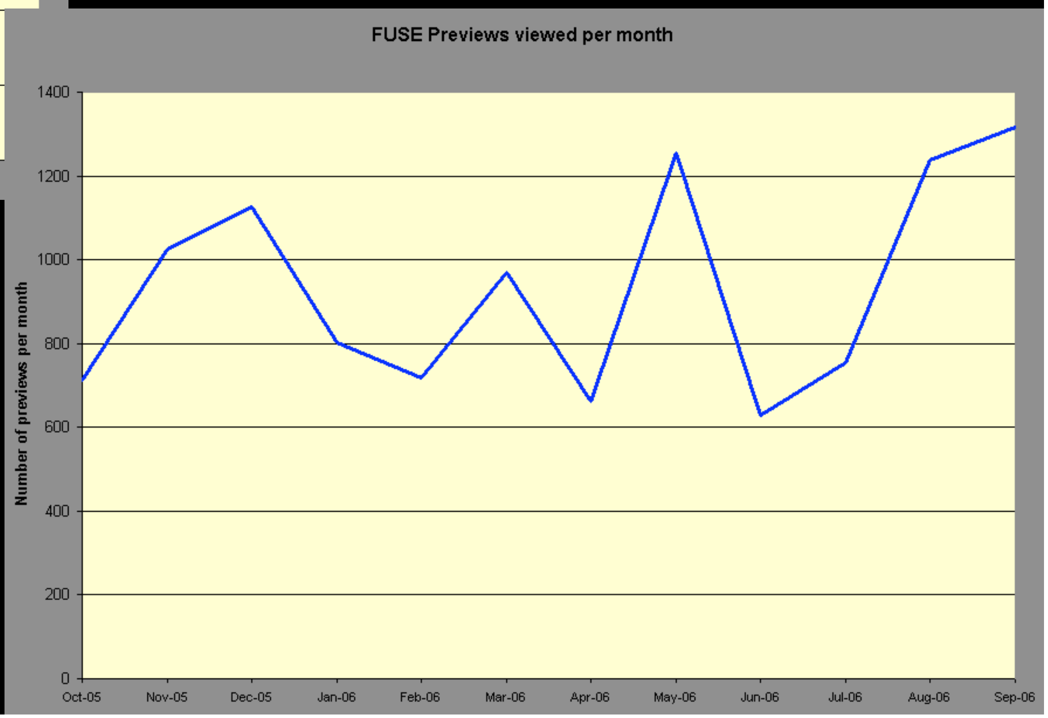
- As of 30 October, 4574 observations are archived at MAST.
  - 1812 were processed with CalFUSE v3.1
  - 2746 were processed with CalFUSE v3.0
  - 16 were processed with earlier versions of CalFUSE (0.0035%)
- We still lack housekeeping files for the periods
  - April 16, 2000 to November 3, 2000
  - July 17, 2001 to December 2, 2001
  - These data require reprocessing from archived control center tapes to provide jitter correction. (Still in progress.)

MAST FUSE Stats

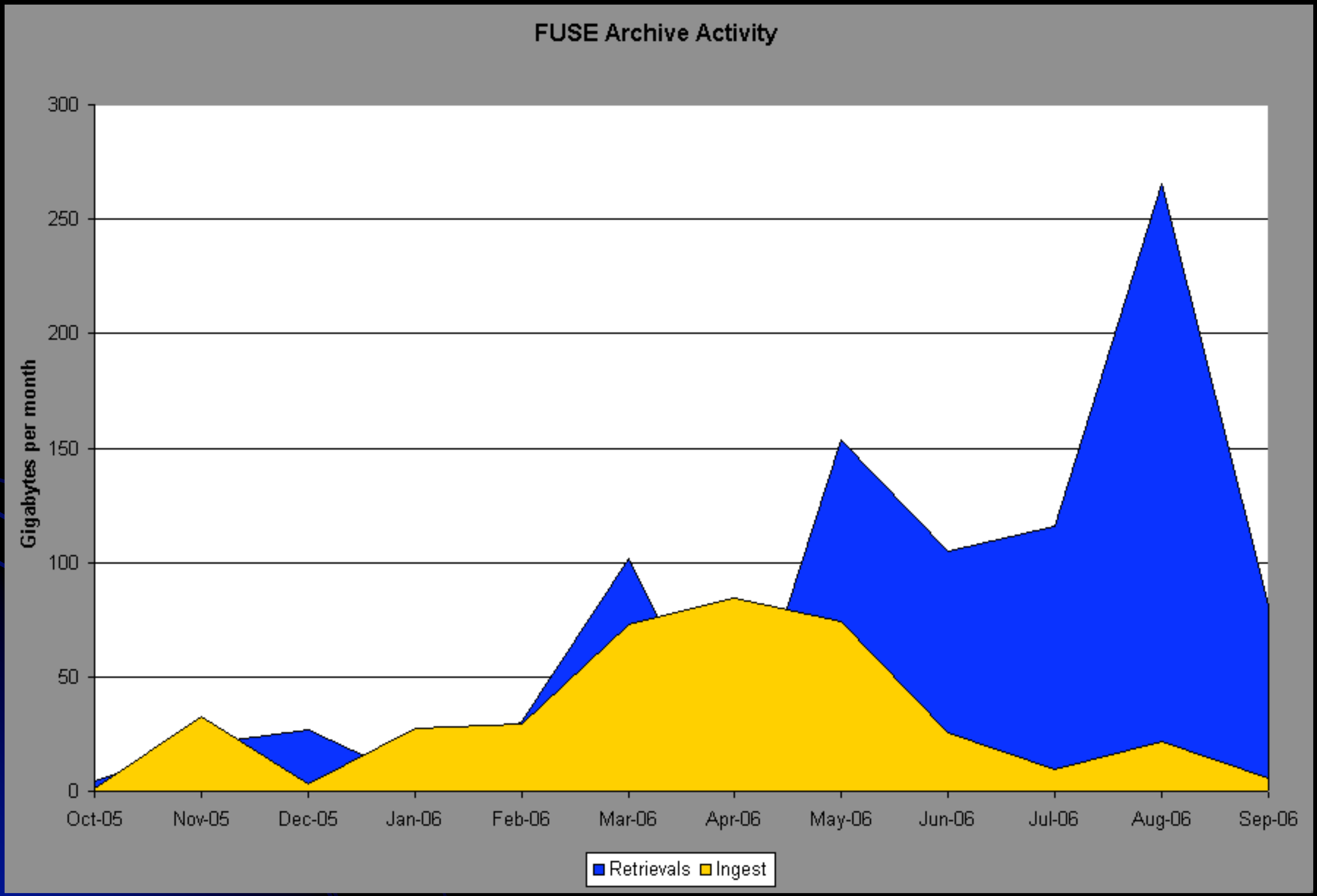


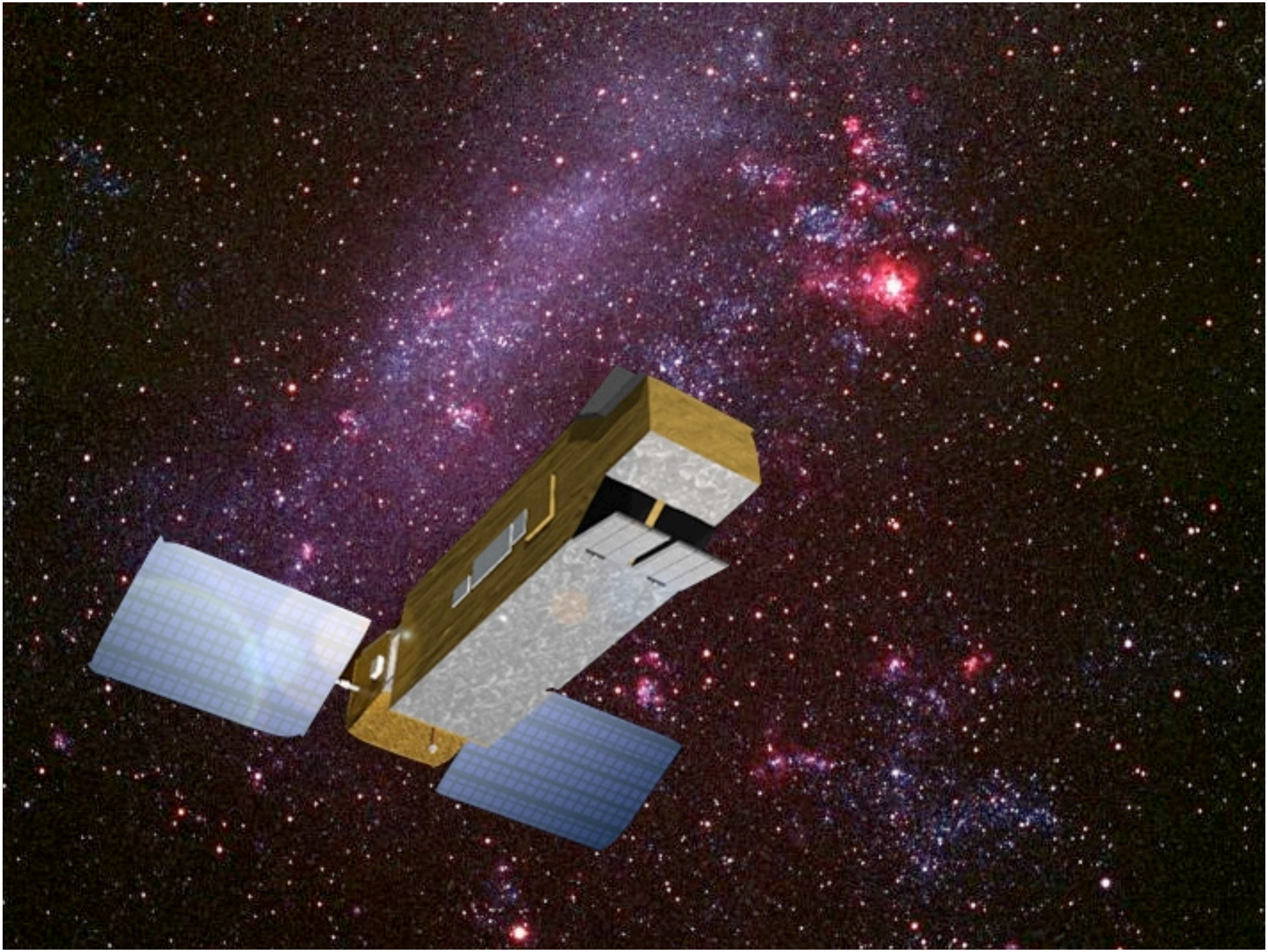
(below) Previews per month

(above) Data Sets per month

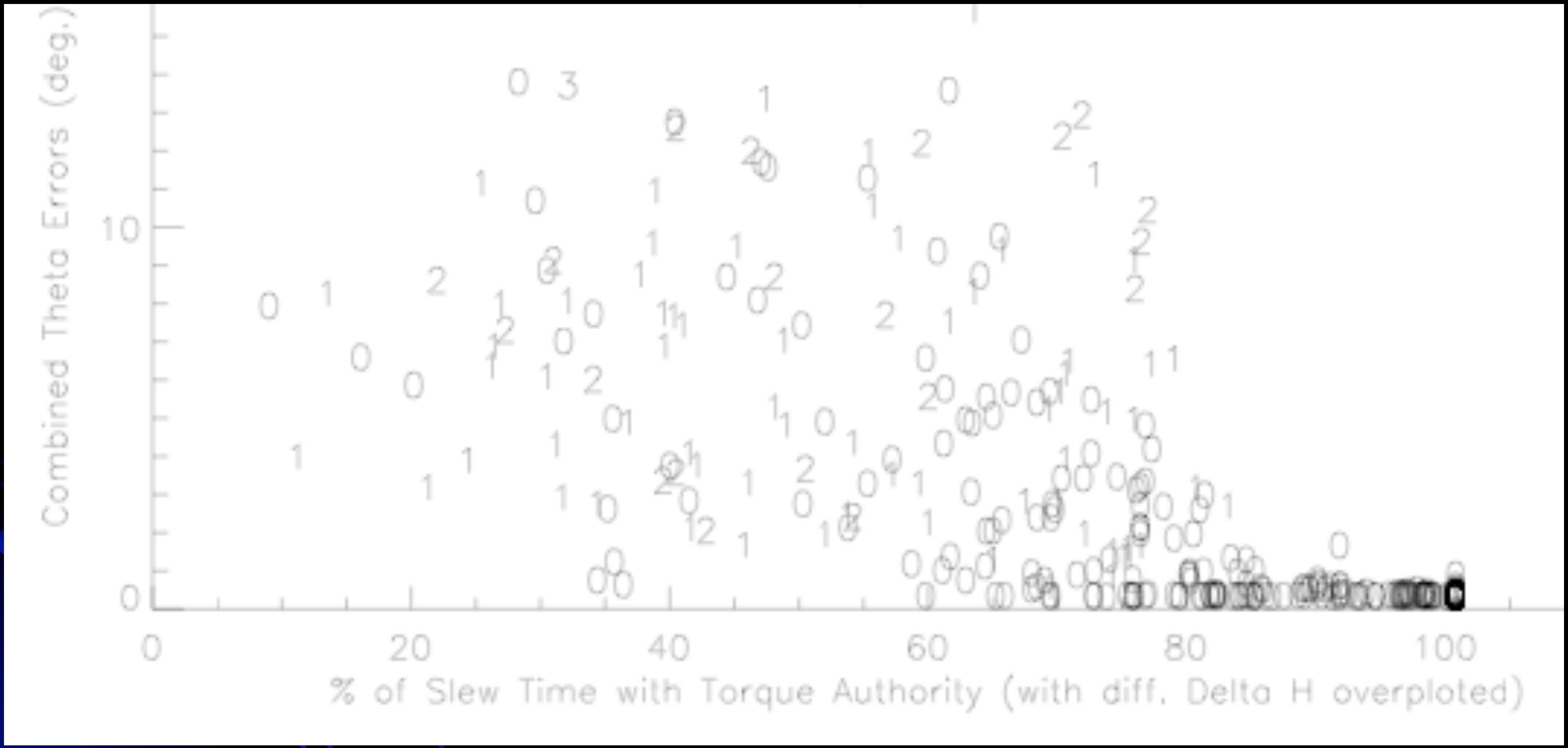


MAST FUSE Stats, con't.



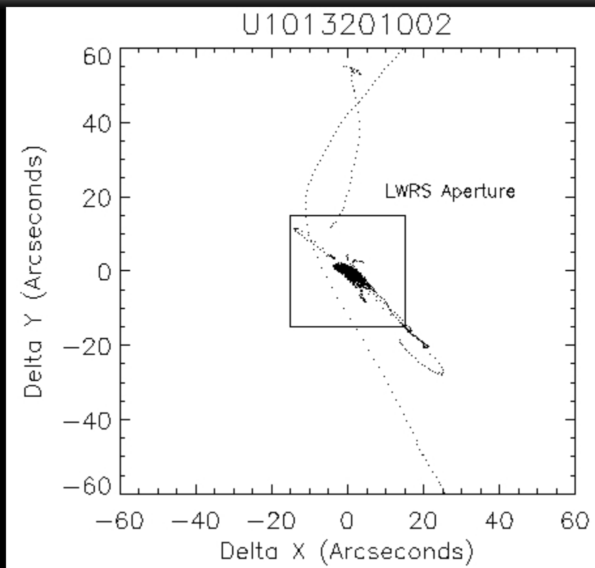


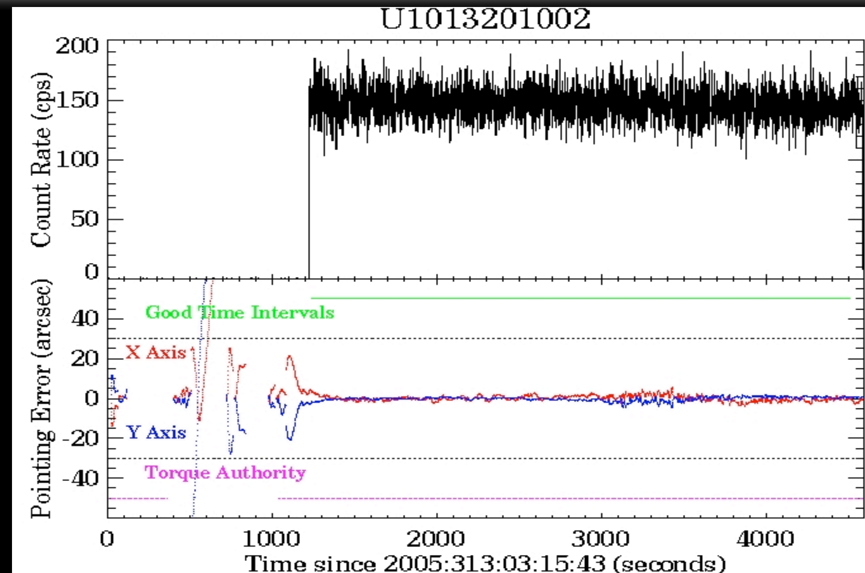
Slew Torques Allowed

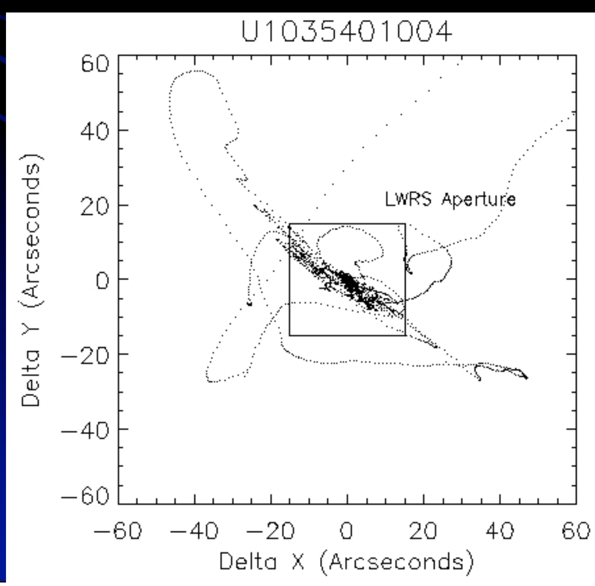


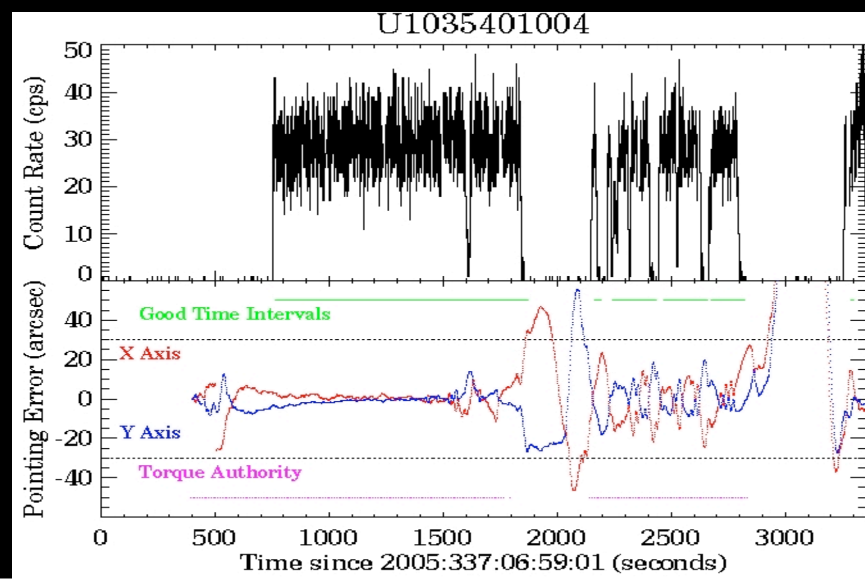
396 Simulated 20 degree slews.
Indicates we can likely decrease the threshold in allowed % Torque Authority when planning slews.

System Performance



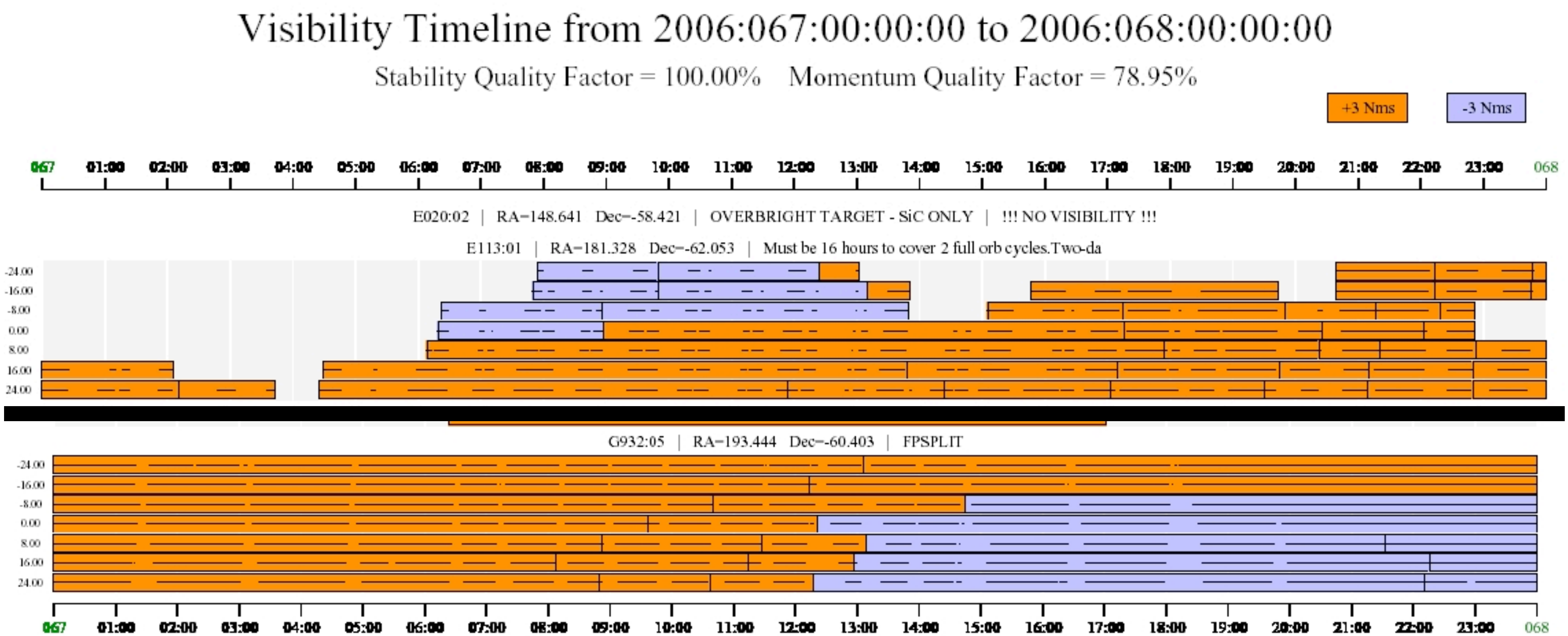






(T. Ake)

MP Tool Improvement



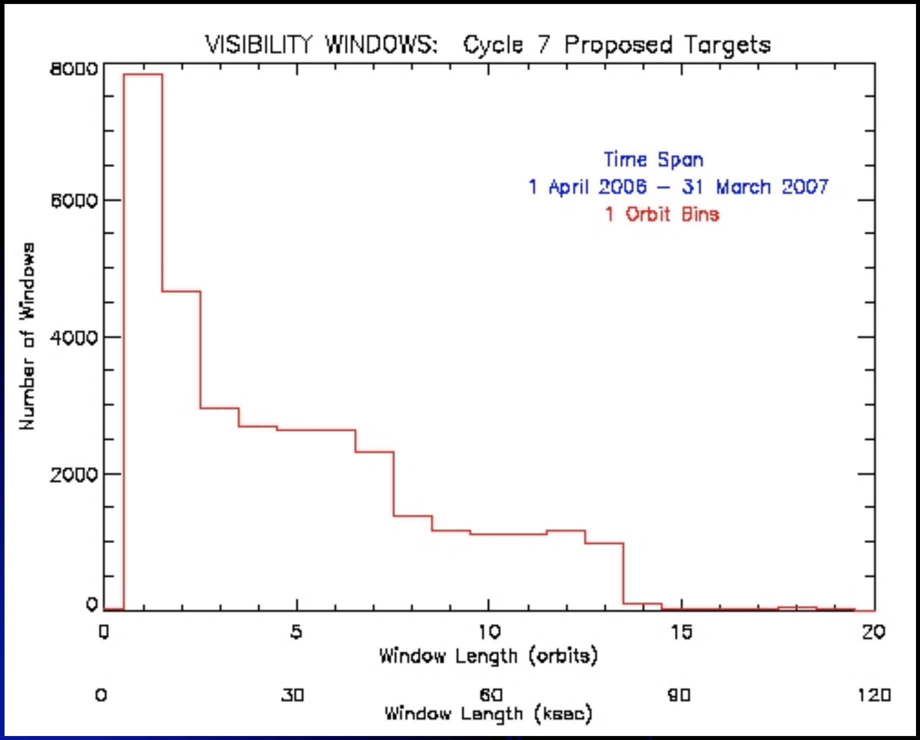
- Assimilating info on stability, momentum rate of change, and flexibility available from roll angle variations, on a target-by target basis and as a function of time, provides planners with nearly all relevant data at once.

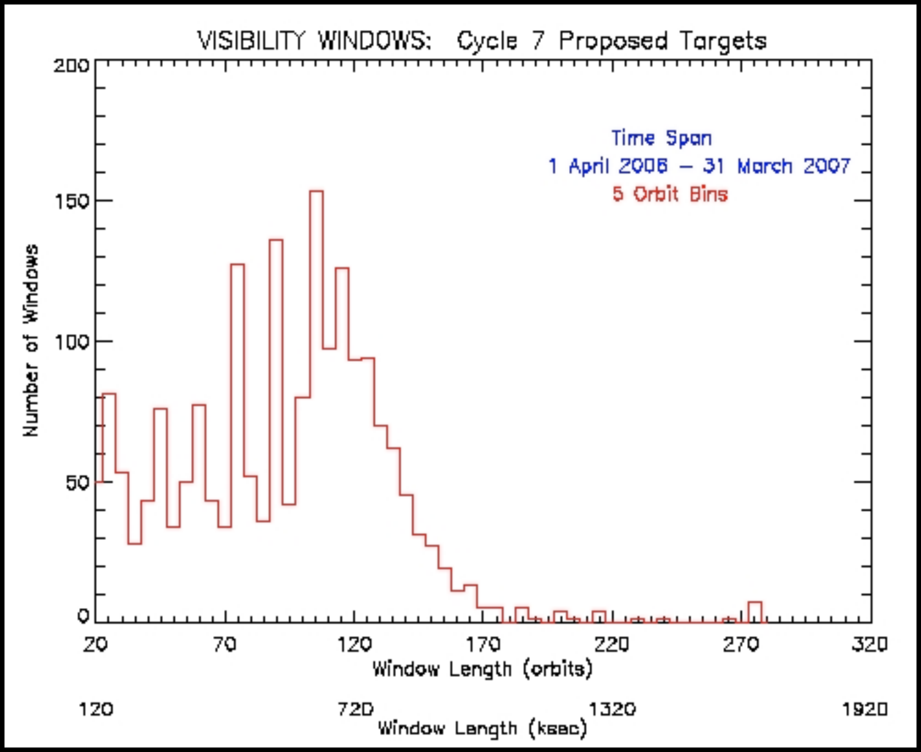
Long Observations

- Substantial effort invested in trying to scope this out but still not able to make very quantitative statements.
- There are target and scheduling condition combinations that allow long (upwards of 100 ks) observations to be scheduled in one period (say over a few days or so).
- Many targets have a distribution of visibility windows with 1-3 larger windows of ~50 ks and a number of smaller windows.
  - Requires a mechanism to lock down certain windows for certain targets.
  - The more of these there are, the larger the probability of conflicts.
  - Could easliy drive otherwise unnecessary N-S changes.
- Clearly some dependence on declination (>60° better than 50-60°).
- In SR06, we said "~10 obs. > 100 ks, with several as high as 200 ks" could be done per year.
- Bottom line: it depends on the specific targets, and on the priority assigned to them. (How hard should we work to get them?)

Long Observations:
Visibility Window Stats

- Using all proposed Cy 7 targets (as representative).
- Stability periods only--No Momentum mgmt included.



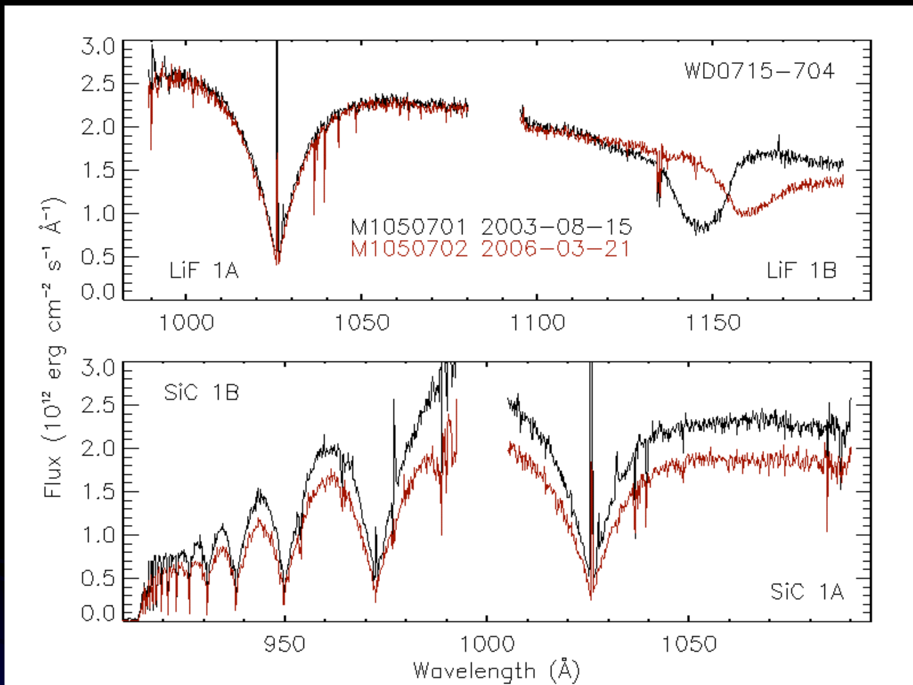


(M. England)

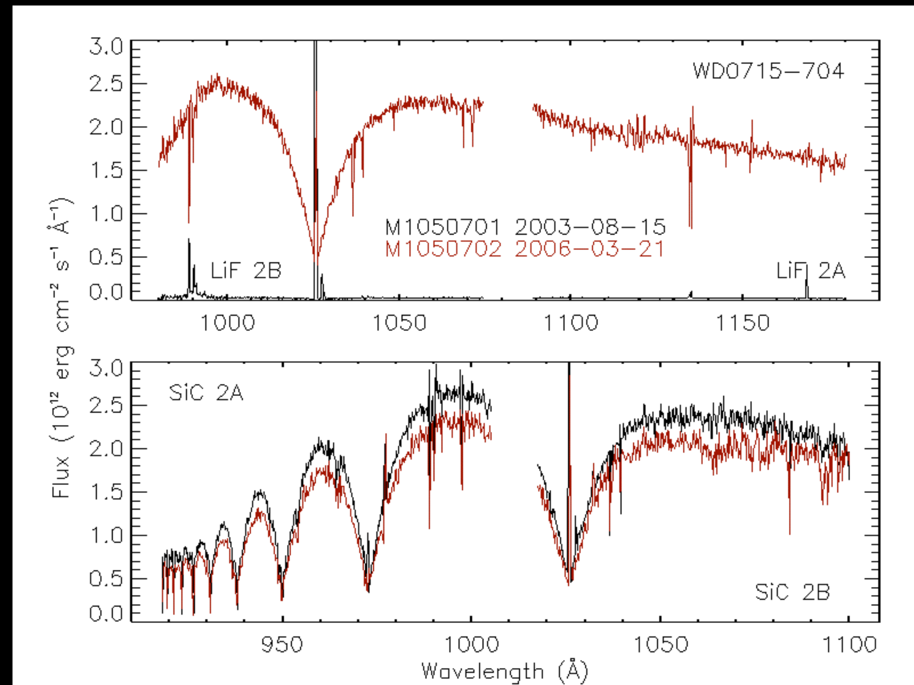
LVLH Safe Mode

- LVLH (Local Vertical Local Horizontal) is a nadir-pointing, non-inertial safe mode.
- Because it in not an inertial pointing mode, transitions back from LVLH to an inertial pole-pointing (pick up point) can be difficult to find.
  - Nominally “safe” slews are found with the HDS.
  - Number of opportunities “per day” are quite variable with time.
  - TDRS or other contact times must be arranged to monitor slew progress and attempt intervention if needed.
- Once at an orbit pole, we must “match momentum” with a planned timeline before picking up.
  - Typically end recovery slew with moderately high momentum on the wheel.
- Process has been automated since last FOAC, so potential slews are available if/when needed. (Substantial effort.)
- New (more robust and predictable) procedure just tried this week; may supplant previous method eventually.

Science Instrument Status



Detector 1

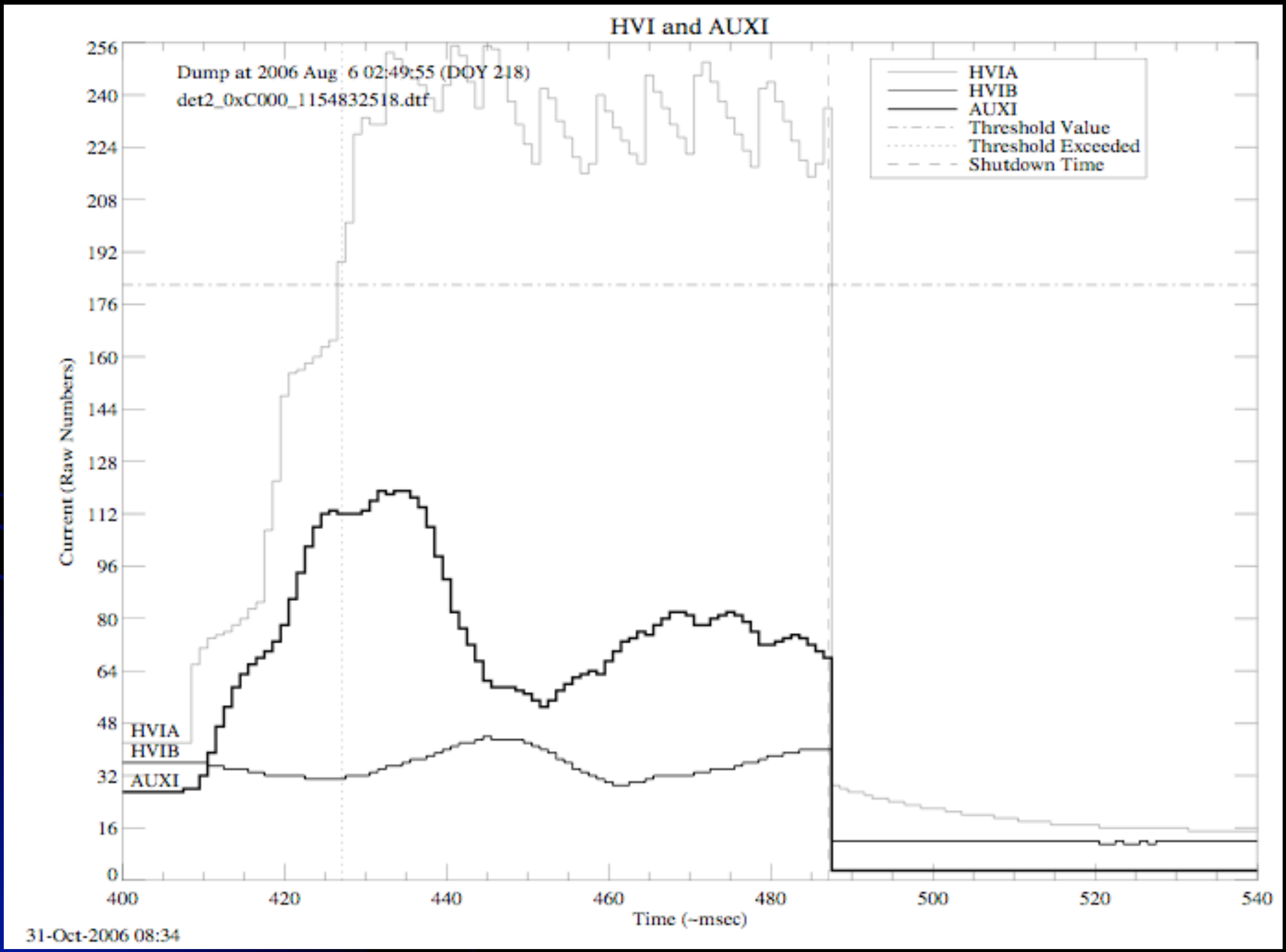


Detector 2

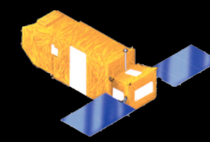
- M10507, WD0715-704, comparison of data taken in Aug. 2003 and Mar. 2006. (~2.6 years apart)
- LiF1-no change; SiC1 ~20%; SiC2 ~10% decreases.
- Consistent with what has been seen earlier in the mission.

(V. Dixon)

Short Persistence ex. #2



CalFUSE Status
(Van Dixon)



- Draft of CalFUSE article for PASP is circulating. Comments (soon) are welcome.
- Production version of CalFUSE is now v3.1.7; includes numerous minor bug fixes.
- By May 1, plan to release v3.2 together with new effective-area, background, and airglow calibration files.
- v3.2 is expected to be the baseline version, with only calibration file updates in the future.