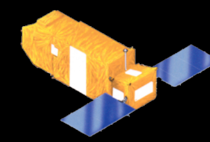
Far Ultraviolet Spectroscopic Explorer



The FUSE Observatory: Status and Update of One Wheel Operations

Bill Blair

FUSE Deputy-PI and

Chief of Observatory Operations

FOAC Meeting, March 31, 2006

FUSE--A Brief History

FUSE-Dec. 1999

FUSE-Feb. 2002

FUSE-~~June~~ 2005

October 2005

FUSE-Mar. 2004

FUSE--A Brief History

FUSE-Dec. 1999

FUSE-Feb. 2002

FUSE-Mar. 2004

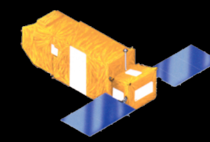
January 2006!

Outline/Themes

FUSE at KSC, May 1999.

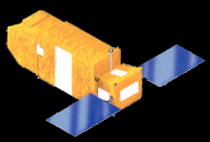
- Background/Terminology
- Status/Improvements since last FOAC meeting
- Momentum Management
- Operations/MP Improvements
- Performance Indicators
- Long Observation Strategy
- ACS/IDS Code Updates
- Possible Future Improvements
- Questions/Issues
- CalFUSE/MAST Status (Dixon)

One-Wheel Ops
A Primer



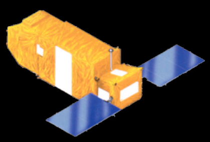
- Attitude Control System (ACS) is the S/C software that controls pointing.
- Only Wheel remaining is the Skew Reaction Wheel.
  - +/- 6500 rpm top speed (+/-21 Nms).
  - Higher wheel speeds mean more gyroscopic torques when slewing.
  - We plan so as to keep this below +/-15 Nms.
    - But Reality does not always follow what is planned!
- 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.
- Two-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.

Mission Status/Overview
(Since last FOAC meeting)



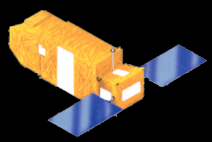
- Science Ops officially restarted Nov. 1, 2005.
- FES-B performance continues to be nominal.
- UPRM Ground station fixed and performance has been steady.
    - Increasing frequency for preventive maintenance.
- Automated/streamlined Safemode recovery slew calculation process. (Next pages.)
- Nov-Dec 2005 “Demonstration period” was difficult, but successful.
    - Got started on some science as we continued to learn.
    - Developed concept of (and tools for) “momentum interventions.”
    - Ops team pulled out all the stops, but nearly burned out.
    - Had to “park” the satellite over the holidays.

Mission Status/Overview
(continued)



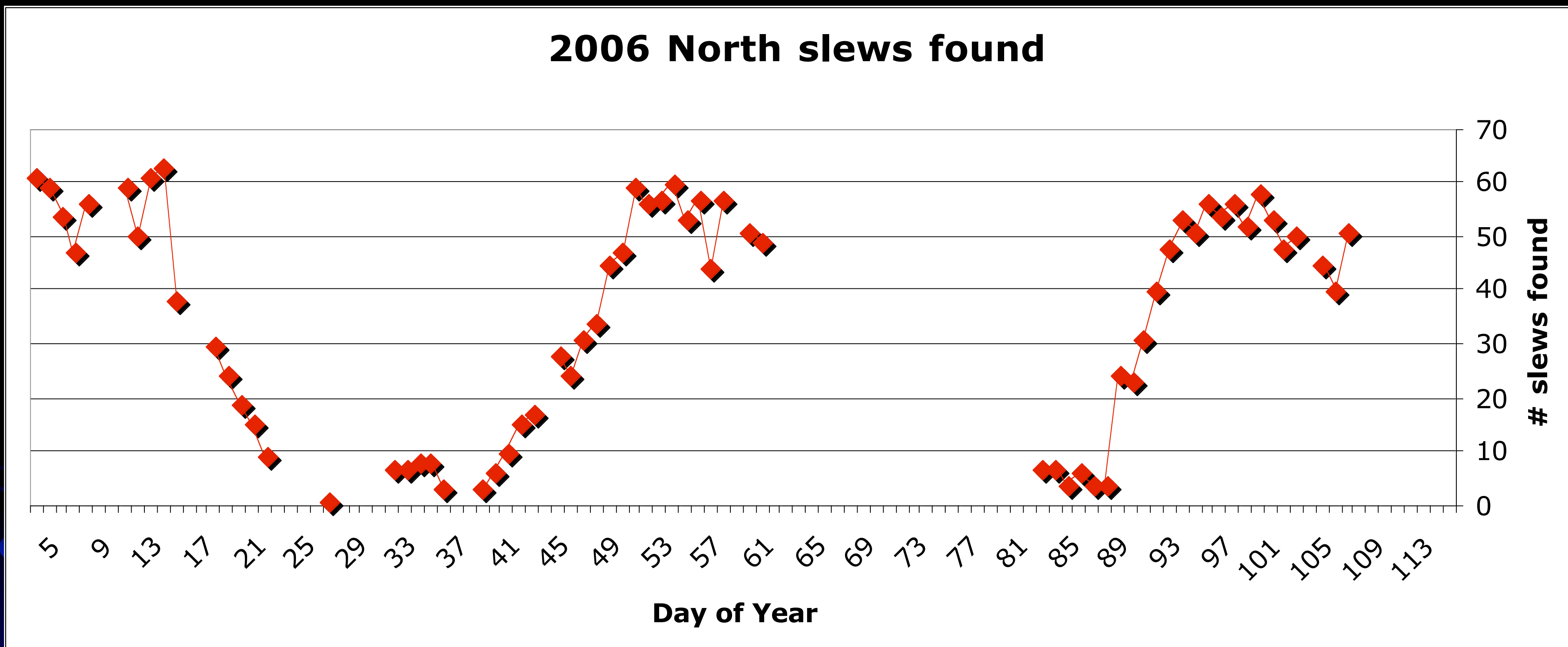
- January AAS meeting was a big success.
  - Special Oral session; 43 papers total.
- Operations have improved dramatically so far in 2006.
  - Fairly subtle change in MP software (mid-Dec) made a BIG difference.
  - Other improvements to MP software are having an effect.
  - JHU press release generated touting “Return to Operations.”
- NASA Senior Review was submitted Mar. 20.
  - Strong case for continued exciting science from FUSE.
- Latest and greatest ACS code (E33) and accompanying IDS script rewrites developed and tested; load occurred earlier this week.
- Instituting a revised methodology for aligning the channels.
- Victoria Proceedings (ASP) have just been delivered to the printer.
- CalFUSE/Reprocessing work has made good progress. (See end.)

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.

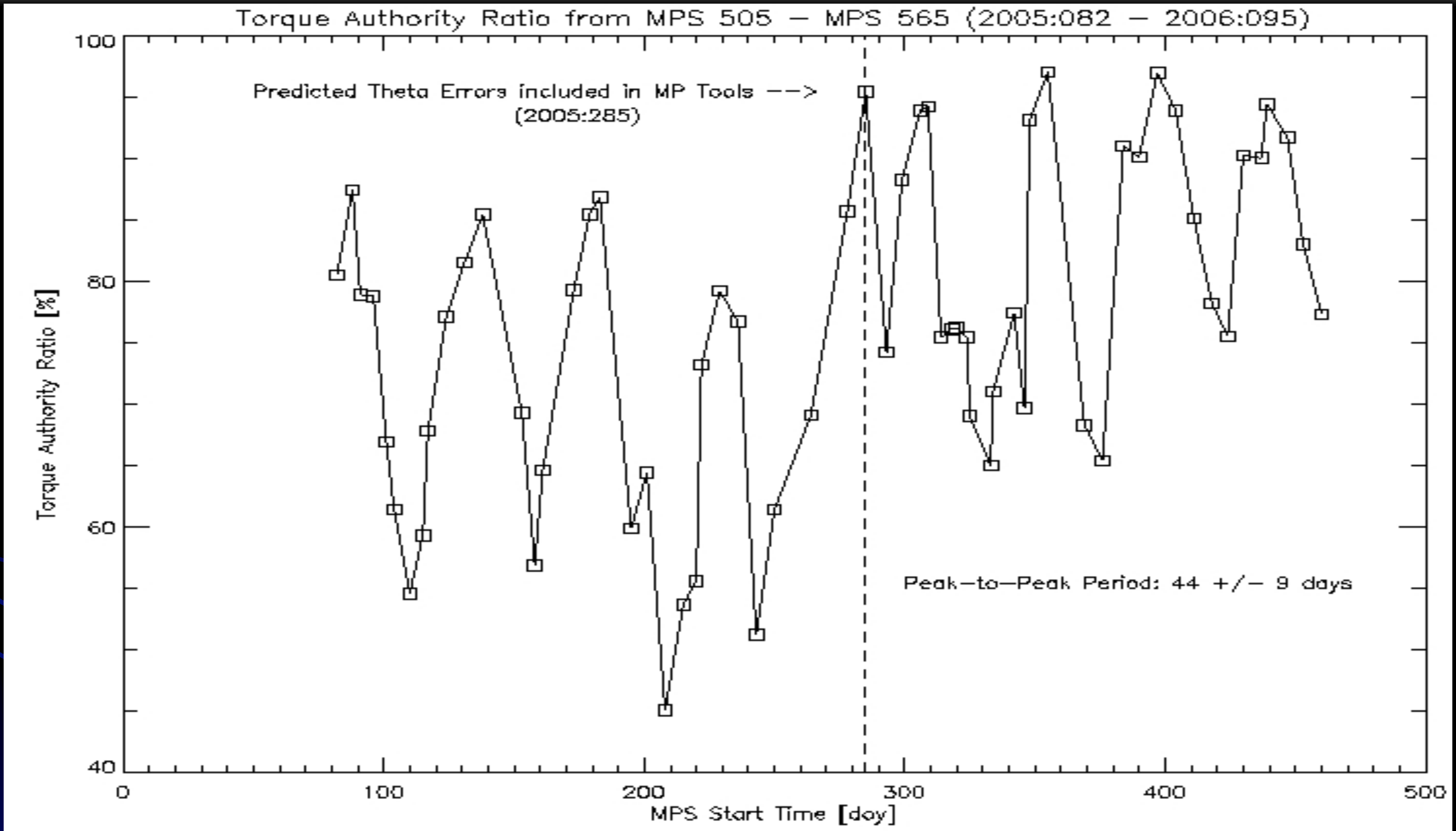
LVLH Recovery Slews vs. Time



Empirical result: Number of recovery slew available per day varies with ~45 day period.

(M. Kochte)

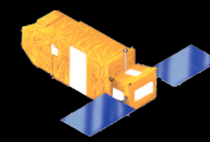
MPS TA vs. time

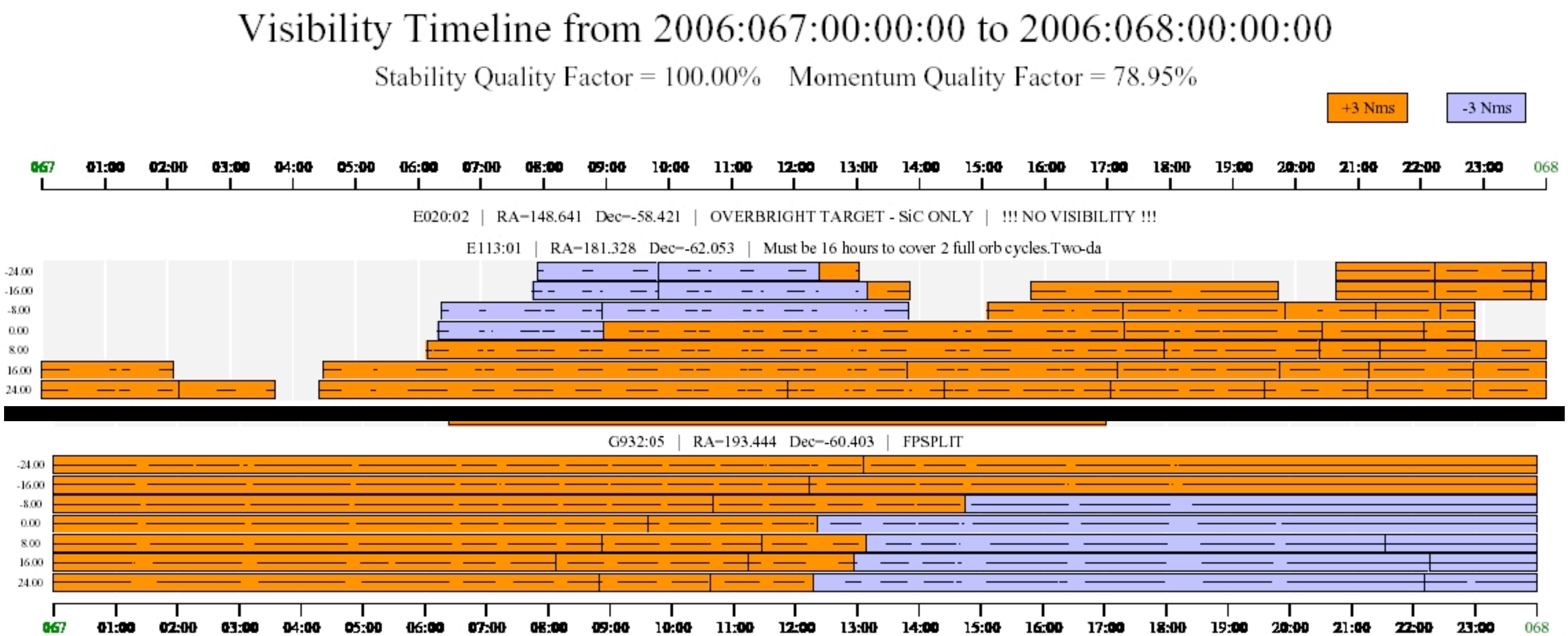


- ✓ **Roughly Periodic oscillation between relatively stable and less stable conditions.**
- ✓ **Note general improvement in Oct. 2005 with the advent of improved planning tools.**

(H. Calvani)

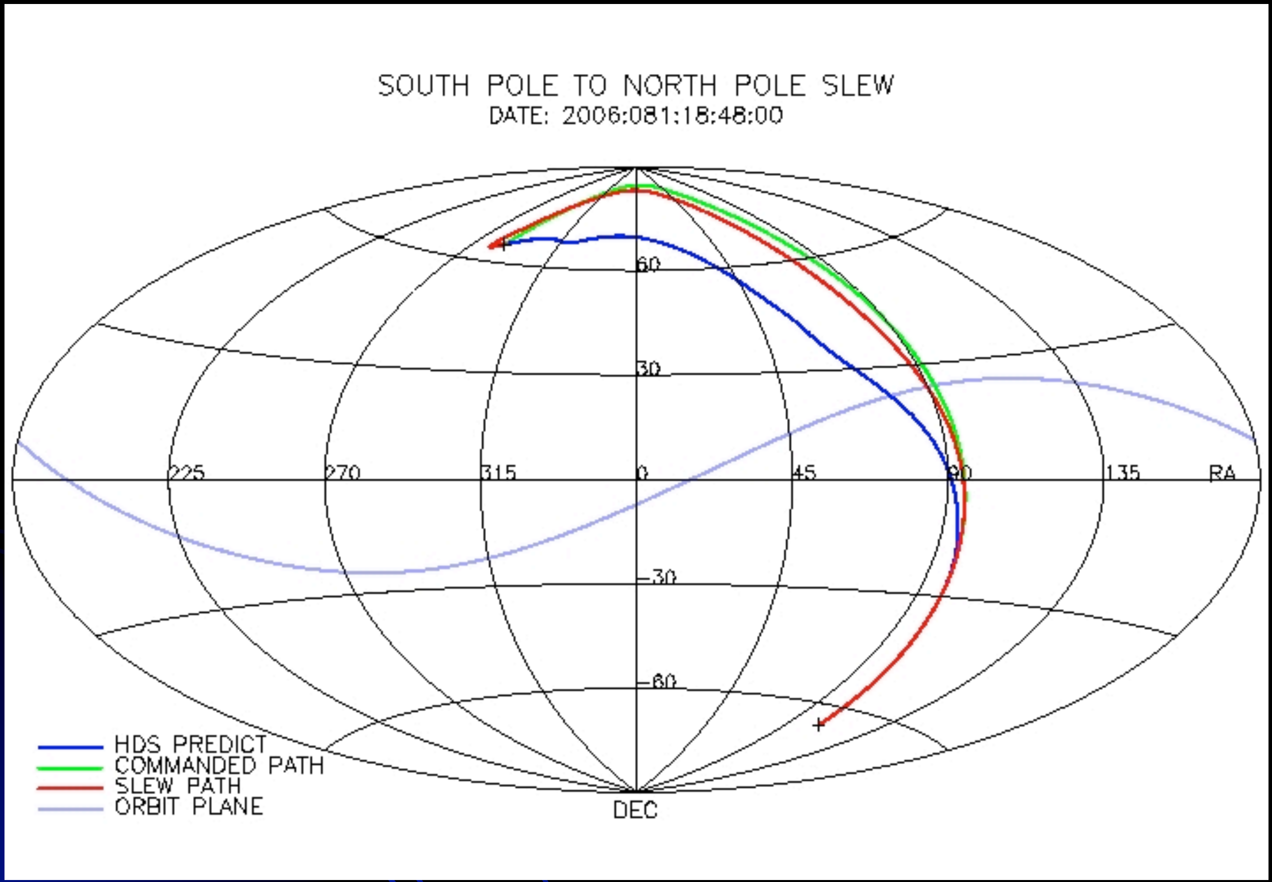
MP Tool Improvement





- 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.

Hemisphere Crossing Slews



Timing and matching of starting momentum is critical to success.

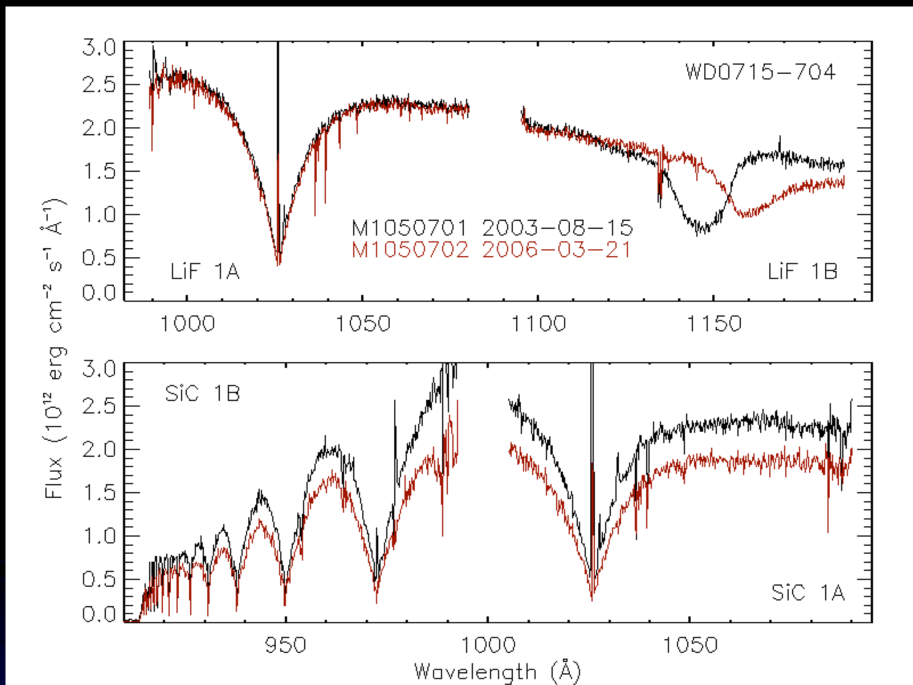
Also need to manage momentum to rejoin the timeline in the new hemisphere.

Two successful slews and one failure to date. Also bailed on two others (went to LVLH and recovered to other pole instead of attempting slew) because of stability concerns.

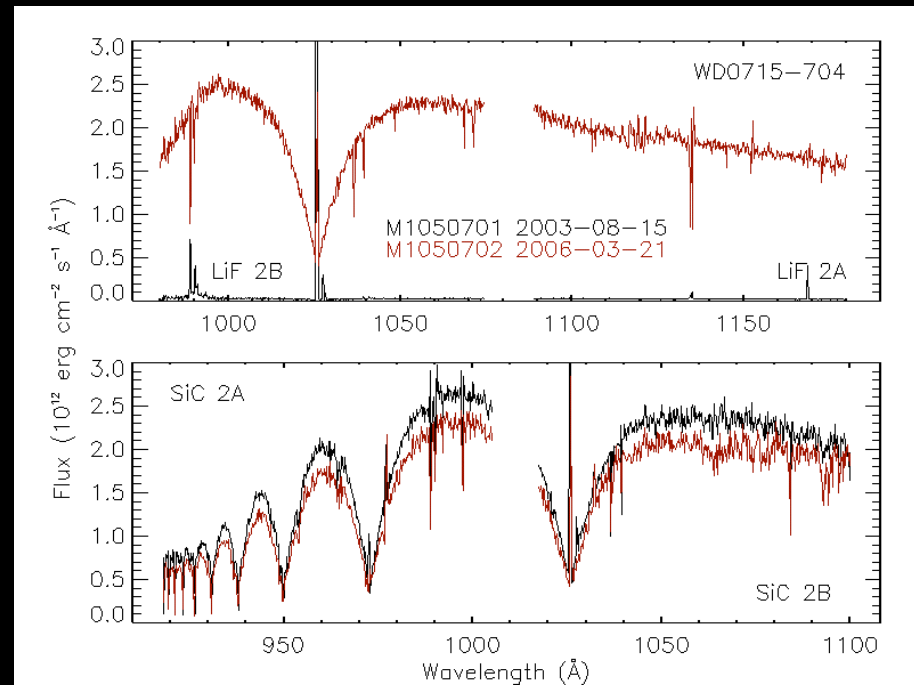
- Preparation for these slews is time consuming and matching starting momentum is tricky. >> Don't do them frivolously!

(T. Ake)

Science Instrument Status



Detector 1

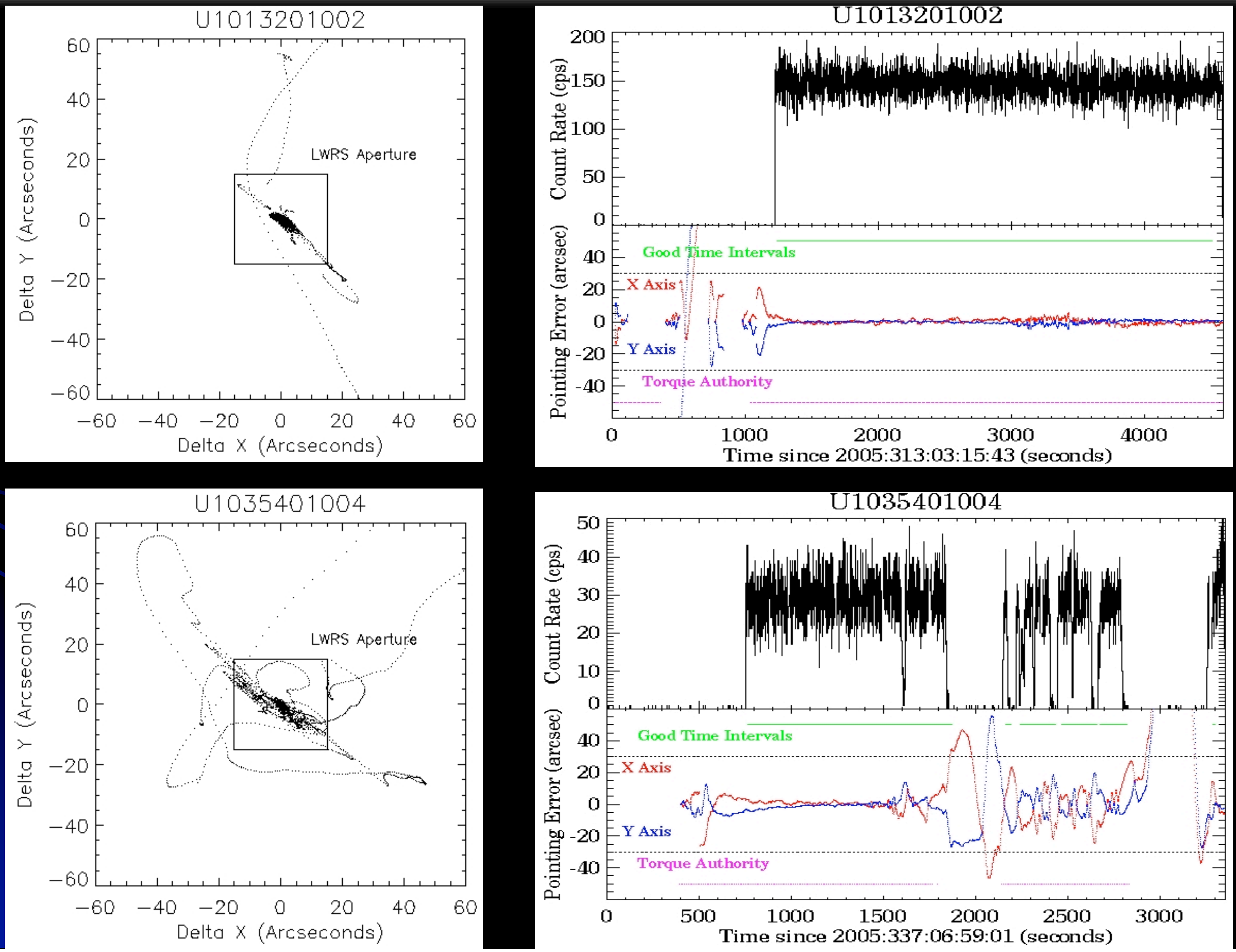


Detector 2

- 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)

System Performance

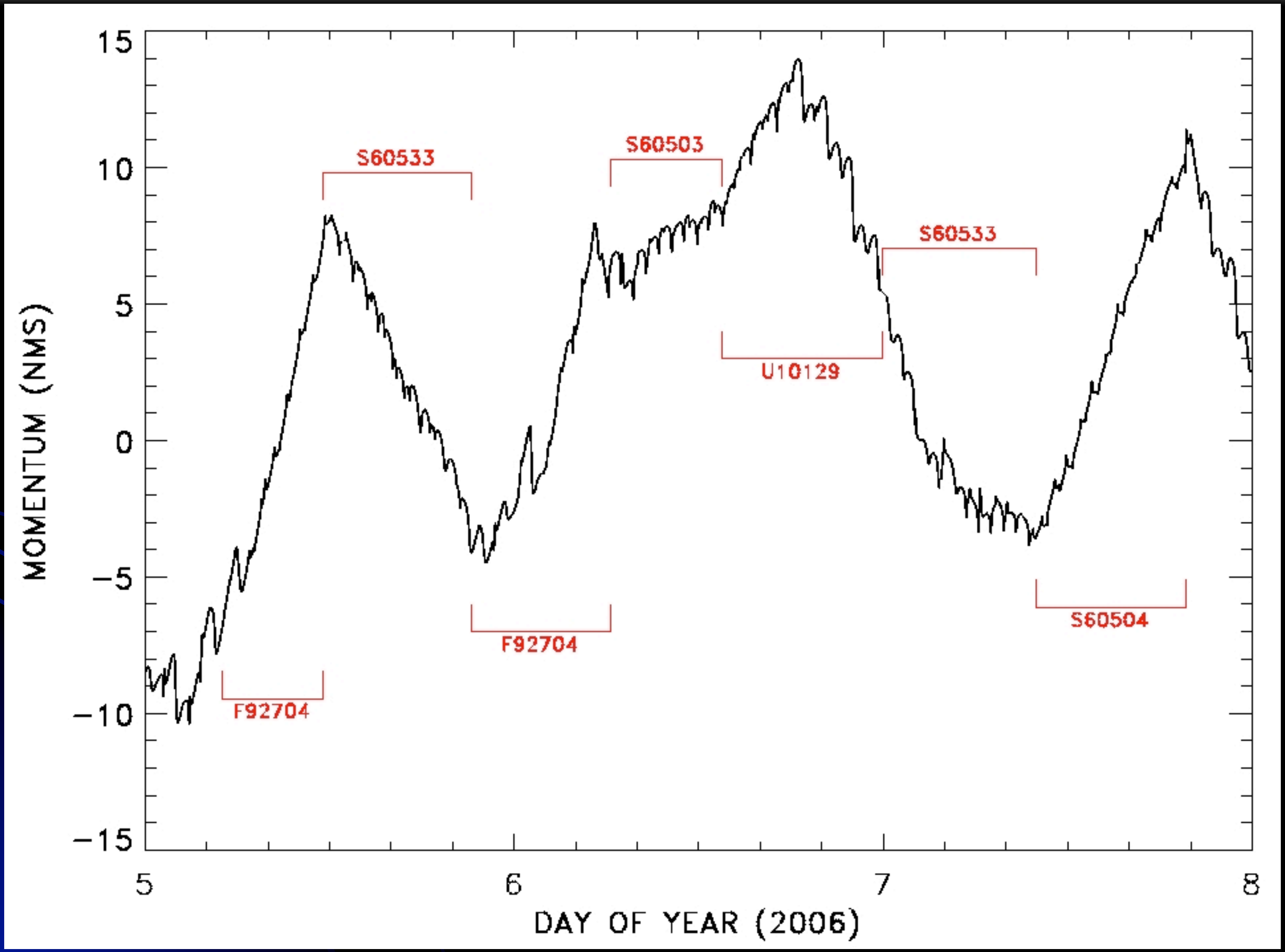


(T. Ake)

Momentum Management

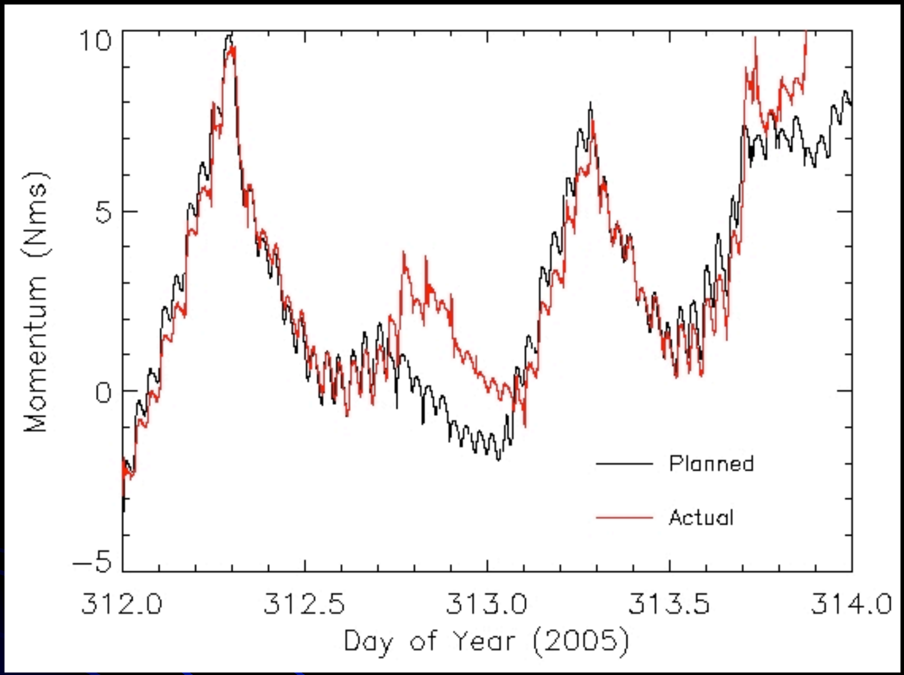
- With one wheel, careful management of momentum is critical to operations.
- Momentum is managed primarily by selection of pointing direction as a function of time.
- Predictive tools, such as the Hybrid Dynamic Simulator, are only accurate to a point. There are non-deterministic aspects that drive simulation and reality apart.
- There are many parameters within the control system that can be tweaked to improve performance, but some of them interact in ways that make accurate prediction of performance difficult.

Momentum Management Using Target Positions

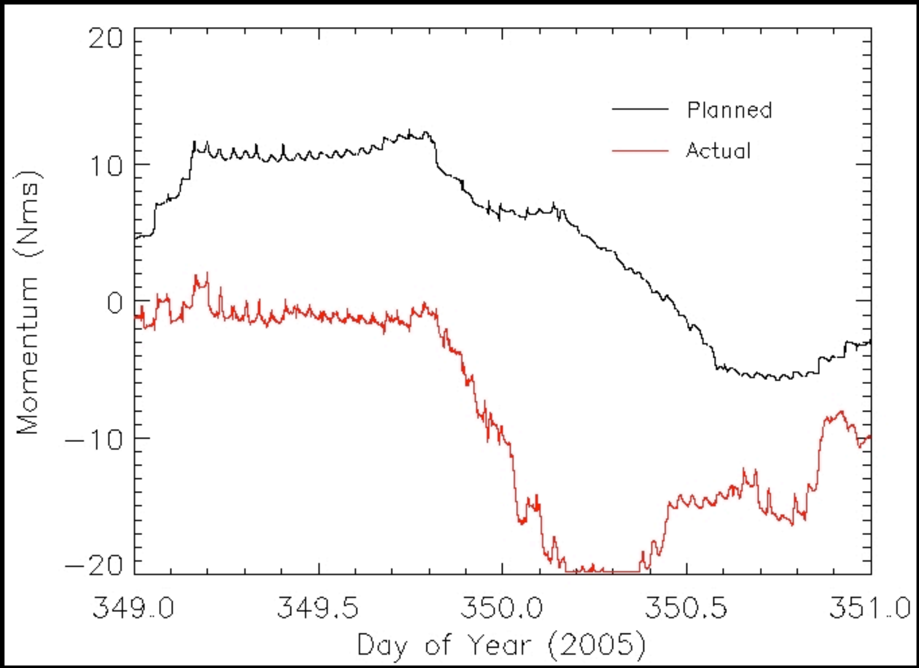


(T. Ake)

Momentum Mgmt. Challenges



Relatively Good Behavior Period

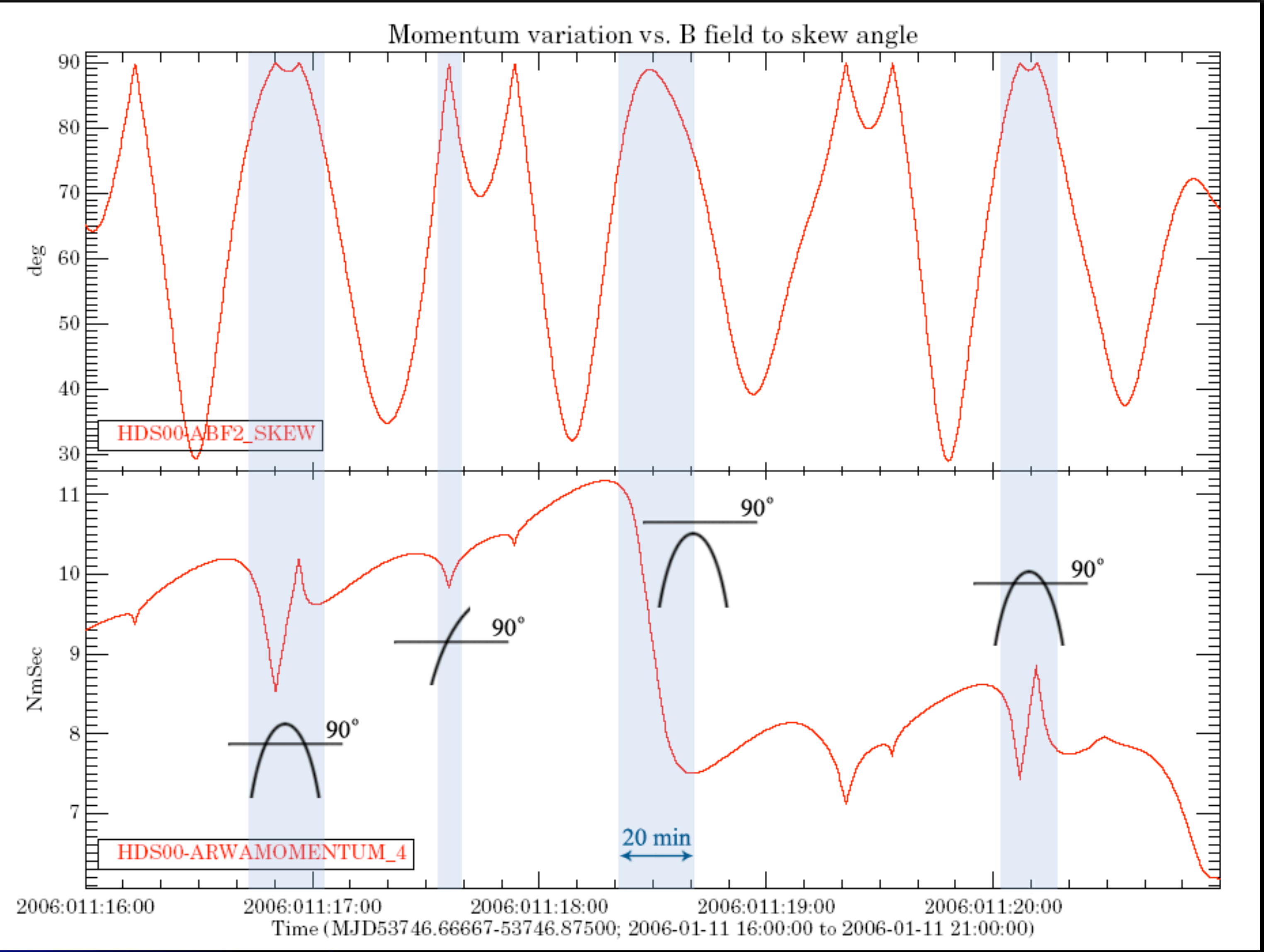


Poorly Behaved Period.

A timely "momentum intervention" might have improved this situation.

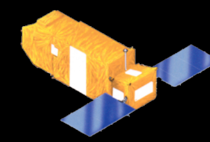
(T. Ake)

B-field-to-Skew angle Sensitivity



(T. Civeit)

January 2006 Performance



FUSE Performance Summary – data from telemetry and MPS's

Total time available (ksec)	2,251.61
Total time scheduled (ksec)	1,140.23
% time sche	**50.64%**
Total time guiding (ksec)	676.51
% time guiding vs. req	76.11%
% time guidi	59.33%

Hemisphere crossing slews		
Date	**Direction**	**Success?**
1/18	N to S	Y
1/31	S to N	N

Spacecraft Downtime		
Type	**# occurrences**	**Time (ks)**
Planned LVLH	1	302.4
Unplanned LVLH	0	0.0
Mom mgmt	5	206.0
Other	0	0.0
TOTALS	**6**	**508.4**

Program Category	Scheduled Time (ksec)	Guiding Time (ksec)	# obs sched
Prime	309.0	182.9	13
Legacy	16.0	12.0	1
Survey	141.6	86.8	9
Calibration	5.0	3.9	1
U programs	284.3	214.3	17
S programs	384.3	176.5	20
TOTALS	**1,140.2**	**676.5**	**61**

LVLH = "Local Vertical Local Horizontal" (Nadir-pointing Safe Mode).

Analysis courtesy of Alice Berman, FUSE MP.

February 2006 Performance

FUSE Performance Statistics – data from telemetry and MPS's

Total time in February (ksec)	**2,332.8**
Time avail for sched (ksec)	**2,075.5**
Actual time scheduled (ksec)	**1,222.9**
% time scheduled in all Feb	**52.4%**
% time sched of avail time	**58.9%**
Actual time guiding	**452.9**
% time guiding in all February	**19.4%**
% time guiding vs scheduled	**37.0%**
% time guiding vs available	**21.8%**

Hemisphere crossing slews

Date	Direction	Success?
None	N/A	N/A

Spacecraft Downtime

Type	# occurrences	Time (ks)	
Planned LVLH	1	257.3	2/24
Unplanned LVLH	2	318.4	2/1, 2/11
Mom mgmt	6	203.8	2/6,2/8,2/21,2/22,2/23
ACS Hold	2	70.1	2/2, 2/16
TOTALS	**11**	**849.6**	

Program Category	Scheduled Time (ksec)	Guiding Time (ksec)	# obs sched	% guiding time
Prime	150.2	51.0	10	11.3%
Legacy	48.6	12.4	5	2.7%
Survey	446.7	194.2	22	42.9%
Calibration	24.9	0.9	6	0.2%
U programs	278.5	113.9	17	25.2%
S programs	274.1	80.5	12	17.8%
TOTALS	**1,222.9**	**452.9**	**72**	100.0%

Successful Observations	# obs
Successful	32
Partial success	2
Missed	22
Failed	16
TOTAL	**72**

Analysis courtesy of Alice Berman, FUSE MP.

March 2006 Performance
(March 1-22 only)

FUSE Performance Statistics – data from telemetry and MPS's

Total time in March (ksec)	**1,987.2**
Time avail for sched (ksec)	**1,987.2**
Actual time scheduled (ksec)	**934.3**
% time scheduled in all March	**47.0%**
% time sched of avail time	**47.0%**
Actual time guiding	**658.8**
% time guiding in all March	**33.2%**
% time guiding vs scheduled	**70.5%**
% time guiding vs available	**33.2%**

Hemisphere crossing slews		
Date	**Direction**	**Success?**
3/22	S->N	S

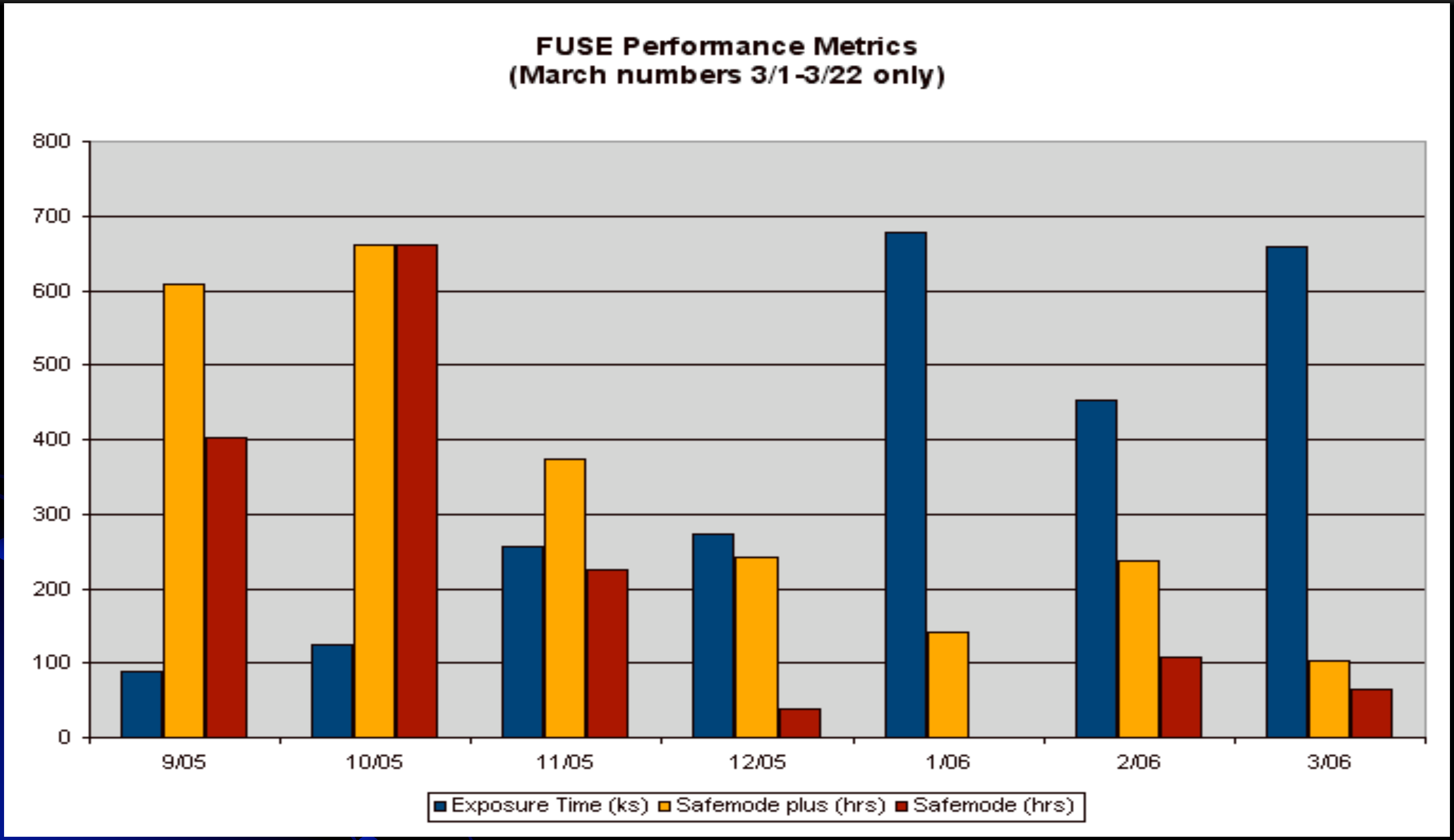
Spacecraft Downtime		
Type	**# occurrences**	**Time (ks)**
Planned LVLH	0	0.0
Mom mgmt	4	138.3
E33 load	0	0.0
ACS Hold	1	5.2
Unplanned LVLH	1	228.3
TOTALS	**6**	**371.8**

Program Category	Scheduled Time (ksec)	Guiding Time (ksec)	# obs sched	% guiding time
Prime	381.7	261.5	27	39.7%
Legacy	0.0	0.0	0	0.0%
Survey	308.2	246.1	16	37.4%
Calibration	45.6	11.7	3	1.8%
U programs	95.5	60.6	8	9.2%
S programs	103.4	78.8	8	12.0%
TOTALS	**934.3**	**658.8**	**62**	100.0%

Successful Observations	# obs
Successful	43
Partial success	0
Missed	9
Failed	10
TOTAL	**62**

Analysis courtesy of Alice Berman, FUSE MP.

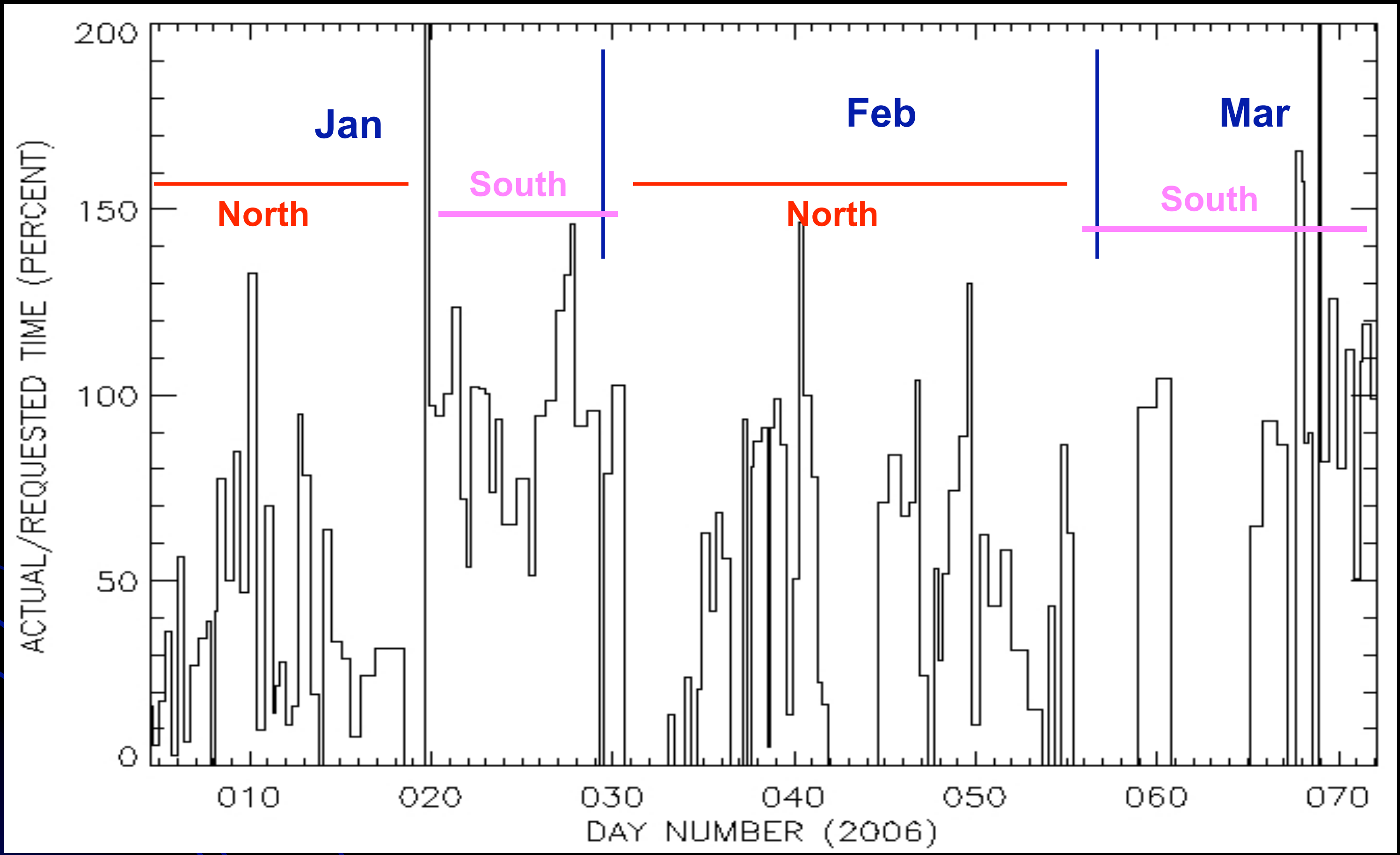
Operations Improvements



Yellow: Momentum mgmt and "planned" safemode time.

(A. Berman)

Jan-mid Mar 2006 Actual vs Requested Times



- By scheduling more time than requested, we typically get close to the requested times even with acquisition and guiding glitches.

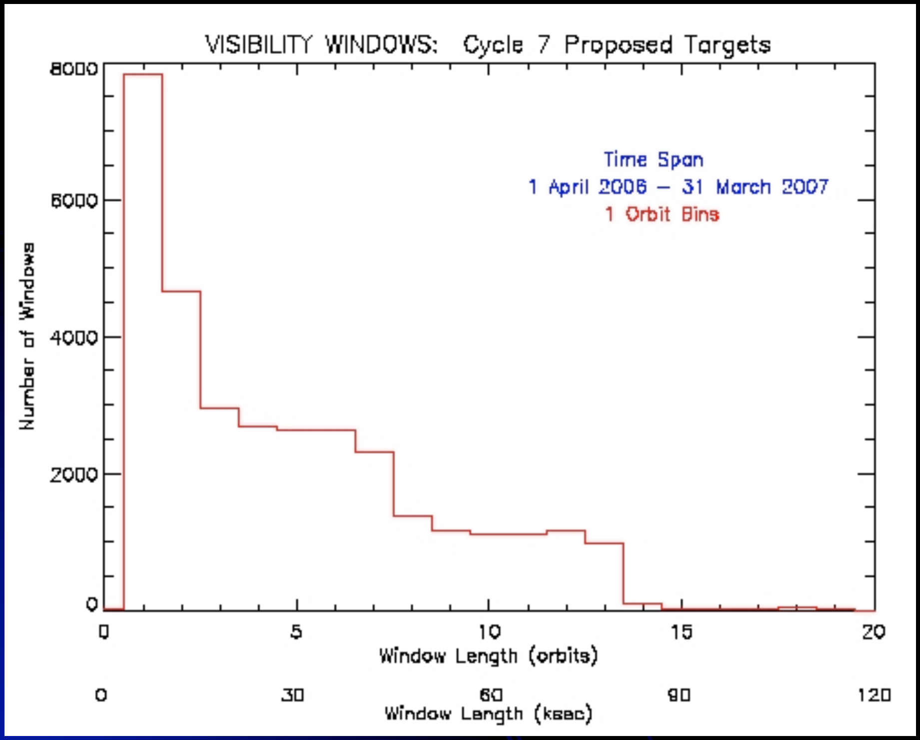
(T. Ake)

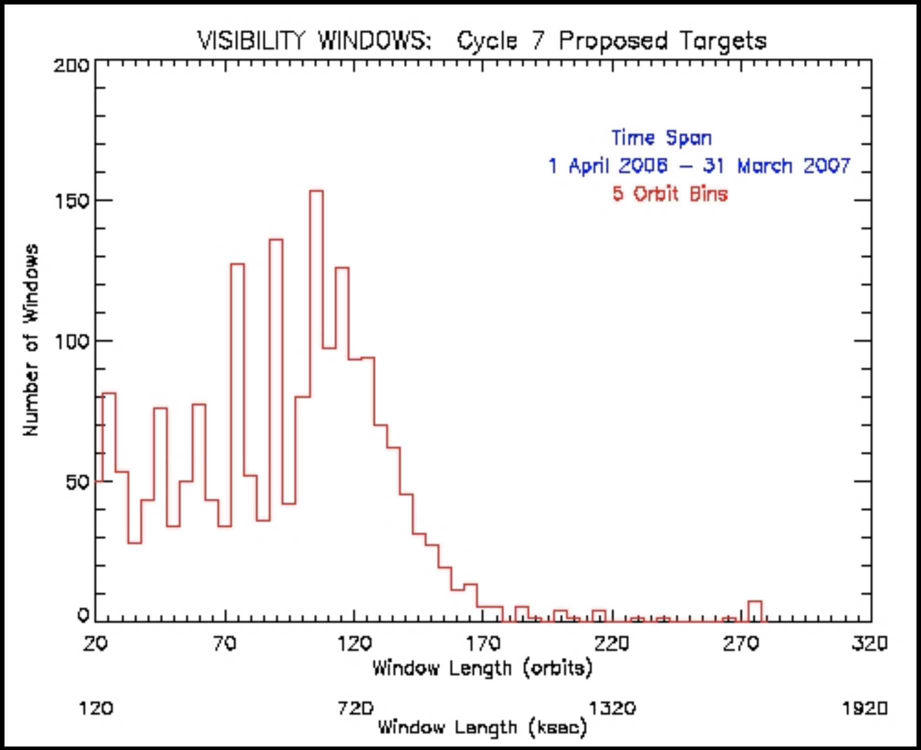
Long Observations

- 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^{o} better than 50-60^{o}).
- 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)

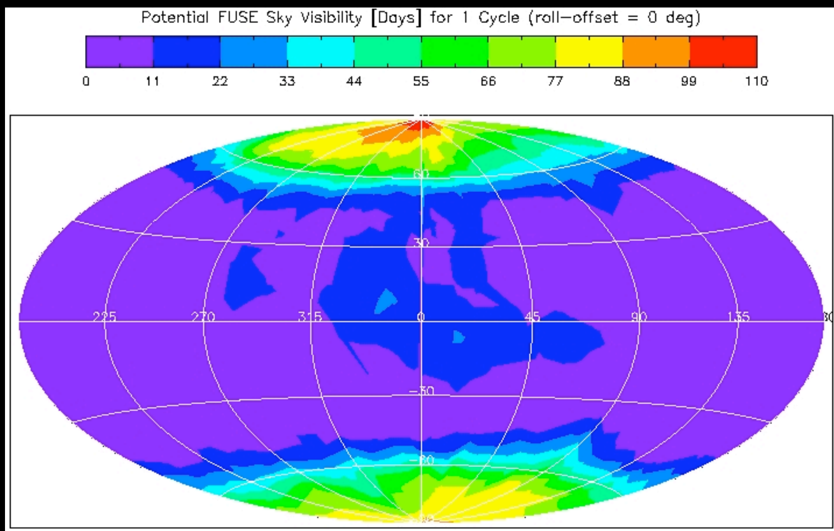
ACS E33 / IDS v3.02

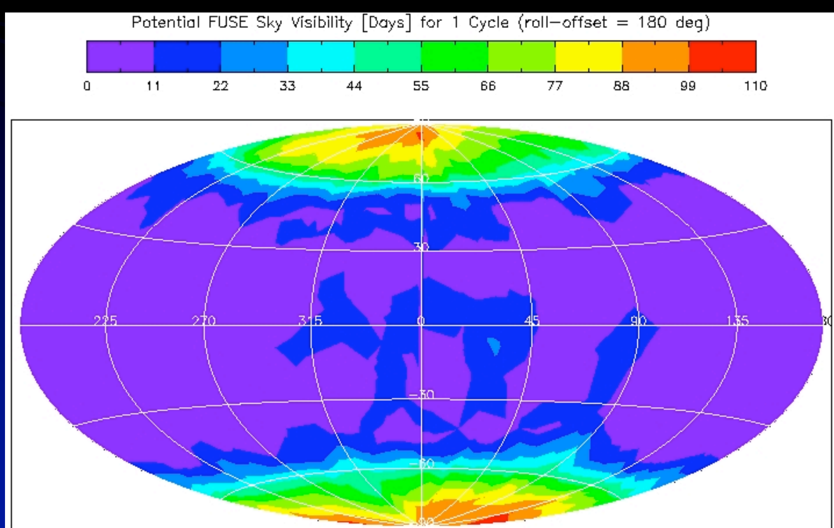
- New ACS flight s/w and new IDS s/w and scripts were loaded to FUSE earlier this week.
- Much improved attitude information sharing between ACS and IDS.
  - Fewer instances of bad FPD data corrupting ACS controller and causing loss of attitude.
- Revised Torque Distribution Algorithm at ***B***-to-***S*** 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/simplified LVLH recovery slews.
  - Not dependent on cyclical behavior with time.

Future Work/Ideas

- Consider different/better slew algorithms.
  - Different slew algorithms may provide more flexibility and improved sky coverage.
    - Would require further ACS s/w development.
- Continue to improve MP tools.
  - Improved momentum mgmt into Long Range Planning.
  - “SOVA” s/w: Bringing AI techniques to short term scheduling.
  - Longer term, this may be the primary means for performance improvements.
- “180 degree roll” Ops concept.
  - Would place skew axis in radically different direction wrt the B-field at any given time.
  - Recent performance >> thermal conditions may be manageable.
  - Possible show stopper: FES scattered light? (Only at certain beta angles?)
  - Would require further ACS and MP s/w development.

180 Roll Sky Coverage

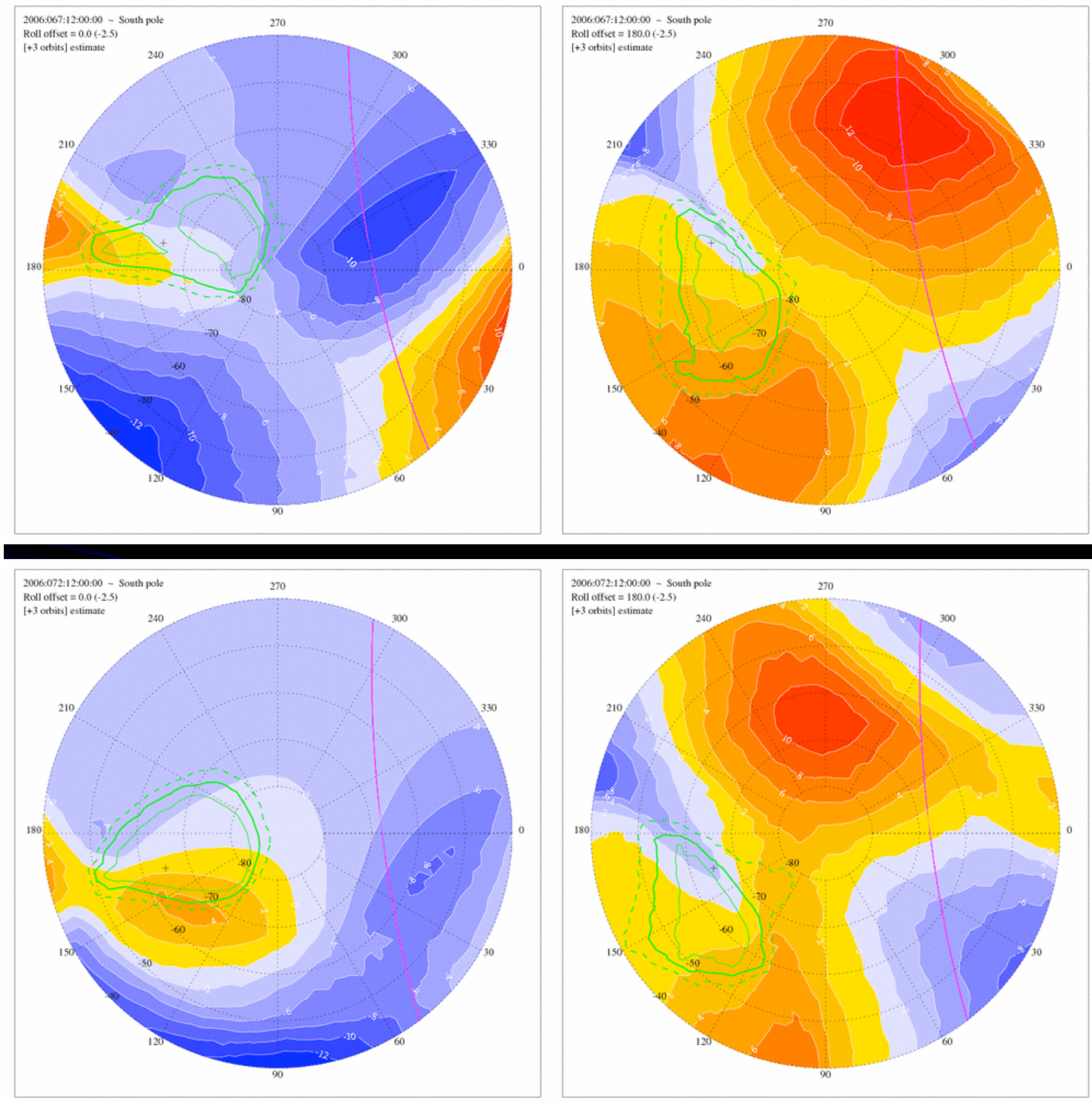




- A 180 roll flip does not do anything dramatic to open up the sky coverage.
  - South cap coverage improves.
- BUT, this is deceptive. It if increases the amount of access a given part of the sky, this could still add a lot of flexibility into scheduling.
  - Example: conflicting needs of south (Mag Clouds) and north (long integration targets) might be better accommodated.

(H. Calvani)

180 Roll Momentum/TACO



- Momentum pattern changes are dramatic with the roll flip.
- If usable for observing, may increase time we can spend on a given sky region, and may help with long obs.
- (If not usable for observing, may still help tremendously with momentum mgmt activities!)

(T. Civeit)

Issues/Questions-I

- Individual very high priority targets are expensive drivers of scheduling. (Ex: Attempt to observe Alpha Cen in early March.)
  - Such targets can cost several days to (worst case) a week.
  - Can use effectively all available human resources to plan.
  - Are not guaranteed to succeed! (Often, the real complexities only show up well into the short term scheduling of such observations.)
  - Clear communication needed on designation of priority targets.
- How best to accommodate/prioritize Long Observations.
  - Almost by definition, long observations must be given high priority in order to get scheduled.
  - A single target priority may not be enough. Need a "sliding priority" scheme? (once a target is "started" it becomes higher priority?)
  - May need to access individual targets and lock down best windows manually in the LRP. (But then they become "drivers." See above.)

Issues/Questions-II

- Programs to Address Density of Targets in Accessible Regions of Sky
  - S605/S705 Pole Background rings (pre-defined positions, N&S).
    - Implemented Late-July 2005
  - “U” programs: ~600 previous FUSE targets made available for standardized, plain vanilla LWRS, 8 ks, observation requests.
    - Implemented Mid-August 2005
    - Has reduced the amount of time we spend on backgrounds.
  - Should these be continued? Enhanced? Scaled back?
  - How do we make availability of these data more obvious to the community at large (within our resources!)?

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.

CalFUSE Version Overview

- v3.0 (Sept. 2004) -- Introduce intermediate-data file.
- v3.1 (Sept. 2005) -- New jitter and high-voltage algorithms reject less good data. Improved treatment of HIST data preserves flux, improves wavelength calibration. Tighter pulse-height limits reduce bkgd.
- v3.2 (May 2006) -- Fix bugs in background-scaling routine and FIFO-overflow correction. Improves LiF1 wavelength zero point (σ = 2.9 km/s), pothole correction, and spectral centroiding algorithm. New effective-area files.

Data Processing Status

- 4200 observations are now in MAST
- 700 processed with v3.1
- 2800 processed with v3.0
- 700 processed before v3.0

Data obtained during most of 2000 and the second half of 2001 are being processed without HSKP and JITR files due to SCC hardware and backup tape problems.

Data Processing Calendar

- May 1 -- All data with v3.0 or above
- Oct. 1 -- All data with v3.1 or above
- Jan. 1 -- All data with v3.2

To meet this schedule, we will devote a third computer to the reprocessing effort.

Efforts to recover the 2000 and 2001 HSKP and JITR files will continue.

MAST Archive

- Mary Romelfanger has identified about 300 data sets that are not in MAST, but probably should be. Most are in-orbit checkout or calibration observations. She and Dave Sahnow are working on this now.
- *Next step:* Organize web documentation of *FUSE* mission for MAST.