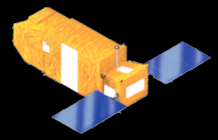
Far Ultraviolet Spectroscopic Explorer



FUSE One-wheel Operations Status and Update: Continuous Improvement

Bill Blair

FUSE Deputy-PI and

Chief of Observatory Operations

FOAC Meeting, Apr. 30, 2007

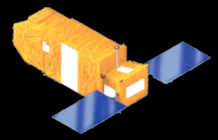
Outline/Themes

FUSE Performance,

April 2007.

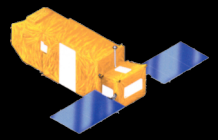
- Since the last FOAC, the FUSE team has continued a process of incremental improvements in operational and planning techniques that have elevated the one-wheel mode to exceptional levels of performance.
- I will highlight some of these changes/improvements as I review recent performance of the satellite and the system.

Mission Status/Overview
(Since last FOAC meeting)



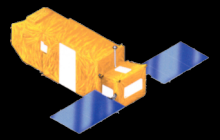
- FES-B performance continues to be nominal.
  - Annealing process scheduled in early May to address increase in hot pixels that sometimes affect guiding performance.
- No change in status of gyros or remaining Reaction Wheel.
- UPRM ground station performance is nominal.
  - Significant period of downtime in March, covered by Wallops.
- Low Dec observing attempts successful (Jupiter).
- Latest version of ACS s/w (E34) installed in Feb. 2007.
  - Additional slew types available.
  - Improved (safer, controlled) LVLH entry and exit capabilities.
- Long Range Planning tool and MP process improvements.
- CalFUSE 3.2 completed and delivered.
  - Full reprocessing still on track to be completed well before EOM.

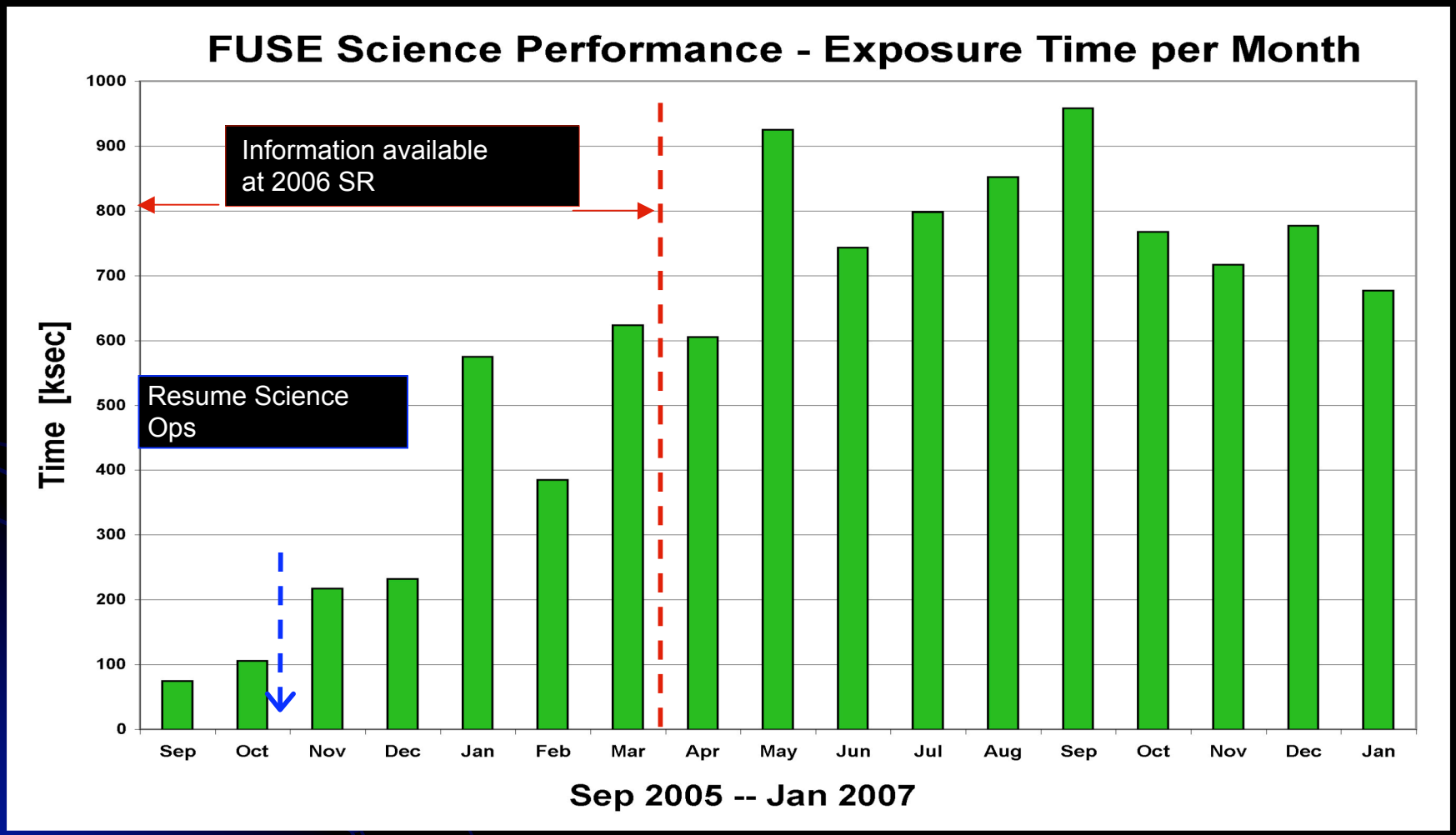
Staffing Changes



- MOT/Control center staffing at 7 (will drop to 6 in May).
  - SCC Staffing is at 16/5 level since September 2006.
  - There has been some turnover in personnel.
- Alice Berman left for APL; Humberto Calvani is now head of Mission Planning.
- One mission planner hired and trained, Anatoly Suchkov.
  - Others being cross-trained on this critical function.
- Attitude control specialist, John Rowe, hired on CSC sub-contract.
- Several partial FTEs are being shared with STScI to support SM4 preparations (or other outside support).
  - Currently 26 (25) people providing ~22 (21) FTE of effort.
- Current staffing consistent with that at last FOAC, but some attrition or downsizing expected by end of 2007.

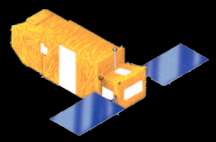
Science Performance

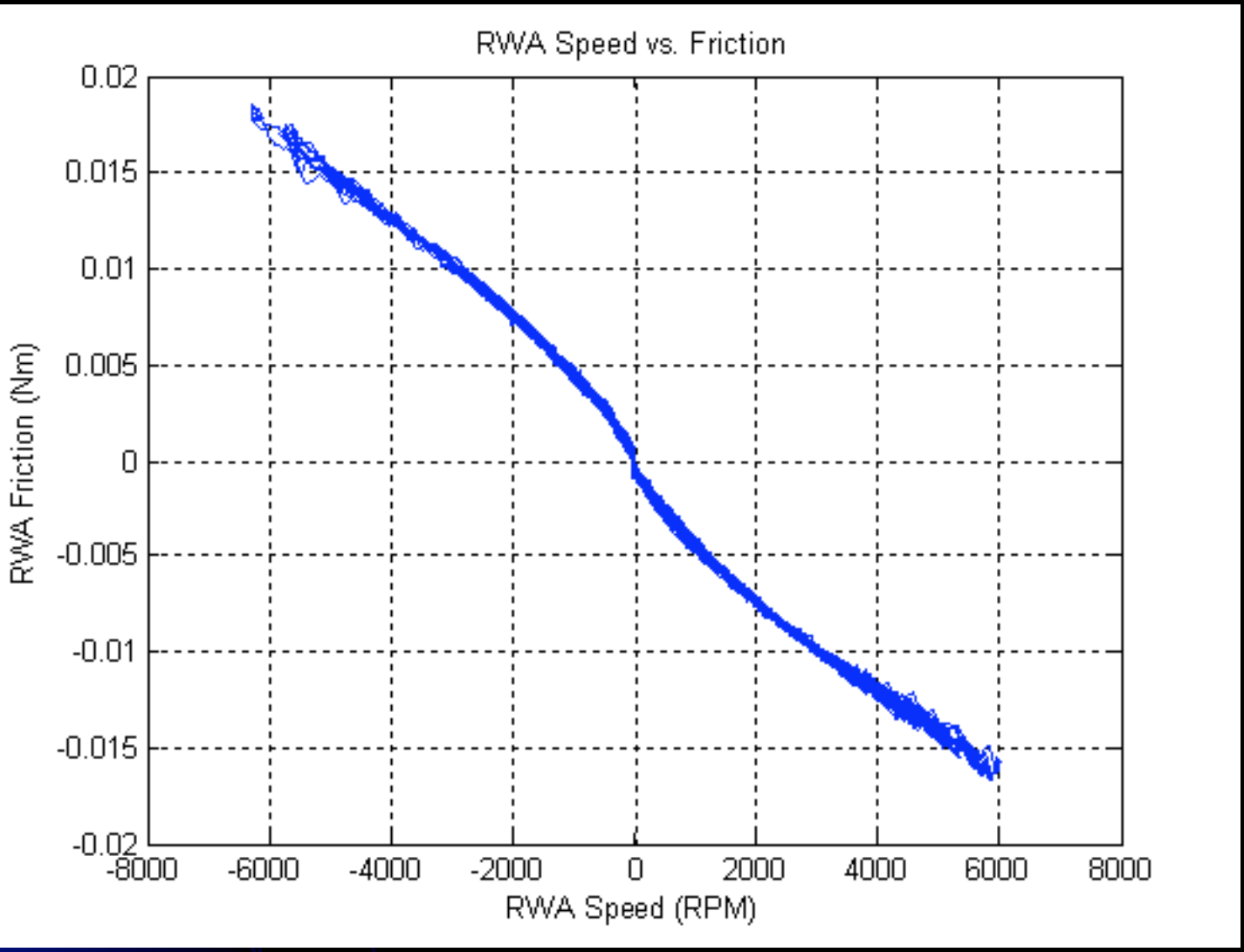




(M. Kaiser, H. Calvani)

Skew Wheel Performance - Nominal!





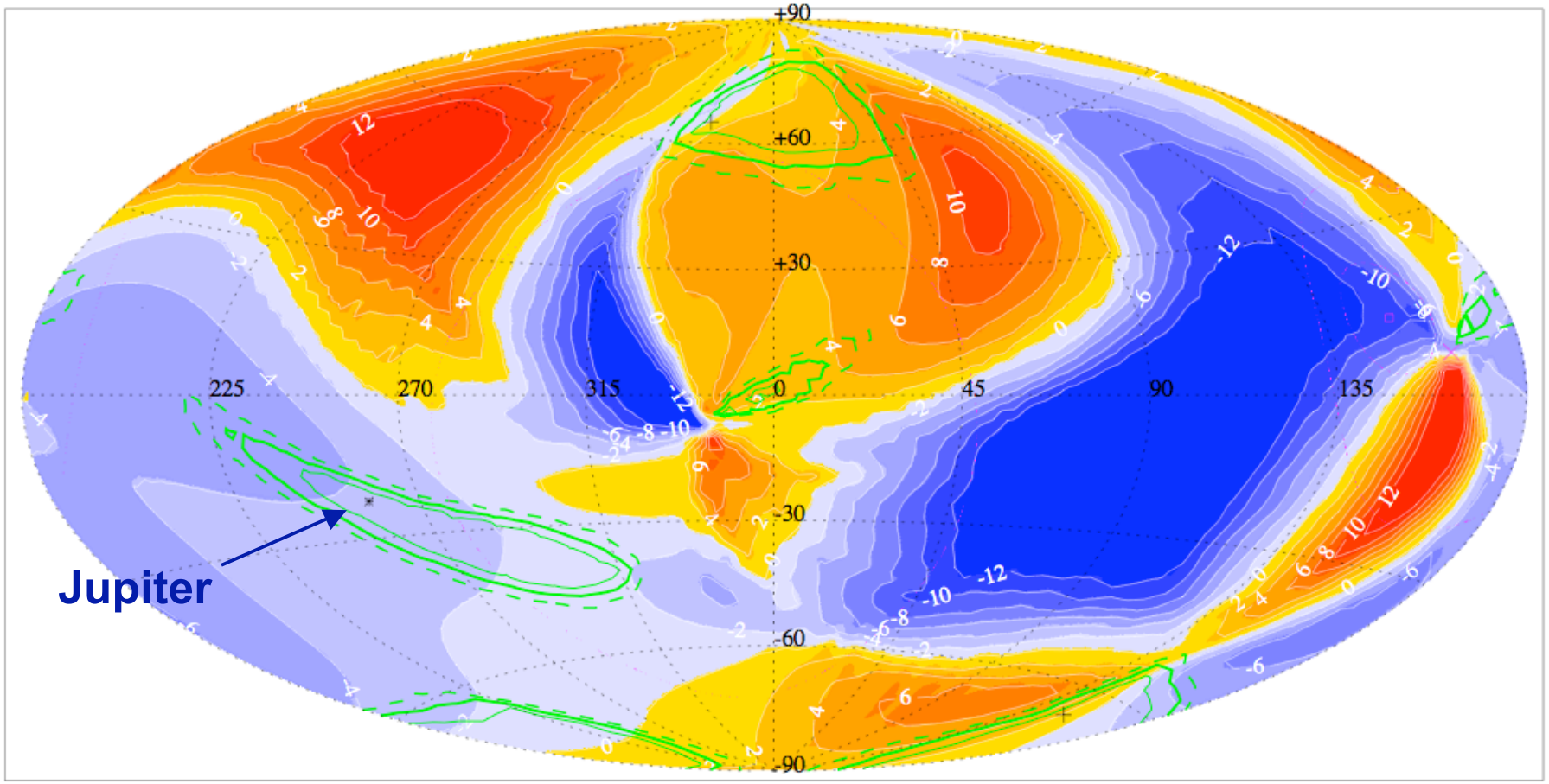
Courtesy: Ithaco, Orbital Sciences Corp.

Low Dec Observing: Jupiter

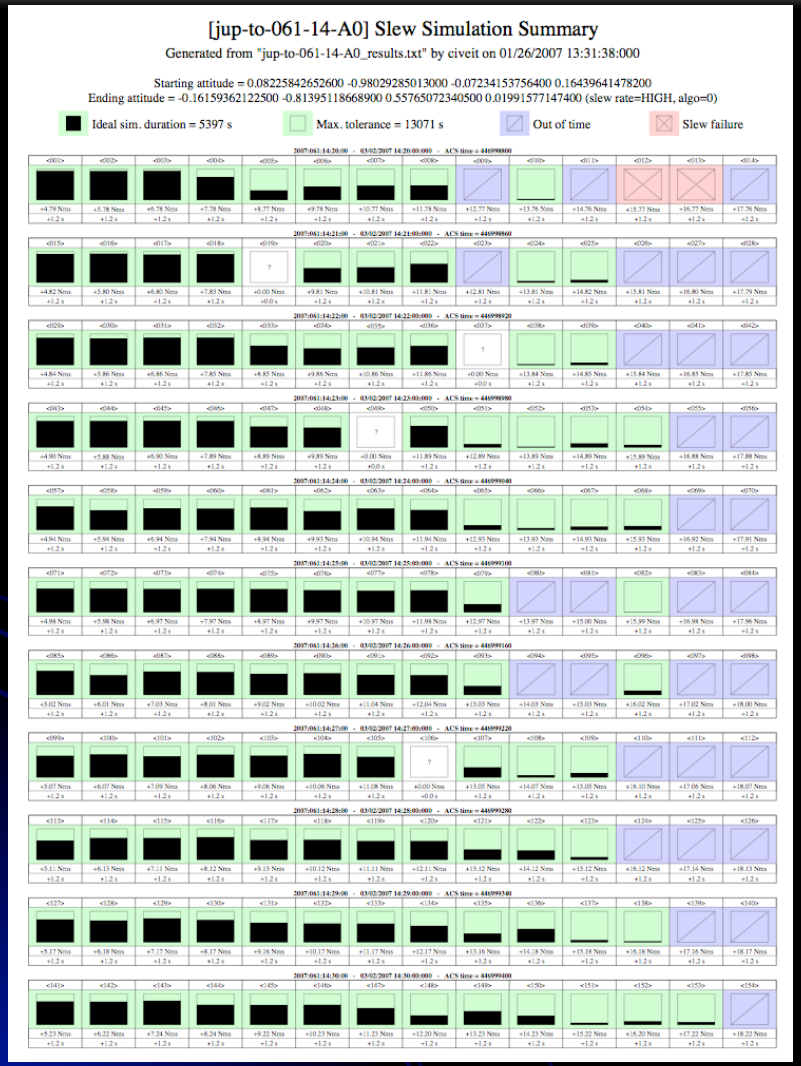
(in support of NH flyby)

2007:061:18:00:00
Roll offset = 17.0 (-2.5)
[+3 orbits] estimate

All-sky TACO/Momentum variation chart-Mar. 2, 2007



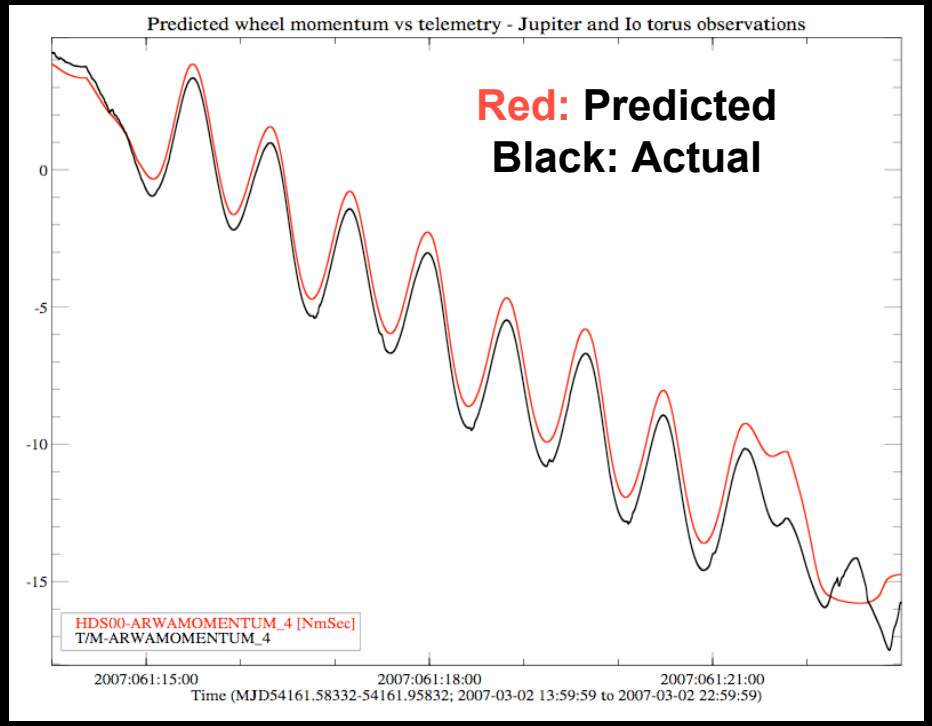
Procedural Details



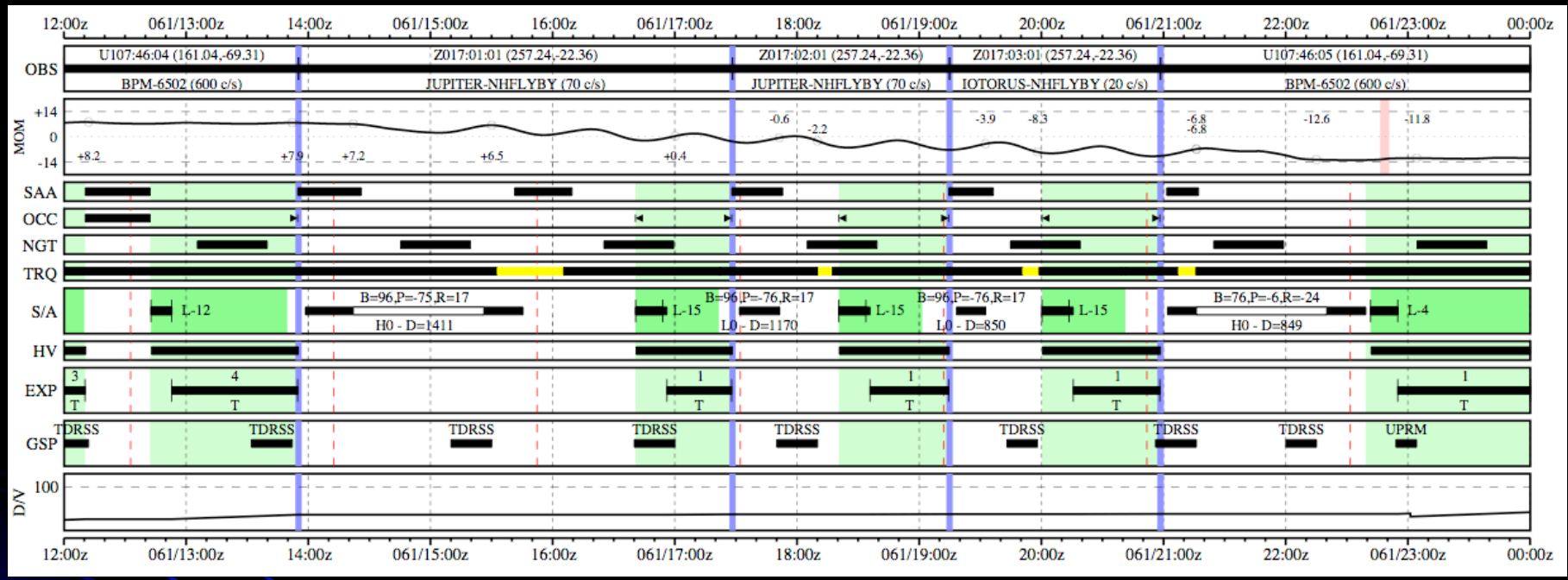
<--Time

(pos) Assumed start momentum (neg)

- Calculate two grids of slews (left) to understand robustness.
- Predict momentum performance while at the target position (below).



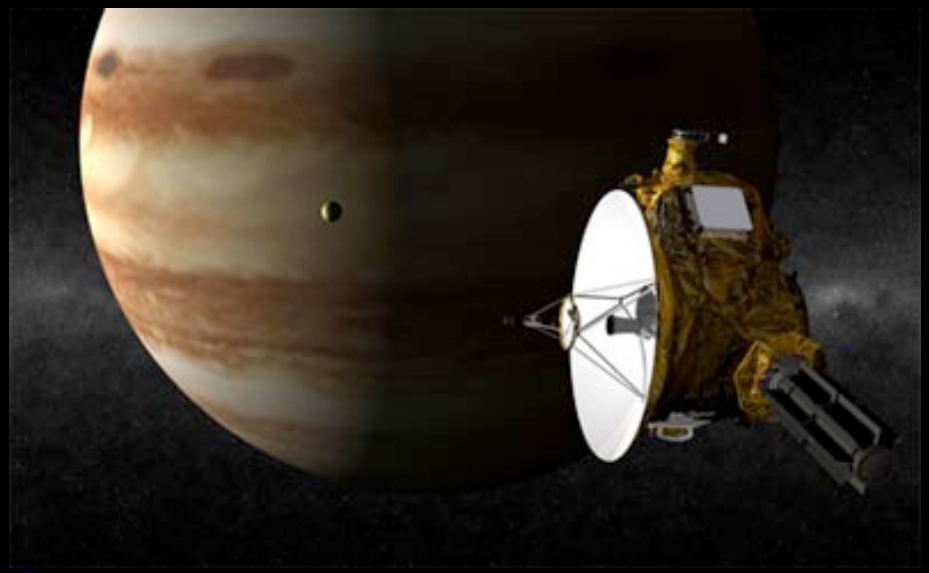
Generate Timeline

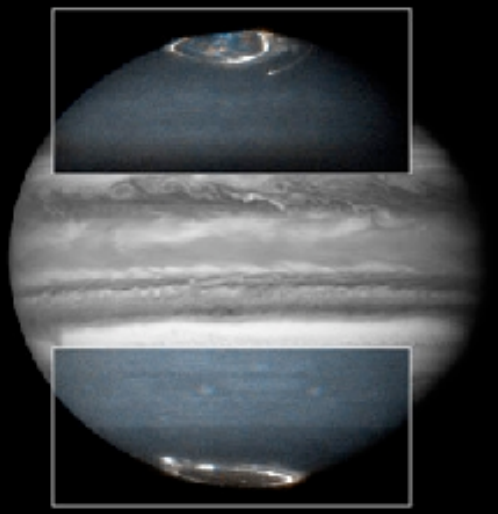


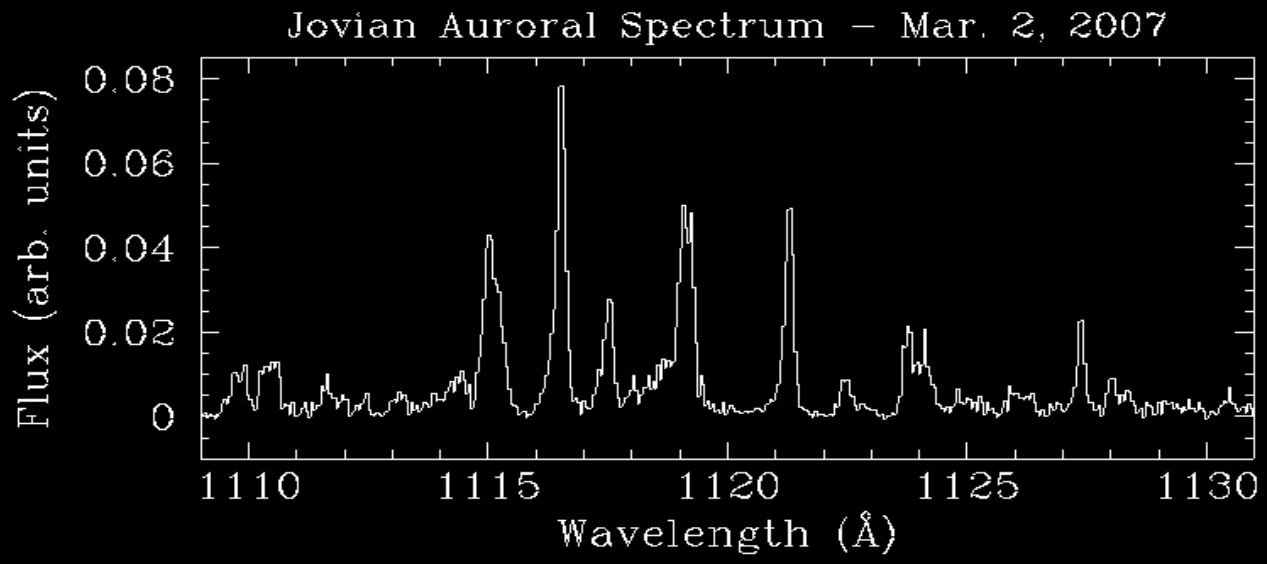
Note: “filler” targets front and back in case of adverse impacts or need for momentum management.

Actual starting momentum was “low” by 3.5 Nms, but “OK” according to grid.

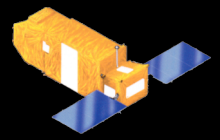
Enjoy Data…





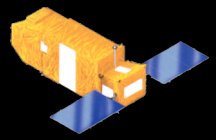

Jovian Auroral Spectrum – Mar. 2, 2007
Flux (arb. units)
0.08
0.06
0.04
0.02
0
1110
1115
1120
1125
1130
Wavelength (Å)

ACS E34 software



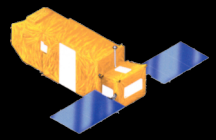
- Uploaded mid-February 2007.
- Expected to by the “final” FUSE ACS software configuration.*
  - *with exception of several very minor bug fixes --> “P34.”
- Basic properties/improvements include:
  - 5 new slew types. (Next page.)
  - Modified TDA for improved performance at high B-to-S angles.
  - Active slew to orbit plane upon LVLH (safemode) entry.
    - Safer, more robust way to get into safe mode.
  - Automated solar array tracking for improved power management on large slews and LVLH entry/exit.
  - Other details of interest to ops (but not to you!).

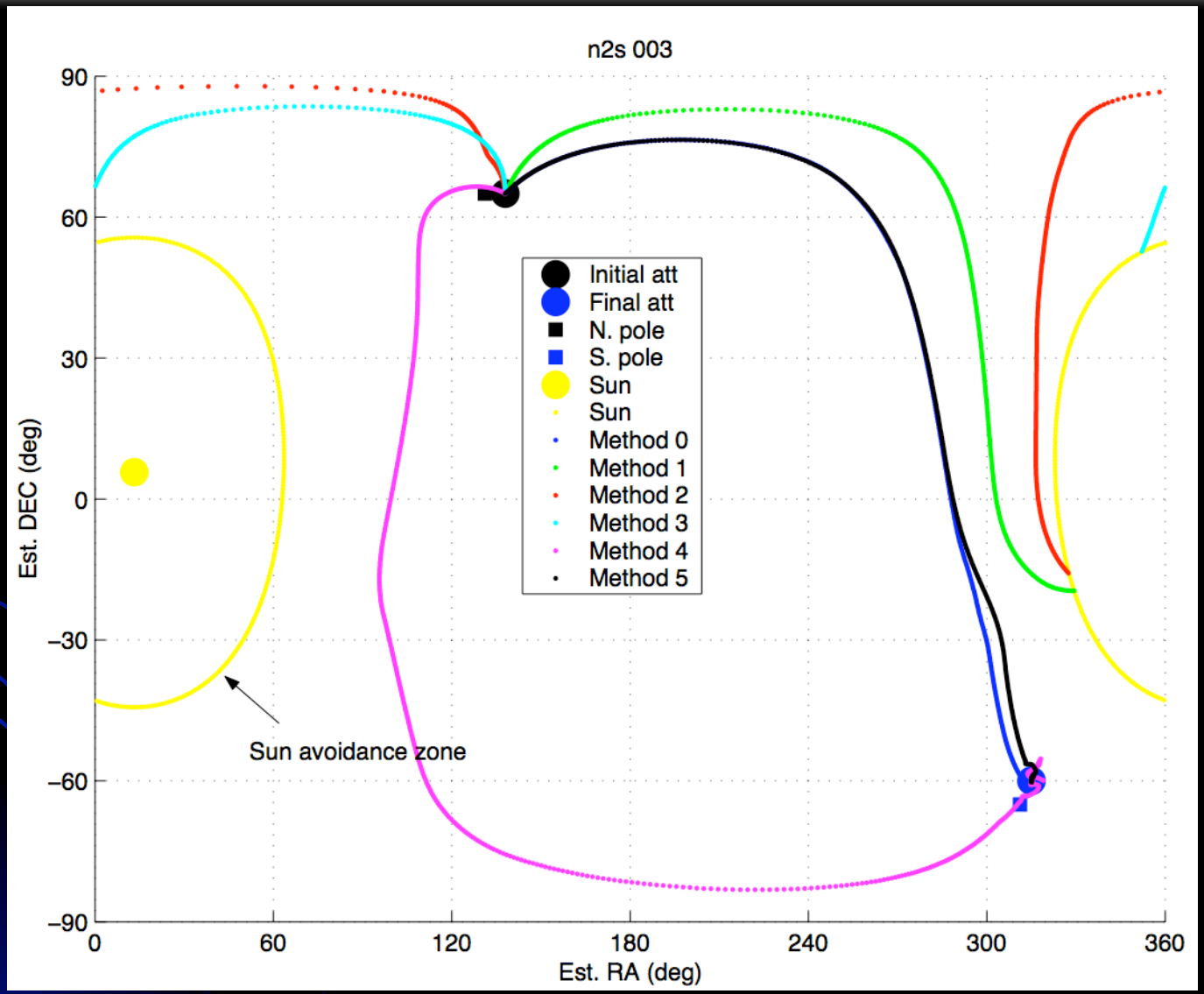
ACS E34: New Slew Types



- Orbital has provided new slew algorithms in this version:
  - Minimize 1) angle, 2) momentum 3) torque requested 4) dipole requested or 5) modified euler-axis slew.
- These differ from the original slew algorithm in that they attempt to dynamically optimize the slew trajectory as the slew proceeds.
- The ability to change course in response to actual conditions in principle provides greater flexibility, especially for very large slews.
  - But these slews are difficult to model (except with full HDS simulations, and even then they are only approximations).
- To take advantage of these, we need to know when and how to apply the different slew types.
- We are in the process of testing these slew types and developing tools for fast assessment of individual slews.

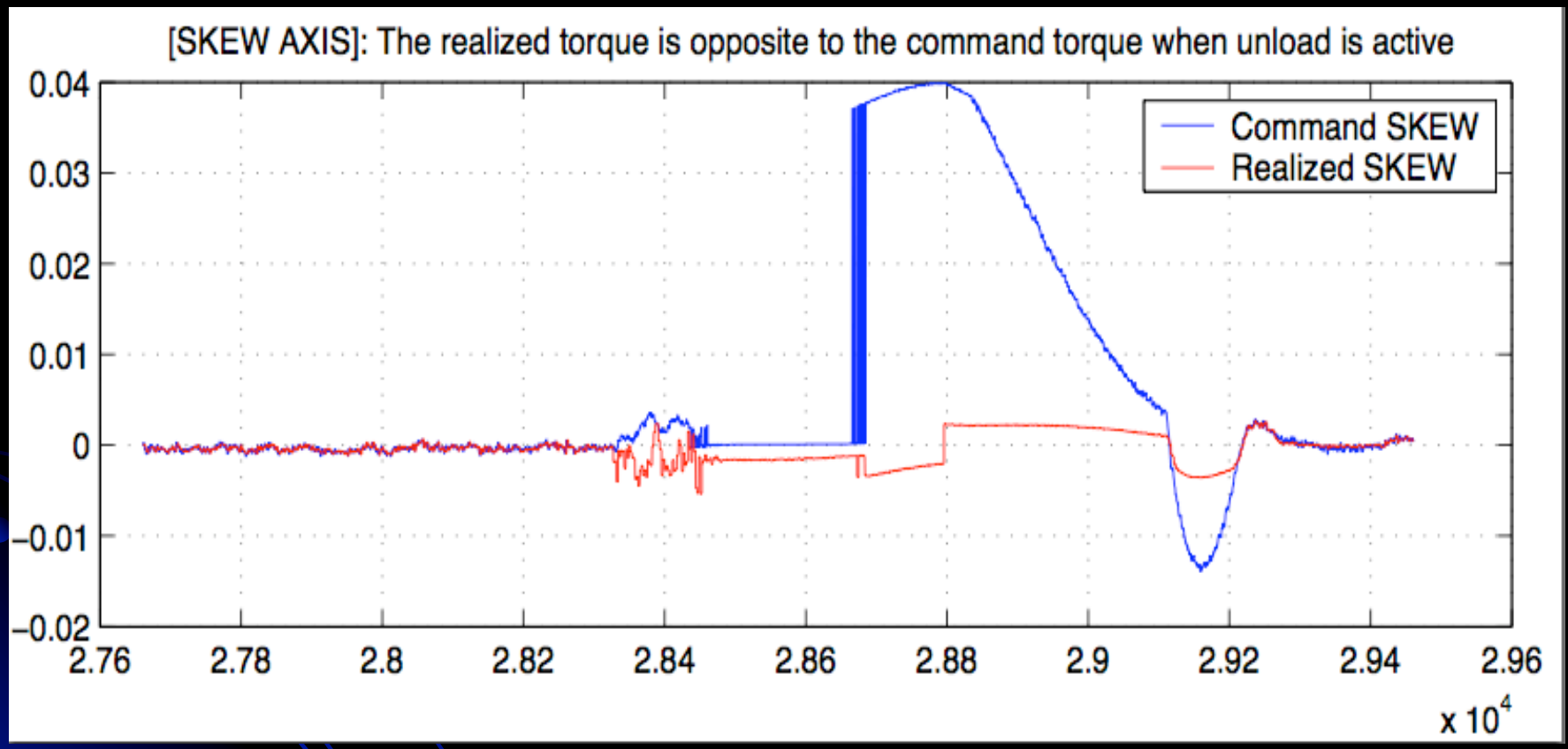
Slew Types Example





(J. Rowe)

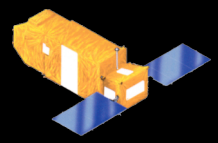
A Bug in E34…



"Telemetry" from E34 HDS simulator verifies bug identified in independent efforts to construct a simple dynamic simulator for use in planning.

(T. Civeit)

Future Improvements: To unload or not to unload…



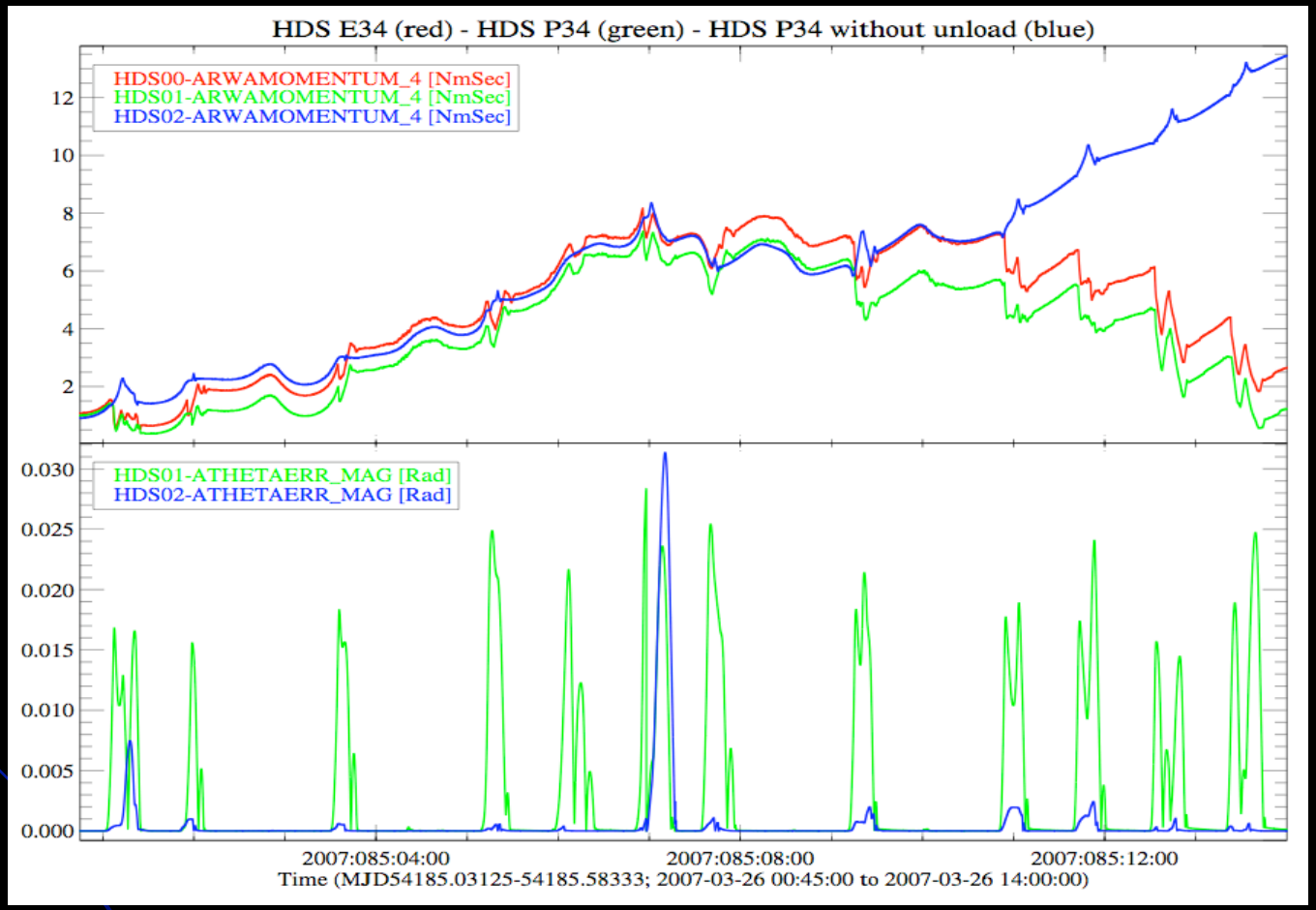
Note: P34 is "E34 with bug fix"

Blue: P34 no unloading

Red: E34 with unloading

Green: P34 with unloading

Default: Try to unload whenever B2S angle is greater than 90°

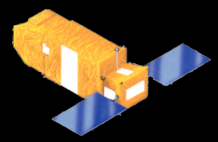


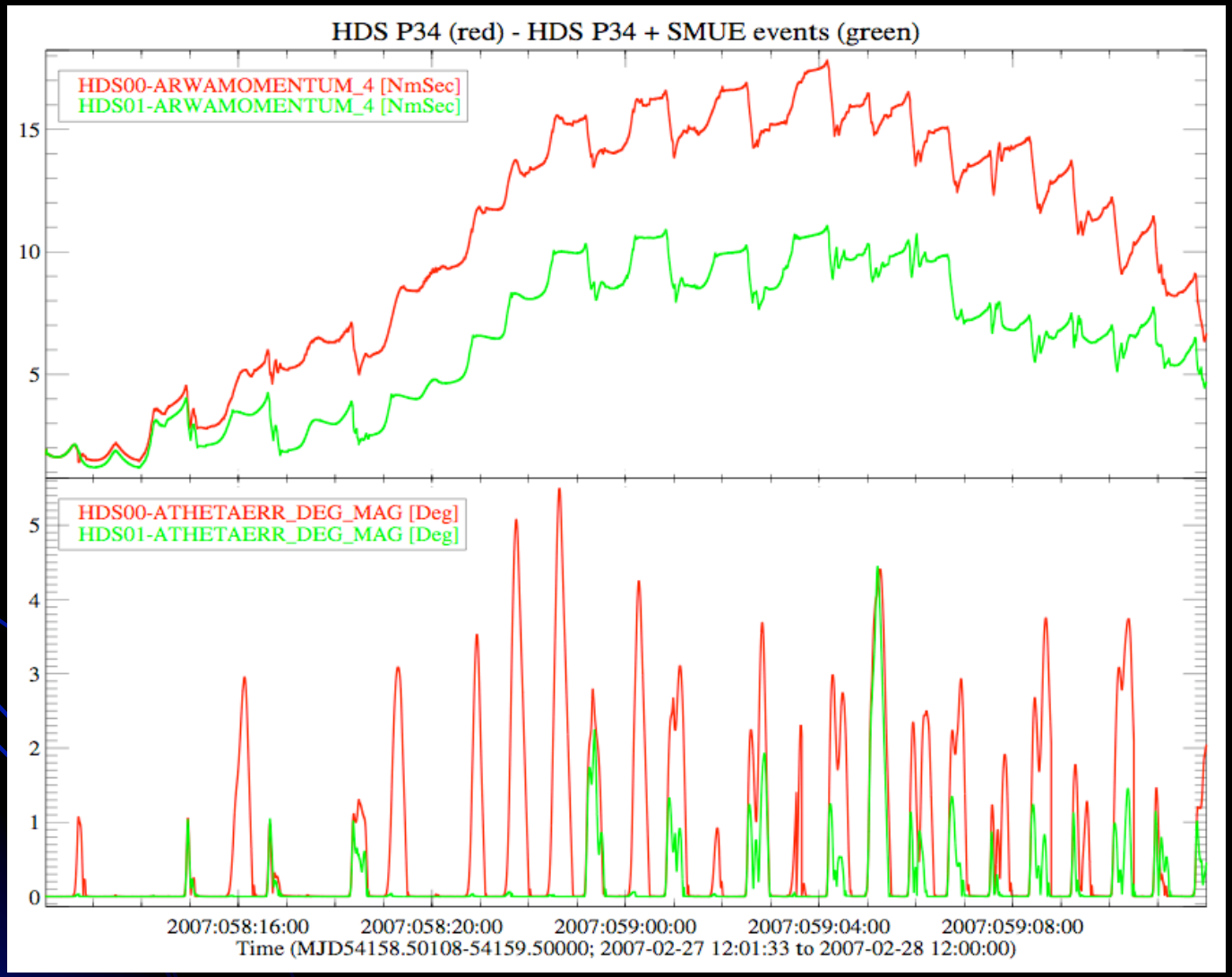
Period where unloading is ineffective and pointing errors are introduced for no positive effect.

Period where unloading is very effective at reducing momentum.

(T. Civeit)

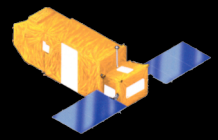
Active Control of Unloading
(promises significant gains)





(T. Civeit)

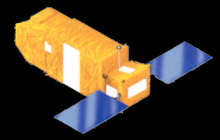
MP Tool Improvements



Process and Tool Improvements are having a significant impact on time line quality while reducing work load.

- LRP and Related Tools.
  - Spike LRP still used to generate overall long range plan for high priority (A and B class) targets (N-S campaigns, etc.).
  - New tools “binmaker” and “binfeeder” used to produce improved weekly target pools containing all available science and filler (S/U).
    - Greatly facilitates momentum management/target ordering selection.
    - Significantly improves science fraction per MPS.
  - 3 2-week MPSs are run serially before needing to run LRP.
    - Binmaker/feeder run between MPSs to refresh and update pool information for the next MPS.
    - Less frequent runs of LRP tool needed --> reduced effort.

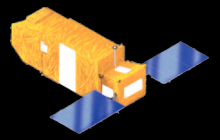
MP Tool Improvements, con't.

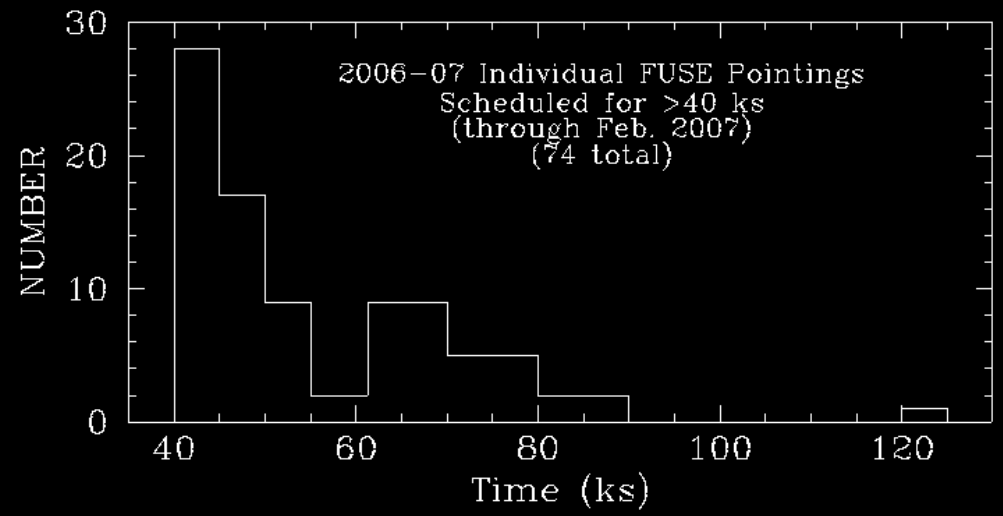


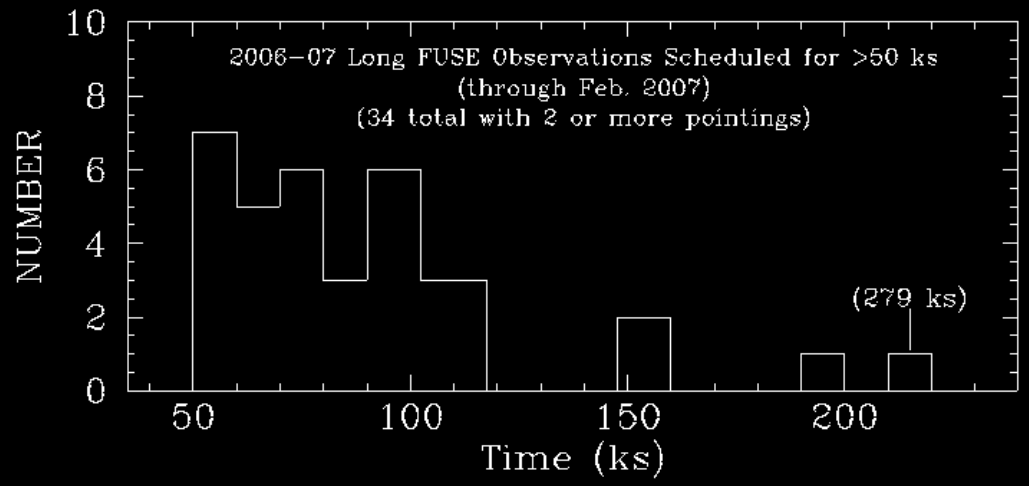
Short Term Scheduling

- Our current short term scheduling methodology has adapted to numerous changes.
- STSing has been greatly streamlined by binmaker/feeder target pools and associated products.
  - MPers can now efficiently select a target ordering to maximize science and manage momentum vs. time.
- STSing tool has had improvements that speed its operation, minimize "hand" repair work, and allow the 2-week MPS strategy to work.
- Can now plan pole-to-pole, C-targets directly in MPSs.
  - But careful real time monitoring is still needed.
- Development/testing of SOVA tool has been concluded.
  - Intended to be a "brute force" STSing tool.
  - New procedures outlined above have superceded the need for this tool.

Long Observations

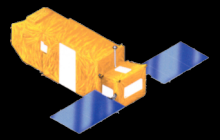






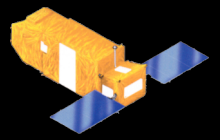
- Even as general operations continue, we are scheduling a significant number of long individual pointings and long total integration targets (multiple pointings).
- This bodes well for a possible period of extended operations in FY09-10.

Odds and Ends



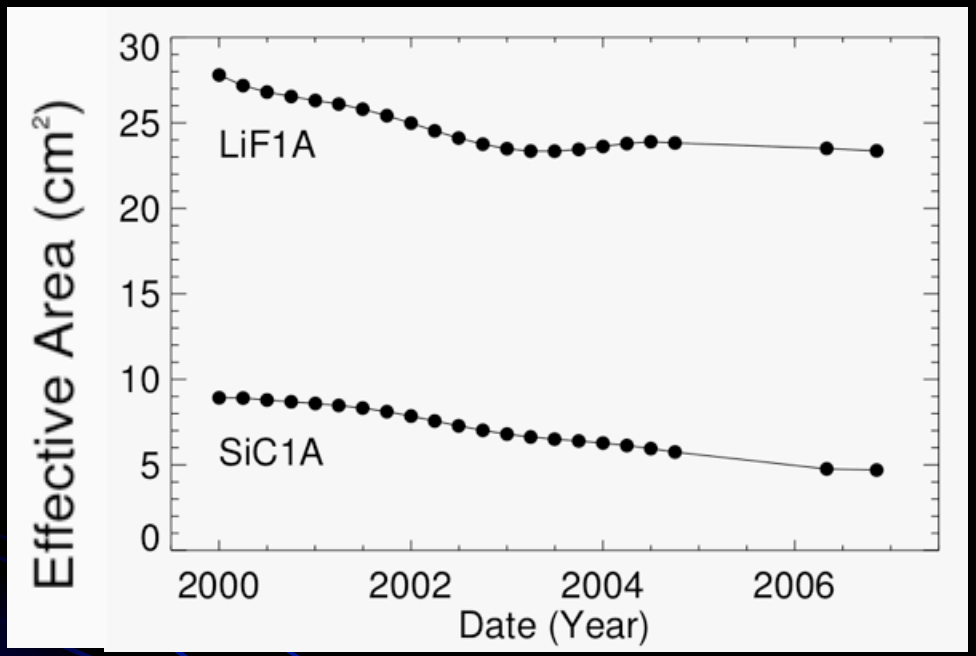
- Channel Alignment
  - ChAT Channel Alignment Tool, integrates assessment tools into an easy to use GUI, greatly simplifies and improves accuracy of alignment data. (Additional cross training.)
  - Working on a revised alignment model to improve predictive mirror motions at high beta angles.
- Momentum Interventions
  - Developing a strategy that permits slew times to be adjusted to help with momentum adjustment.
    - Tool to assess potential slew time adjustment.
    - Change scripts to gracefully allow tweaking of planned slew times,
  - Working on a tool similar to “ChAT” that will integrate some of the diverse tools currently used to plan and execute a momentum intervention.

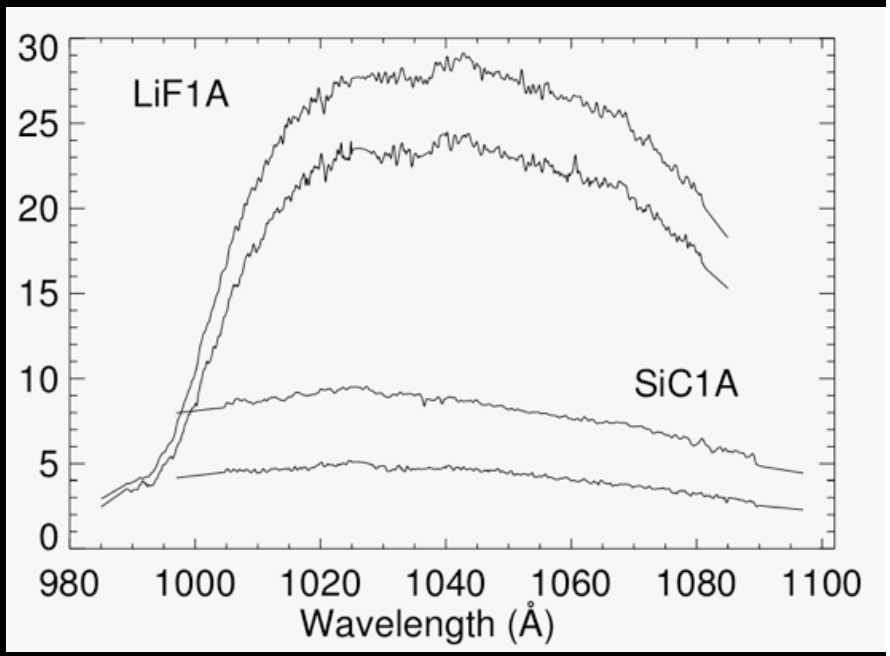
CalFUSE 3.2 Status



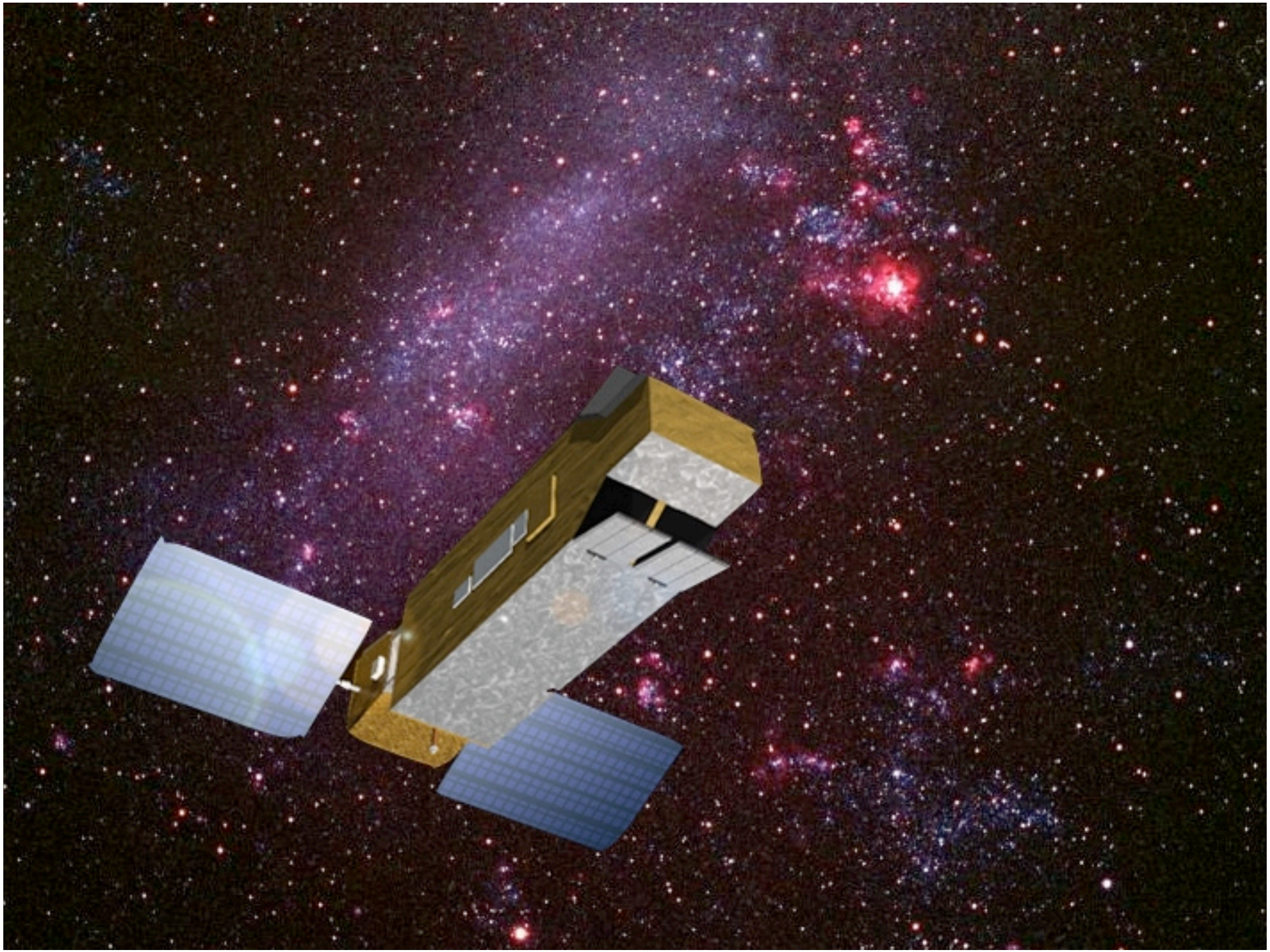
- CalFUSE v3.2 was released on Apr. 9, 2007
  - It is being used to process all new data coming down from the telescope.
- All CalFUSE-related documentation has been updated to reflect the latest changes to the code.
- Web page postings are all current.
- CalFUSE paper by Dixon et al. has been finalized and will appear in the May 2007 issue of PASP.
- Bulk reprocessing of all FUSE data with CalFUSE 3.2 has begun.
  - Currently 4965 observations in MAST.
  - Barring any unforeseen circumstances, reprocessing should be completed by early 2008.
- Latest calibration shows sensitivity holding steady (next).

FUSE Sensitivity

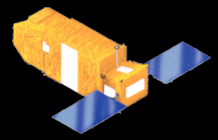


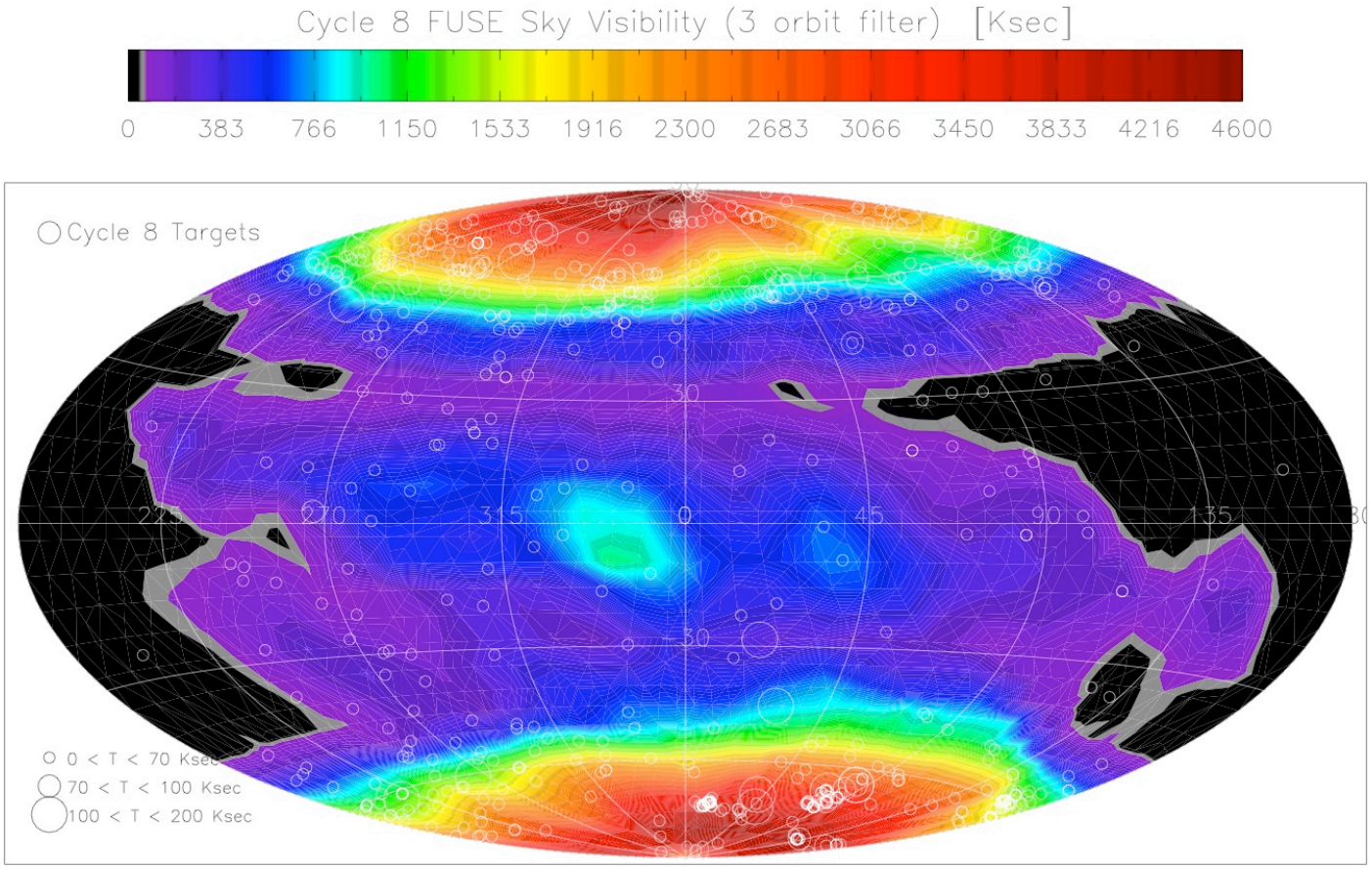


- Nominal flux calibration targets are in difficult-to-observe regions.
- Additional flux calibration targets have just been selected to provide more opportunities for sensitivity monitoring.
- Limited resources remain to continue calibration updates.

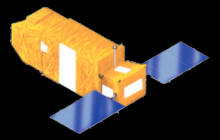


Cy8 Sky Coverage w/Targets



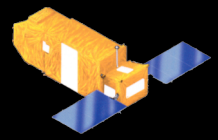


One-Wheel Ops
A Primer



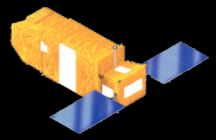
- Attitude Control System (ACS) is the S/C software that controls pointing.
- Only Wheel remaining is the Skew Reaction Wheel.
  - +/- 6500 rpm top speed (+/-21 Nms).
  - Higher wheel speeds mean more gyroscopic torques when slewing.
  - We plan so as to keep this below +/-14 Nms.
- Three Magnetic Torquer 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.

Opening Sky Coverage



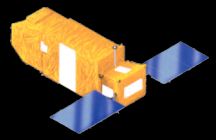
- Primary requirement: demonstrate we can slew to (and from) lower declination regions which have predicted (temporary!) stability and still have enough time to make an observation.
- At present, can perform simulations (as with hemisphere-crossing slews) to assess expected performance and range of allowed 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.

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.

Extended Operations?



- Ongoing development is being done to improve operations for the *remainder of the approved mission.*
- 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.