



# GALEX Science Operations Center Mission Planning

Karl Forster

*June 29th 2006*

*GALEX Operations Review*

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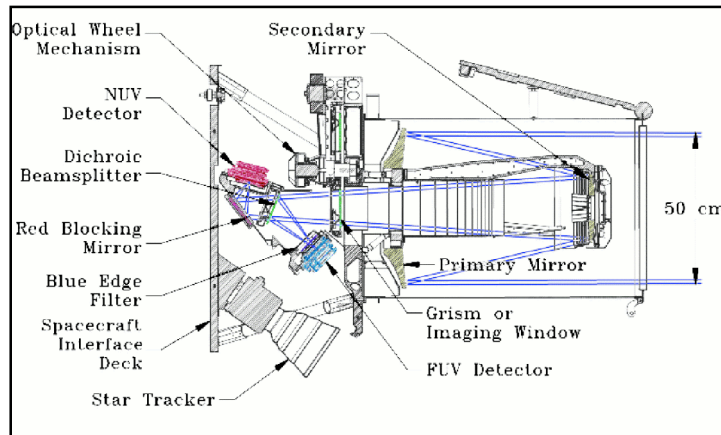


# GALEX Science Mission



## Spacecraft

- Small Explorer mission (SMEX)
- Launched April 28th 2003
- Low Earth Orbit: 690km altitude 29° inclination
- No consumables
- Orbit lifetime >25 years
- Power margin >30% through 2010

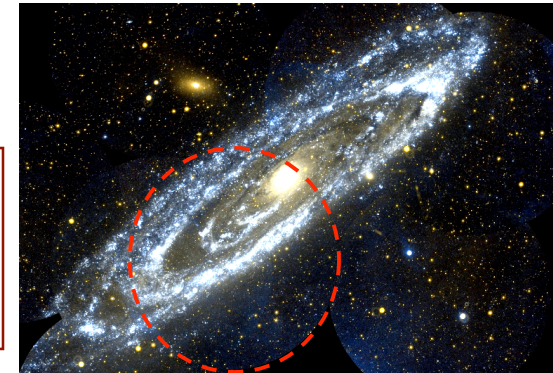


## Instrument

- 50cm telescope, 1.2 degree field of view
- Two 68mm microchannel plate photon counting detectors
- UV 1350-1750Å & 1750-2750Å
- Imaging (4.5/5.1") & grism spectroscopy (R 100 - 200)

## Science Goals

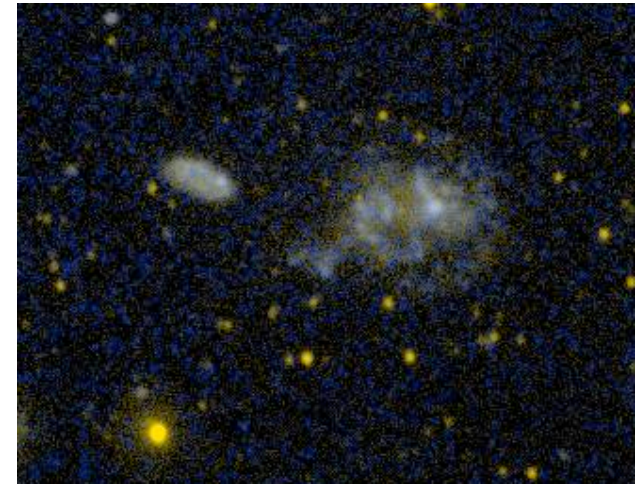
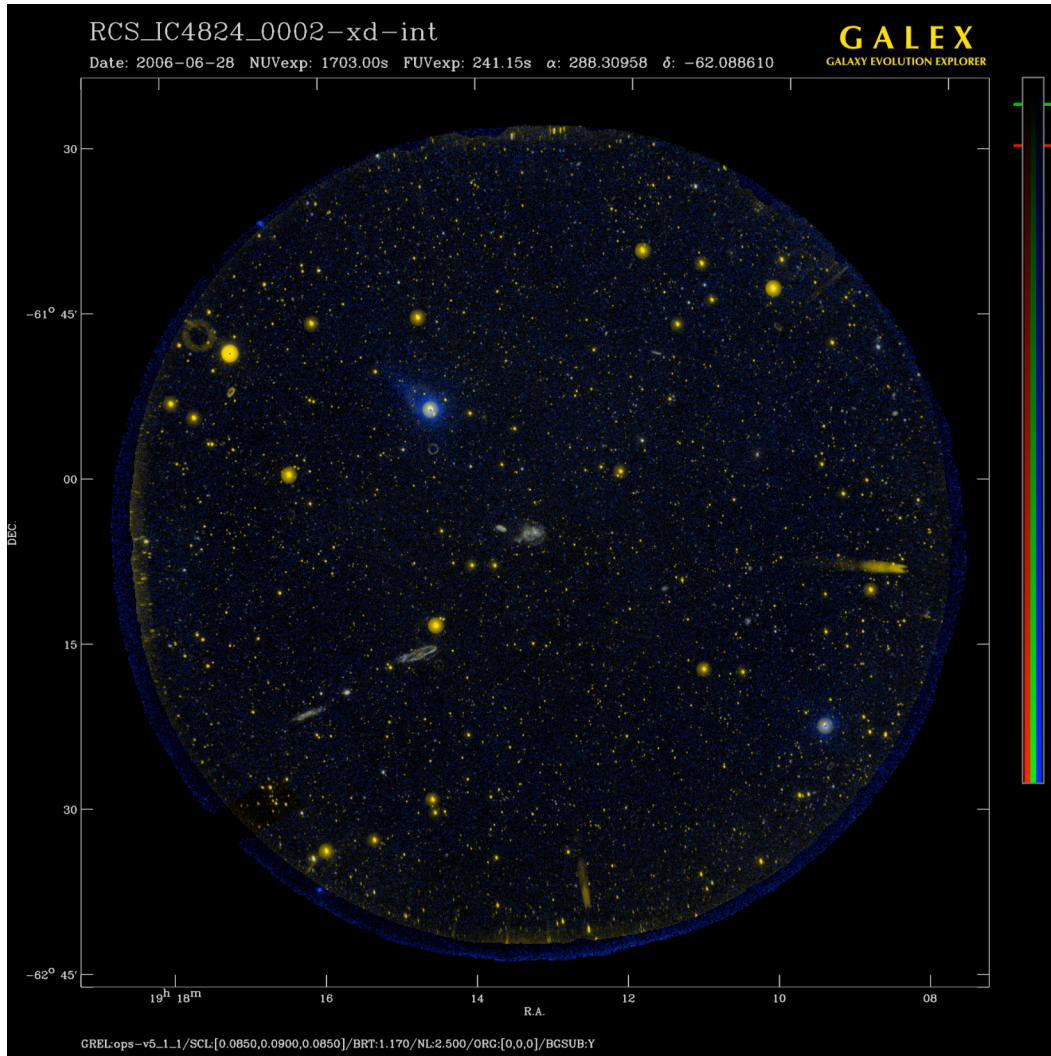
- ★ Relate UV to Star formation in galaxies
- ★ Map star formation history over 80% of the age of the universe
- ★ Explore the UV universe



Andromeda galaxy



# FUV nominal HV cycle



IC 4824  
Eclipse 16892  
2006-06-28 10:29:01Z  
240s FUV (14%)

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# Orbital Events

## Orbit Data

Altitude: 690 Km

Inclination: 29°

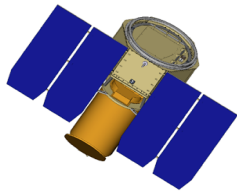
Period: 98.6 min



## Night/ Day Slew Mode

Slew to daylight attitude starts  
3 minutes prior to umbra exit

- Telescope away from Sun & Earth
- Orient Spacecraft normal to Sun
- slew duration 6 minutes

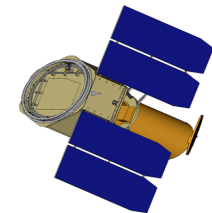
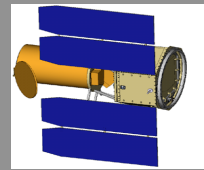


## Observation Mode

Dither about Target position

Eclipse duration 25 to 35 minutes

Detectors at low voltage while in SAA



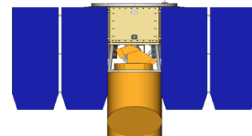
## Day / Night Slew Mode

Slew to Target about 9 minutes  
prior to detectors reaching  
operating voltage

- slew duration 6 minutes
- settling 3 minutes

## Daylight Mode

- Charge Batteries
- Detectors at low voltage
- Orient Telescope away  
from Sun & Earth



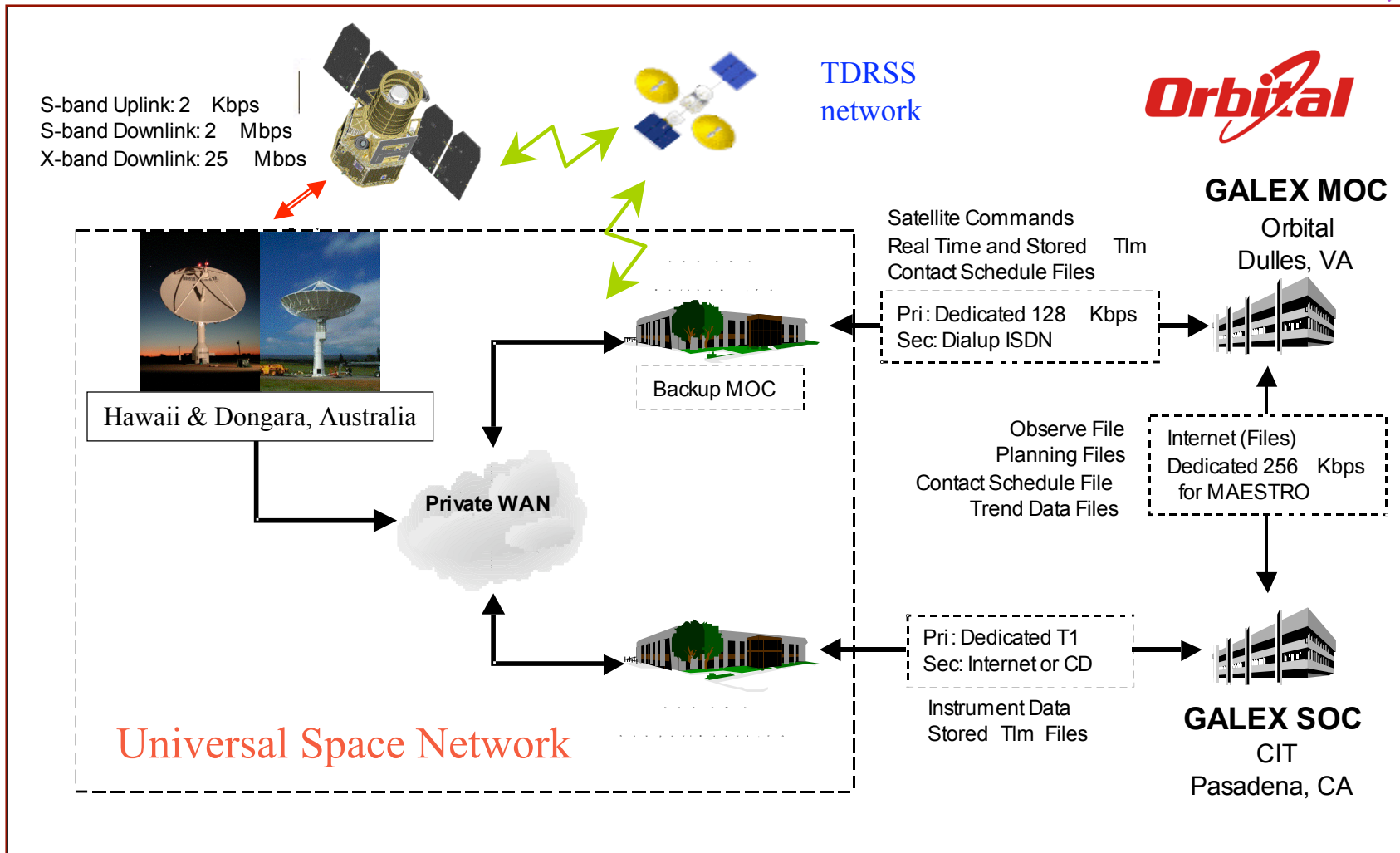
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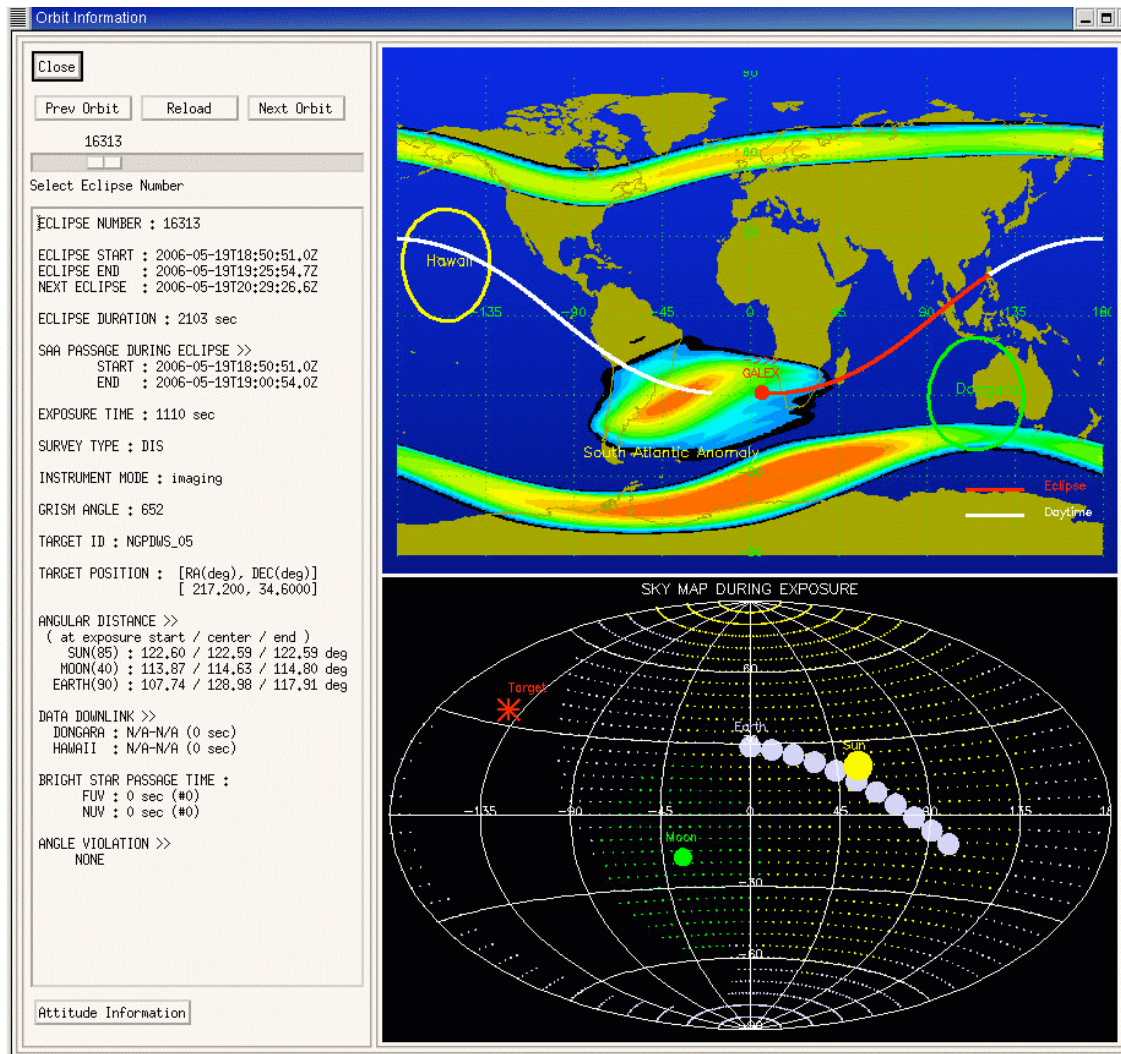


# Mission Operations





# Data Management



- Solid State Recorder
  - 3GB capacity
  - 2 partitions (Science & Engineering)
- 3-4 ground station contacts / day
  - Real time telemetry at MOC and SOC (maestro)
  - Contact durations 7 to 12 min
- Science Contacts
  - 1.5GB science data
  - <24hr latency processed data
  - 0.5GB engineering telemetry
  - <8 hour latency
- Engineering Contingency Contacts
  - Re-dump of Failed Pass
  - Scheduled in advance
  - <50% successful in recovering lost science data

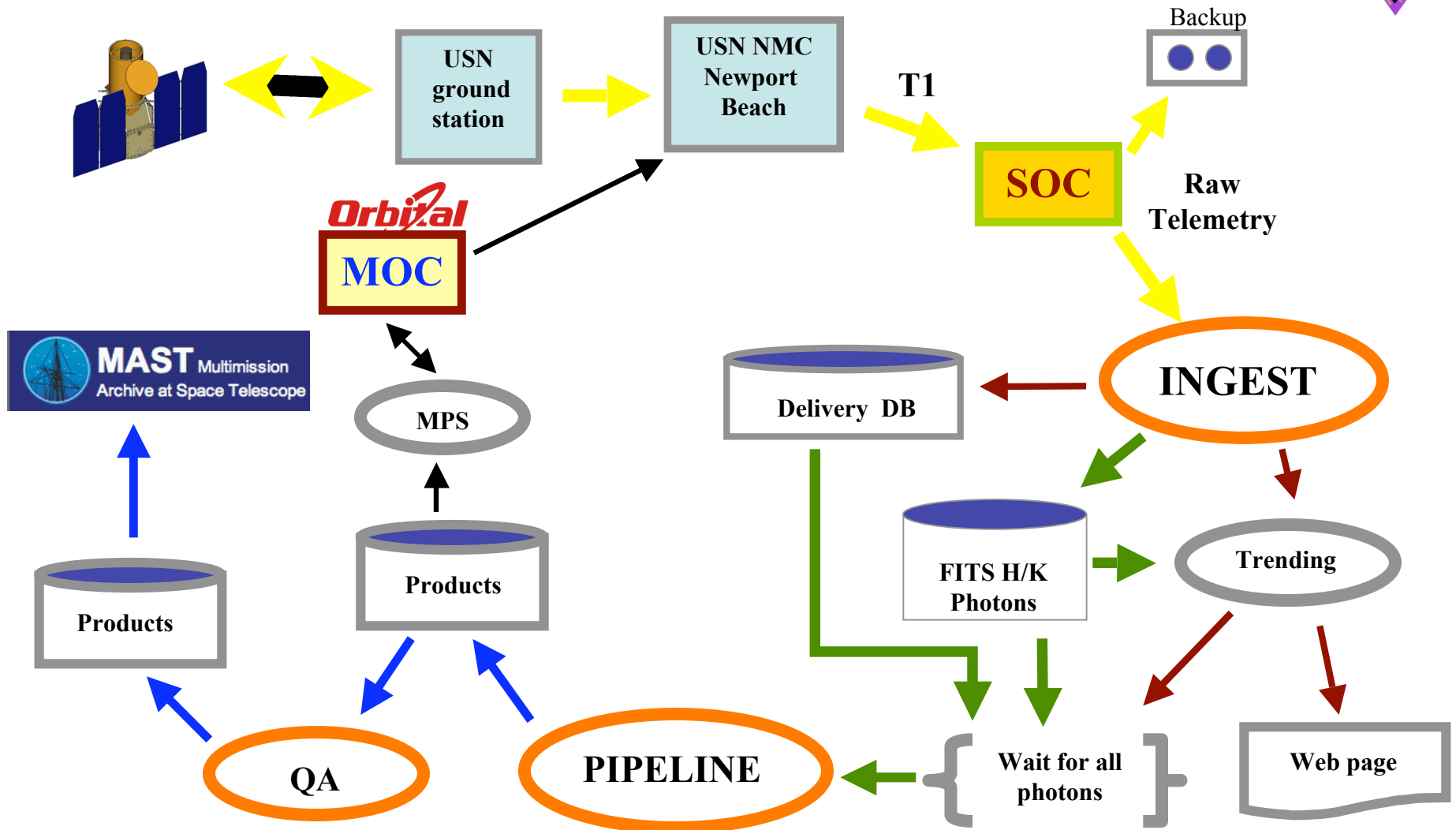
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# Operations: Data Flow



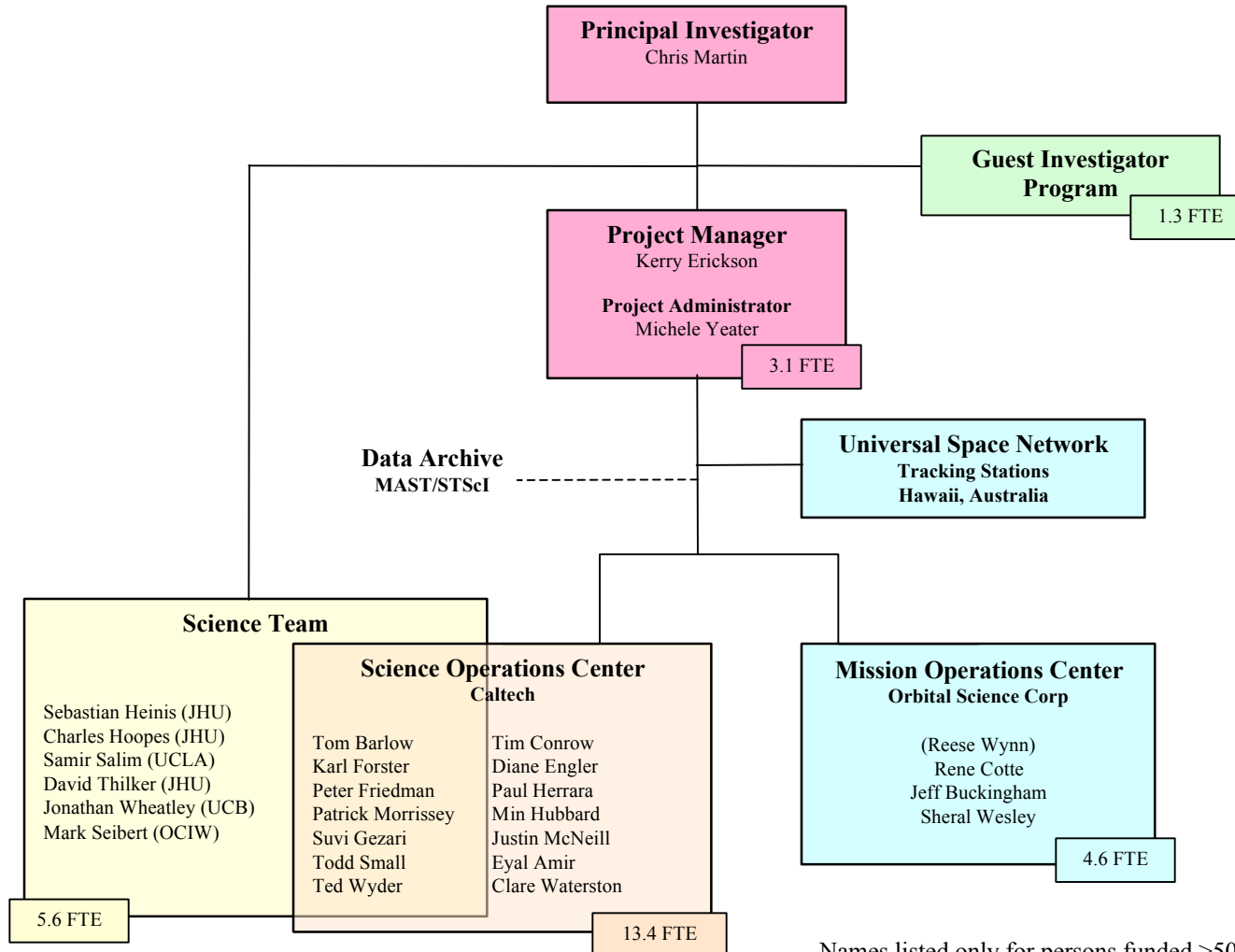
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# GALEX Team



Names listed only for persons funded >50% by GALEX,  
FTE numbers for each box include all personnel





# MOC Mission Planning (RW)

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# GALEX Science Operations Center



- Caltech Campus, Pasadena, CA
- Mission Planning Activities
  - Target selection - KF (DS)
  - Observe file generation - PH (KF, EA, JM)
  - Safety checks - PH, KF (DS, KE)
  - Raw telemetry backup - DE (KF,TC)
- Instrument health and safety - PM (FS + science team)
- Pipeline processing - TC, CW (TB)
- Telemetry Trending - KF
- QA - MH (CW + Science Team)



# SOC MPS



- Command line driven (Linux OS)
- C++ IDL Perl (PostgreSQL)
- Shell scripts call modular code elements
- Controlled by parameter files
- Safety checks
  - At many points in observe file (obs) generation procedure
  - Absolute Time Sequence (ATS) file generated by MOC from obs
  - ATS approval meeting reviews remaining issues before upload
- Planning cycle
  - Long Range - ~~60 days~~ *~every week*
  - Pre-planning, contact selection - ~~2 weeks~~ *~every week*
  - Short Range - weekly *(as designed!)*



# SOC MPS procedure (PH)

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# Operations issues



- Long Range Planning
- SSR management / Contact selection (USN)
- MOC / SOC interface
- Contingency pass success?
  - VC18 redump during contingency passes
  - More accurate SSR slice redump
- Planning cycle adjustments
- Relaxing instrument limits?
- Hardware & software upgrades
- Science mission efficiency



# Long Range (Target Planning) Issues



- Update Bright Star catalog
  - Improve Estimated count rates (SDSS → GALEX)
  - Include gain sag
  - GALEX measured countrates
- Target Planning
  - Bright star exclusion from central 10 arcmin
  - Auto AIS → allocation to SAA eclipses
- Match exposure times used in long range planning to those created in short range planning (GNAT 143)
  - more efficient eclipse allocation
- Need major code upgrade for time domain survey planning



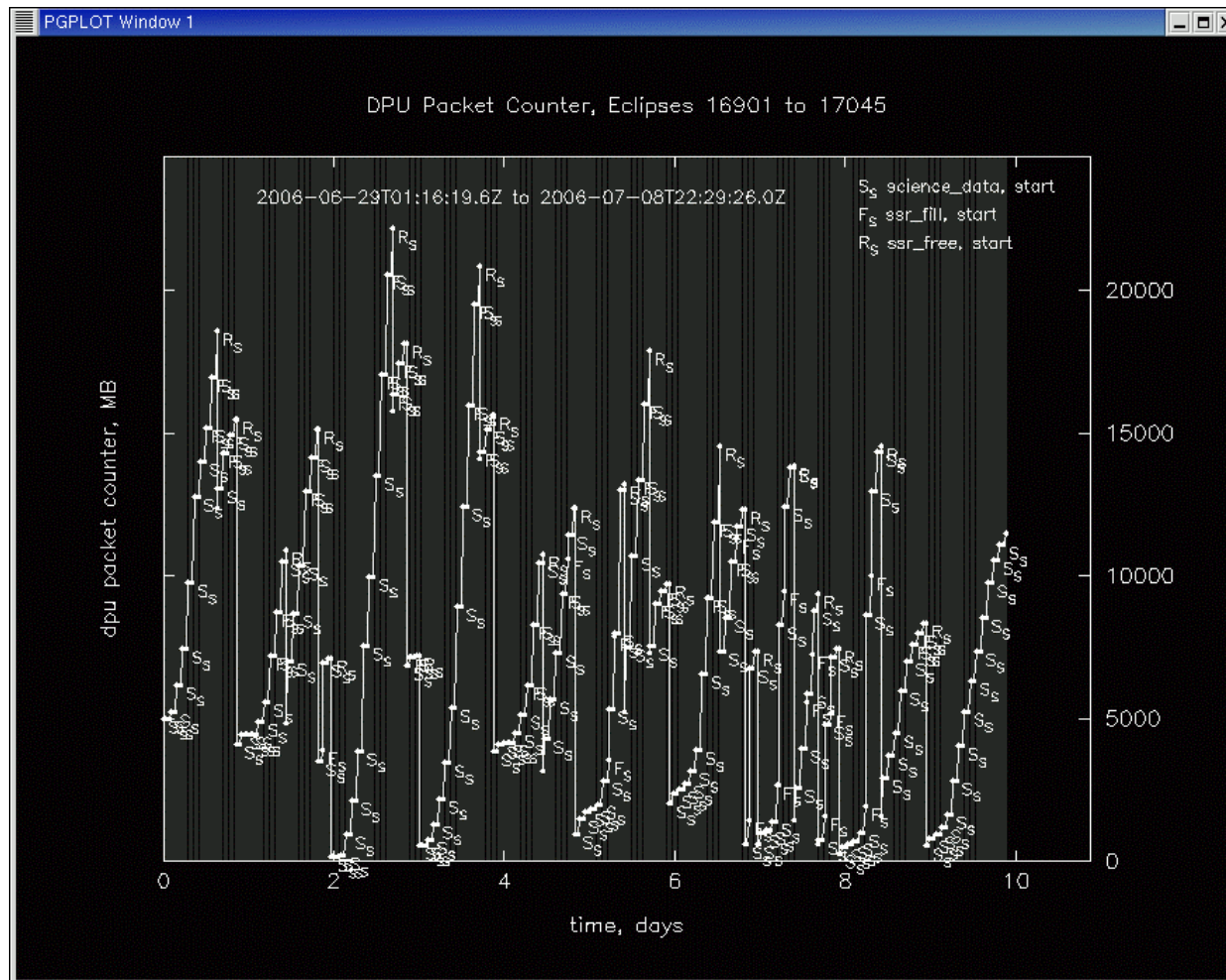
# SSR Management Issues



- Inaccurate data volume (dvv photon rate) estimates
  - 110% NUV 75% FUV
  - Inefficient SSR use and contact selection issues
  - Historical fluxes
  - Error warning when dvf total photons > count rate limit
  - Duplicate star counting
- Manual contact selection
  - Time consuming (longest process in observe file generation)
- New SSR management and contact selection tool (Min H.)
  - IDL widget code *cf* QATOOL (sap2dtf, reportssr, dtf2pcf, chkcon)
  - Visibility into target, eclipse, potential contacts, contact conflicts
  - To be efficient we will require regular standardized updates of the USHI/AUWA contact schedule from USN
  - Send .sap to USN?



# Today's SSR management



.sap converted to downlink time file (*sap2dtf*)

.dtf manually edited to choose contacts

*reportssr* used to view SSR data management

*dtf2pcf* used to generate .pcf and .ecf sent to MOC

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# MOC / SOC interface



- File transfer via *narvi*
  - Manual FTP process
  - Automatic file push-pull, e.g.
    - MOC places `<plan>.sap` `<plan>.mps_v###.rpt` `<plan>.att` on *narvi*
    - Files automatically transferred to rcv and work directory
    - mps-obspostchk automatically started
- Can MOC FDS, Compiler, Planner be automated in a similar way?



# Planning Cycle adjustments



- Whither obp?
  - Return to 2 week planning cycle
  - Improved USN information flow for 2 week contact selection
  - Do we need an obp?
- Whence Long Range Plan?
  - Time domain survey may impose restrictions on target/eclipse assignment so LRP needs to become fixed for ## days
  - E.g. LSST can replan their entire survey in 6 hrs of cpu
- Wherefore ToO?
  - Advertised response time is 10 days but ToO's have been achieved within 5 days (SN2005ay)
  - Community interest in faster response
  - Minimum CPU time to generate obs file (inc.file push/pull)?
  - TDRSS for ATS and switch time load?



# Instrument limit adjustment



- Moon avoidance angle (OECR 40)
  - Reduce from  $40^\circ$  to  $\sim 20^\circ$
  - Improved target visibility probably required for TDS
  - SAA, Earth limb avoidance reduction?
- Detector countrate limits
  - FUV to 30k/100k NUV to 30k/150k?
- Optical wheel motion within eclipse
  - Imaging/grism in single eclipse (FS, MOC, SOC, pipeline)
- Dayside FUV operations
  - Galactic plane FUV slew survey (can we dither on dayside?)



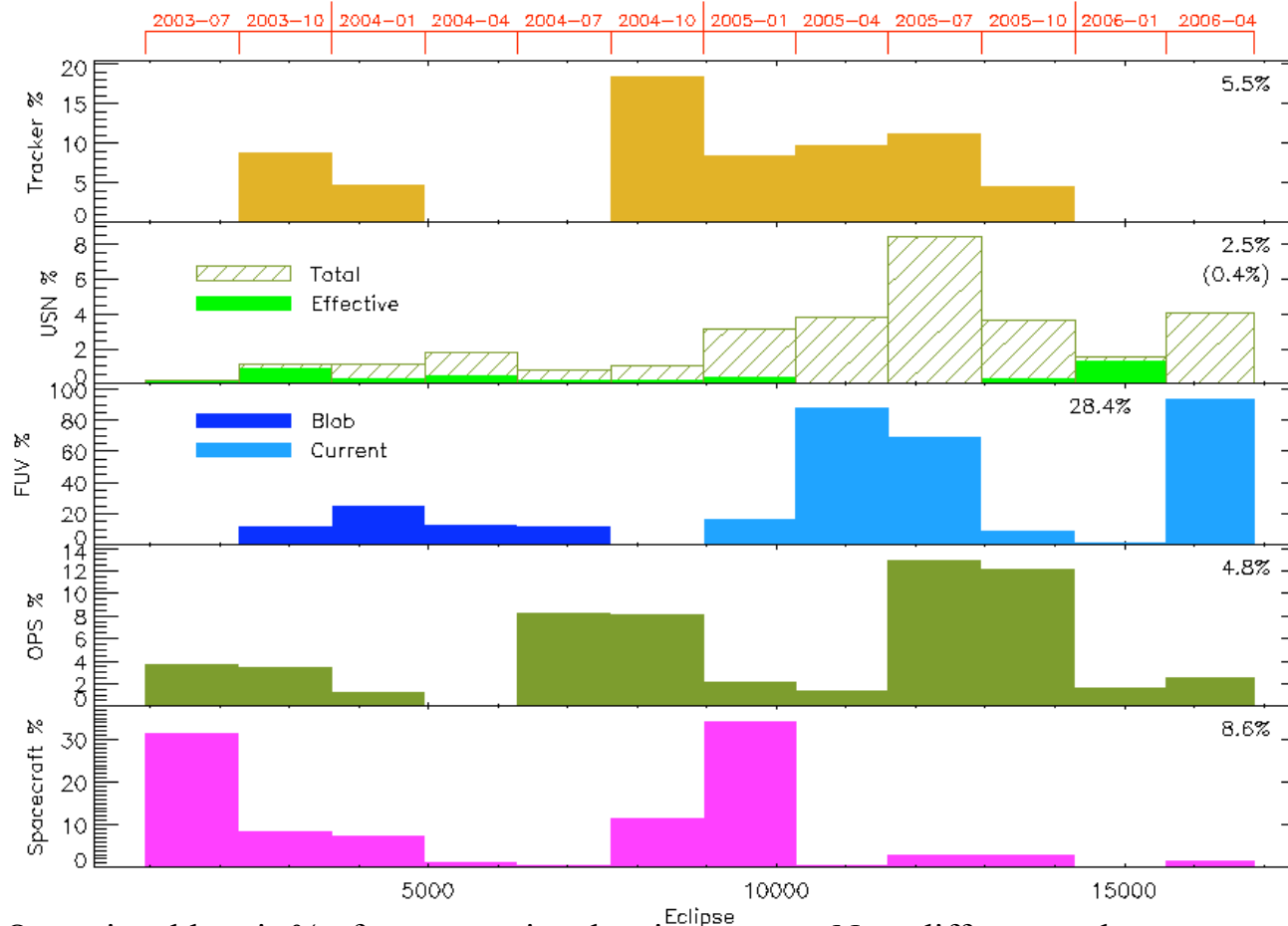
# Hardware Software upgrades



- OS to Redhat Enterprise
- Document server
  - Project documents are not collected in one place
  - CVS for documents?



# Quarterly Operational Losses



Star Tracker issues (inc. Engineering tests)

Ground station issues (inc. cancellations for LEOP support)

FUV detector issues  
Window charging (2004)  
Current anomaly (2005-6)

Operations (inc. Solar Weather, underestimated target brightness)

Engineering (inc. DPU errors & code changes)

Operational loss is % of exposure time lost in quarter. Note different scales  
Total losses for each category are shown as %.

Total losses by band are: **NUV 20.4%** **FUV 47.5%**

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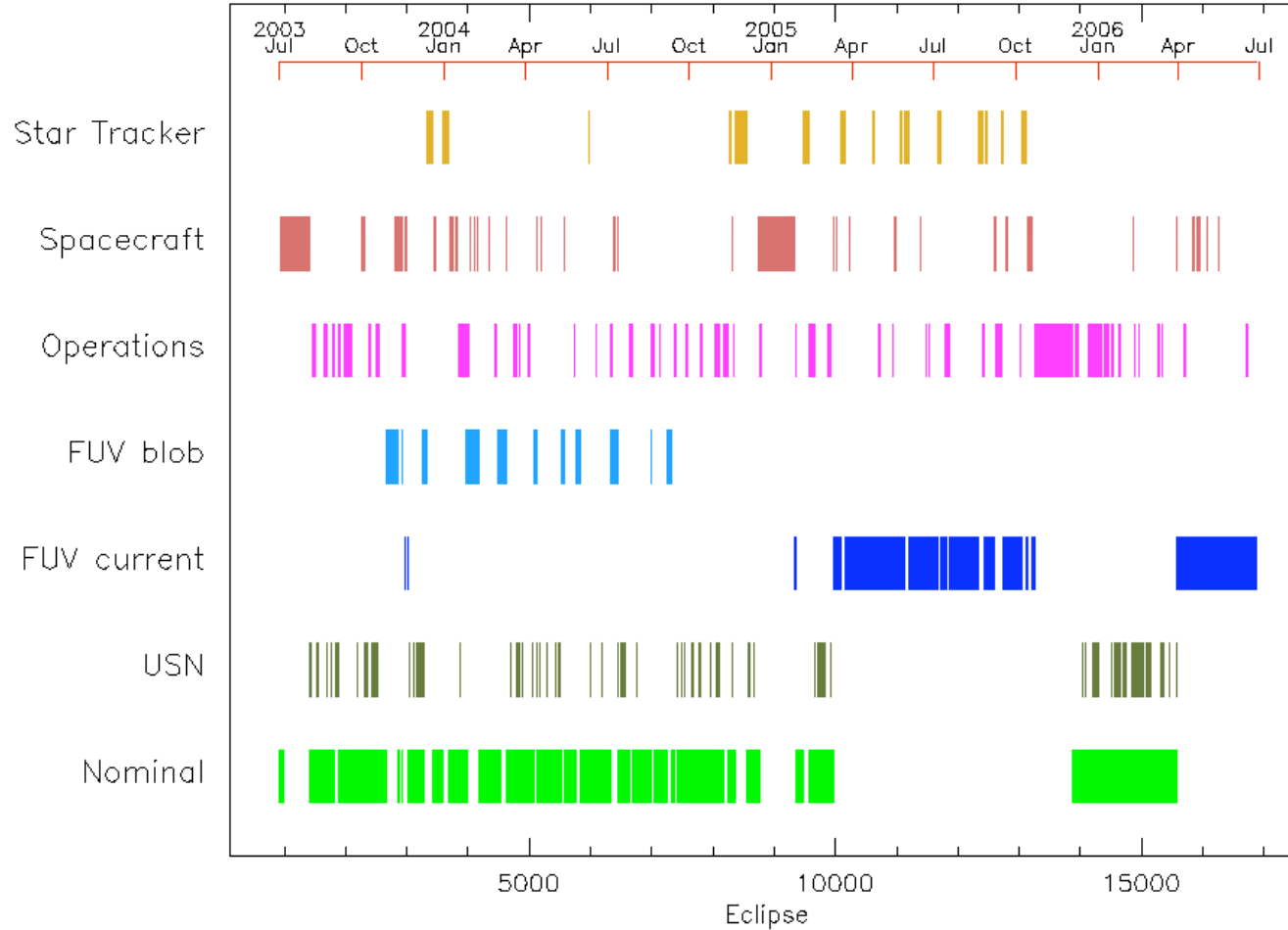
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# Loss category history



Loss category events – 2006-06-26



- Eclipses where losses in each category occurred

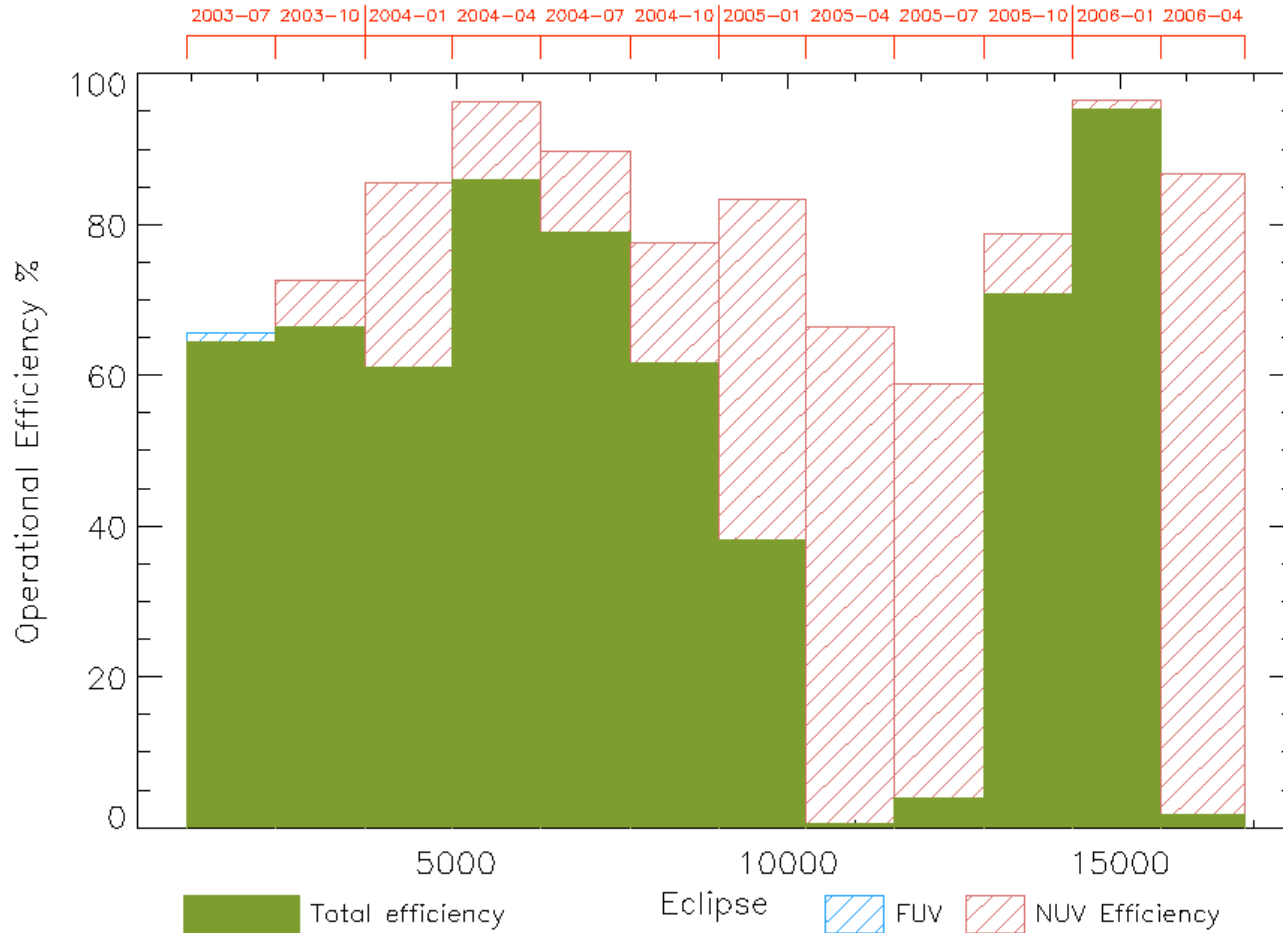
- NOT magnitude of loss

- No double counting

- Nominal is both detectors working



# Quarterly Operational Efficiency



Total efficiency is with both NUV and FUV nominal



# Observation Efficiency Contributors



**Lost observing time and responses that improve operational efficiency.**

Cause of lost data	Loss <sup>c,d</sup>	Measured efficiency or response/mitigation
Ground sys problems	5 %	Upgrades, spares, & redundancy at ground stations; antenna adjustments; ground SW & ops procedures improved.
SC & instr. problems	7 %	SC & instrument flight SW improvements to mitigate or eliminate the effects of SC & instr. idiosyncrasies.
Star tracker problems	6 %	ST CCD temperature 0 → -10C; loosened CSP pointing limits; updated attitude control system SW tables.
<b>System downtime</b>	<b>18 %</b>	<b>82 % system availability, defined as able to produce good observing data (assuming detectors are on).</b>
FUV detector “blob” <sup>a</sup>	6 %	Monitor blob. If seen, turn HV off to reduce downtime & response labor. Seems eliminated by HV cycling.
FUV detector HV-current anomaly <sup>a</sup>	16 %	Cycled HV on/off at increasing voltages to resolve anomaly. Continuing to cycle HV off every orbit dayside. Upgraded ground & flight SW to automate 10x faster cycling in the event of reoccurrence.
NUV downtime <sup>b</sup>	3 %	Down ~1 mo to investigate 7/4/03 event. Turned off detector to fix. Flight SW patch now protects autonomously.
<b>Detector downtime</b>	<b>25 %</b>	<b>74 % detector availability. Detector downtime is essentially entirely due to now-corrected anomalies.</b>
<b>Operational downtime</b>	<b>43 %</b>	<b>56 % operational efficiency (both detectors observing) during Phase E.<sup>b</sup></b>
<b>Recent performance</b>	<b>5 %</b>	<b>95 % operational efficiency for 3 mos since we fixed ST, FUV, &amp; MPS SW (12/2/05-3/31/06).</b>

<sup>a</sup> NUV data not affected

<sup>b</sup> FUV data not affected

<sup>c</sup> 6/30/03 (Phase E start) to 3/31/06

<sup>d</sup> Emergency & planned engineering time, but not calibration observations, count as downtime

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# Telemetry Trending



Netscape: GALEX Telemetry Trending Top Page

File Edit View Go Communicator Help

### GALEX Flight Telemetry Trending - 2004

<b>SOC</b> (626) 395 5922, 5923 FAX (626) 395 5877	<b>LAST UPDATED</b> 2006-05-19 15:44:02 UTC	<b>MOC</b> FC (703) 404 7471, 7473 EBR (703) 404 7476, 7478 FAX (703) 404 6592
----------------------------------------------------------	------------------------------------------------	-----------------------------------------------------------------------------------------

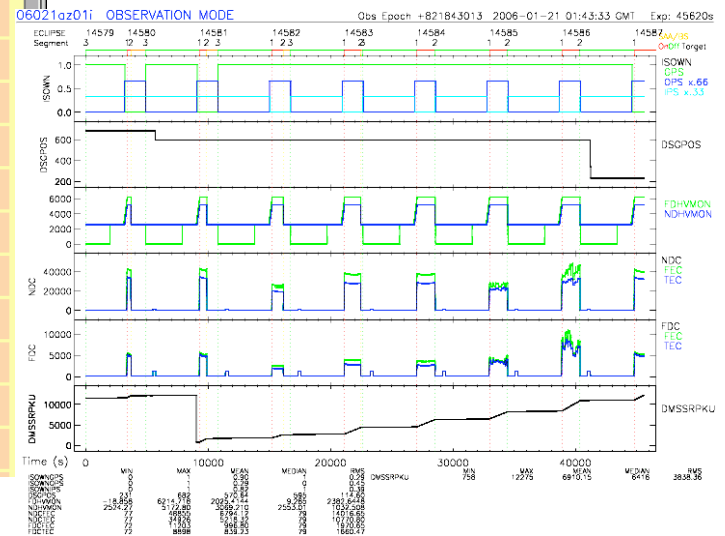
OTHER AVAILABLE TABLES: [VD18 apid Table](#) (ps pdf txt), [DPU Telemetry Dictionary \(GAL-JPL-325\)](#) (pdf doc), [GALEX Telemetry & SODA OOL Dictionary](#) (ps pdf txt csv), [Critical Events Timeline](#) (csv), [Long Term Trending](#)

Jump to: Bottom [YEAR 2003](#) [YEAR 2005](#) [YEAR 2006](#) Week: 04361 04354 04347 04340 04333 04326 04319 04312 04305 04298 04291 04284 04277 04270 04263 04256 04249 04242 04235 04228 04221 04214 04207 04200 04193 04186 04179 04172 04165 04158 04151 04144 04137 04130 04123 04116 04109 04102 04095 04088 04081 04074 04067 04060 04053 04046 04039 04032 04025 04018 04011 04004

FOR WEEK BEGINNING: 2004 Dec 26 DOY = 04361 Mission Day = 609

Delivery ID <i>Latest update</i>	Eclipses Present	Time Range in Delivery Spacecraft Clock & GMT	Summary Pages	Processed on (UTC)
<a href="#">05001hz02i</a>	8962 8963 8964 8965 8966	788606645 to 788628600 2005-01-01 09:24:05.0Z to 2005-01-01 15:30:00.0Z	<a href="#">PTAG</a> <a href="#">ALERT</a> <a href="#">Concern</a>	2005-01-02 00:38:58.0Z
<a href="#">05001hz02s</a>	NONE	788610880 to 788636032 2005-01-01 10:34:40.0Z to 2005-01-01 17:33:52.0Z	<a href="#">PTAG</a> <a href="#">ALERT</a> <a href="#">Concern</a>	2005-01-01 18:38:12.0Z
<a href="#">05001hz01i</a>	8959 8960 8961 8962	788587889 to 788606643 2005-01-01 04:11:28.9Z to 2005-01-01 09:24:03.0Z	<a href="#">PTAG</a> <a href="#">ALERT</a> <a href="#">Concern</a>	2005-01-01 18:09:46.0Z
<a href="#">05001az01i</a>	8952 8953 8954 8955 8956	788545379 to 788570496 2004-12-31 16:22:58.9Z to 2004-12-31 23:21:35.9Z	<a href="#">PTAG</a> <a href="#">ALERT</a> <a href="#">Concern</a>	2005-01-01 13:50:10.0Z
<a href="#">05001hz01s</a>	NONE	788603008 to 788610880 2005-01-01 08:23:27.9Z to 2005-01-01 10:34:40.0Z	<a href="#">PTAG</a> <a href="#">ALERT</a> <a href="#">Concern</a>	2005-01-01 12:54:39.0Z
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<a href="#">04366hz01i</a>	8947 8948 8949 8950 8951 8952	788518676 to 788545378 2004-12-31 08:57:55.9Z to 2004-12-31 16:22:57.9Z	<a href="#">PTAG</a> <a href="#">ALERT</a> <a href="#">Concern</a>	2005-01-01 02:24:15.0Z
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- Instrument & Spacecraft telemetry trended on delivery to SOC
- 300 telemetry points trended
- OOL Alarm system
- All telemetry in SQL database
- Long term trending



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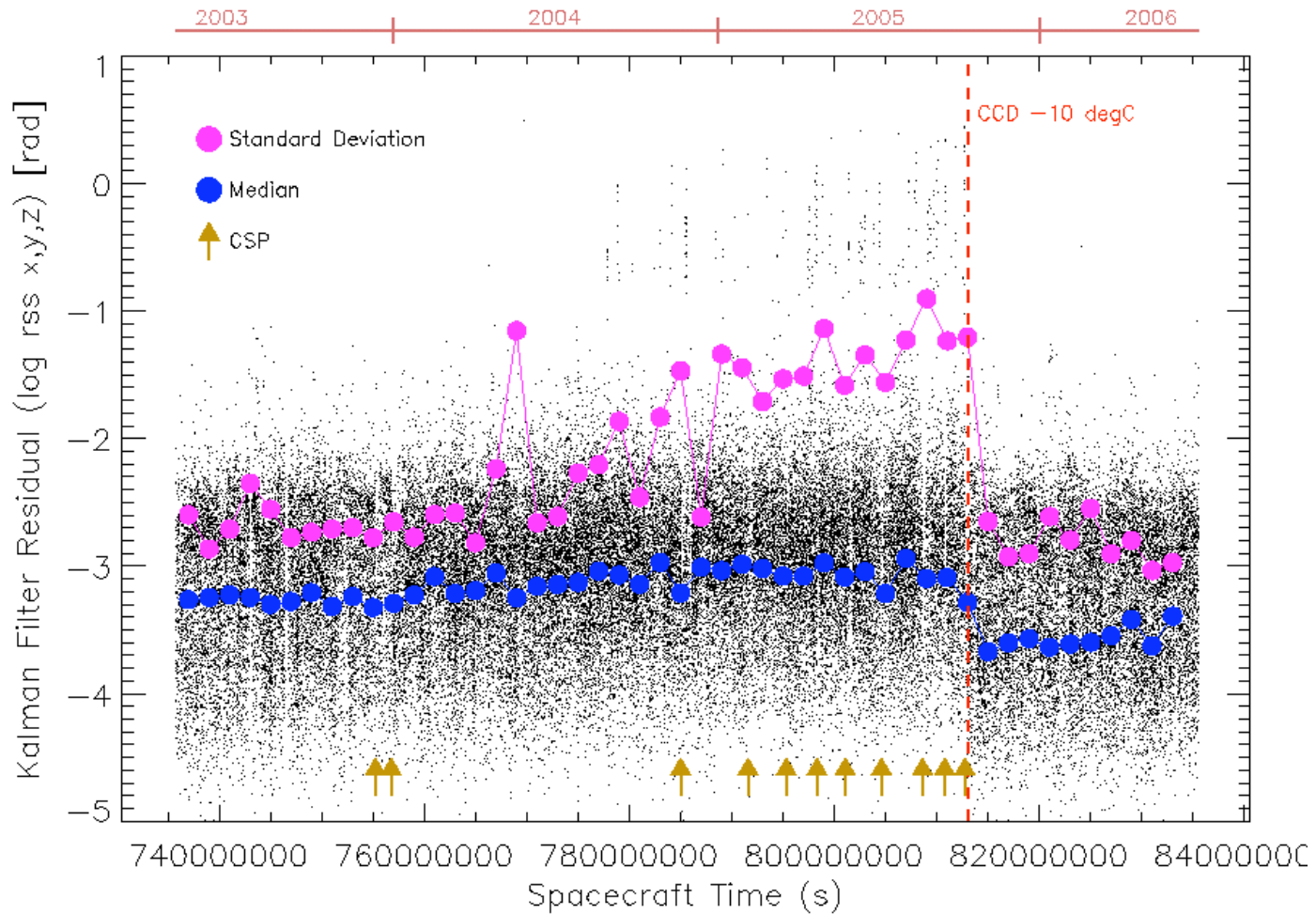
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# Star Tracker Performance

AD Star Tracker Measured Residuals: 2006-Jun-28



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## Future



- OECR 40 moon avoidance angle
- SOC GNATS closed
- Upgrades to SOC SSR/Contact management
- SOC MPS bi-weekly meetings
- Time domain survey need to be implemented by Oct 2007
- Task list with benefit in flexibility data efficiency, labor cost (automation), and risk document on Todds wiggy