EO-1 Spacecraft Bus

Initial Early Orbit Checkout (IOC) Review

December 14th, 2000

Review Overview

Michael J. Cully
EO-1 Program Manager, Swales Aerospace

Agenda

- *Overview*.....*Michael Cully*
- *Chronology of Spacecraft Bus Checkout*.....*Mark Perry*
- *Systems Engineering Performance*.....*Mark Perry*
- *Electrical Systems*.....*Bruce Zink*
- *Mechanical Systems*.....*Pete Alea*
- *Attitude Control Subsystem*.....*Paul Sanneman*
  .....*Dave Speer*
  .....*Kathie Blackman*
- *Reaction Control Subsystem*.....*Michael McCullough*
- *Power Subsystem*.....*Al Billings*
  .....*Ralph Sullivan*
- *Thermal Subsystem*.....*Nick Teti*
- *Communications Subsystem*.....*Tom Spangler (GSFC Support)*
- *Command and Data Handling*.....*Steve Schumacher (GSFC Support)*
- *Flight Software*.....*Gary Smith*
- *Management Wrap-Up*.....*Michael Cully*

Scope of Review

- ***Provide Initial On-Orbit Performance of Subsystems***
- ***Provide details of any anomalies or problems***
- ***Provide GSFC Flight Director & Operations Team with list of Major changes to operations as a result of initial on-orbit performance***
  - ***Nominal configuration changes since launch, and new operational alerts or constraints***
    - *Revised limits*
    - *Deleted commands (commands that are no longer necessary)*
    - *Revised calibration parameters*
- ***Provide Lessons Learned to GSFC to improve future missions in same class***
  - ***Address lessons learned from major Problem Reports***
  - ***What did we do right that made EO-1 a success!***

Systems Status

Mark Perry
EO-1 Spacecraft Systems Engineer, Swales Aerospace

EO-1 Milestones During On-Orbit Checkout

Event	Time	Date	Comment
Pre-launch	326-04:00	11-21-00	Initial GSE problems. Recovered 5 hours before launch
Launch	326-18:24	11-21-00	Within 1 second of optimal time
Ascent	326-18:50	11-21-00	Nominal. S-band telemetry and power-positive
Separation	326-19:24	11-21-00	Spin rates within 1-sigma of predictions
S/A deployment	326-19:28	11-21-00	Nominal
De-spin	326-19:28+	11-21-00	Nominal.
Sun acquisition	326-22	11-21-00	Lowest BSOC ~83%
AST on	326-23:03	11-21-00	Nominal
GPS on	326-23:15	11-21-00	Acquired more quickly than expected
Safe-hold test	327-15:25	11-22-00	Nominal
Earth acquisition	327-20:25	11-22-00	Nominal: pointing, s/a tracking, power
IRU calibration slues	328-15:00	11-23-00	Nominal. Takes 7 hours for all slues
Engineering burn	329-15:19	11-24-00	ACS nominal. Within 1% of expected thrust.
X-band on	329-18:34	11-24-00	
WARP on	329-20:11	11-24-00	
S-band image dump	329-20:29	11-24-00	WARP test data
X-band image dump	329-21:52	11-24-00	WARP test data
ALI on	330-12:44	11-25-00	
ALI internal cal	330	11-25-00	Nominal.
ALI cover opened	330-19:15	11-25-00	Nominal.
ALI image	330-15:58	11-25-00	3-degree offset from expected
Delta-V	331-13:49	11-26-00	Nominal. 1% more thrust than predicted
AC on	331-21:36	11-26-00	
AC dark cal image	331-23:17	11-26-00	
AC image	332-01:00	11-27-00	
Hyperion on	332-12:30	11-27-00	Temperatures higher than predicted
Hyperion internal cal	332-15:46	11-27-00	Lamp concerns
Hyperion cover open	332-19:12	11-27-00	Nominal
Hyperion image	332	11-27-00	
Hyperion cryo on	334-12:25	11-29-00	
LFSA deploy	334-19:02	11-29-00	Earlier command errors caused s/a drive anomaly
All instrument DCE	336-14:22	12-01-00	ACS stability beats goal. Hyperion/ALI slight offset.
ACS alignment load	339-21:01	12-04-00	Corrects slight IRU-to-AST mis-alignment
Hyperion solar cal	340	12-05-00	
PPT on	341-22:32	12-06-00	Not fired
AC solar cal	342	12-07-00	
1-minute behind L7	348	12-13-00	

Overview of EO-1 On-Orbit Performance

- ***The EO-1 spacecraft is "hugely successful"***
  - *Nearly flawless during deployment, early orbit, and normal operations*
  - *Fully tested, except for PPT firing, the lunar raster scan for calibration, and some Fault Detection and Correction (FDC) that we do not intend to test*
- ***3 known hardware or software anomalies (only one s/c anomaly)***
  - *Intermittent GPS drop-outs: understood, mitigated by simple table load*
  - *Hyperion-to-ALI misalignment: Hyperion FOV not entirely within ALI FOV*
  - *One LFSA temperature sensor failed. LFSA technology already evaluated*
- ***Two areas of disappointing performance***
  - *AST loses track at ~60 degrees to sun rather than ~30 degrees: no effect on normal operations*
  - *Oscillations in s-band: mitigated by large margins*
- ***Many areas perform better than required and expected. Some examples (details in subsystem presentations):***
  - *ACS stability during images has been measured better than the goal*
  - *S-band uplink/downlink margin is more than 25 dB higher than budgeted!*
- ***Command and ground station errors caused anomalous conditions***
  - *The s/c team recovered each incident quickly, without problems*

FDC/TSMs

- Safe-hold and load-shedding successfully tested (see ACS presentation)
- Several TSMs (M5-controlled FDC) tripped due to anomalous conditions precipitated by command errors
  - All TSMs functioned as expected
  - All unplanned events corrected without adverse effect on EO-1
- Several ACS FDC checks tripped
  - Some due to anomalous configurations or conditions, others due to expected conditions
  - All FDC trips are understood
- All FDC and TSMs tested before launch

Pre-Launch Testing and Training

- ***EO-1 operational success attributed in part to extensive test and simulations***
  - ***Five comprehensive performance tests***
  - ***More than five two-day simulations than included contingencies***
  - ***Second thermal-vacuum test***
- ***S/C engineering team and FOT fully prepared before launch***
  - ***Extensive documentation: S/C User's Guide, Pre-Launch and Early-Orbit Handbooks, Contingency Flow Charts***
  - ***Contingency trees reviewed and contingency procedures tested***

Changes to Flight Software, Database, and Limits

- **Software modifications described in subsystem presentations**
  - Some modifications to optimize performance (e.g., some ACS alignment parameters)
  - Some adjustments to FDC trip points based on on-orbit experience
- **Many changes to EO-1 operations based on experience to date**
  - Changes to procedures, planning system, constraints, and limits
  - Improve old RTSs and add new RTSs to increase efficiency and to correct errors that created anomalous conditions
- **Changes captured in Database Change Requests and approved by the EO-1 CCB**

Lessons Learned

- ***Two lessons from late avionics:***
  - ***Development projects take more time than COTS. The ACDS, PSE, C&DH S/W, and 1773 transceivers did not meet schedule.***
  - ***ETUs are needed. They save time, schedule, and resources***
- ***Lots of test time is good. At both the box level and at the satellite level. This includes launch and orbit simulations.***
- ***The minimum set of necessary documentation is not zero***
  - ***Needed C&T handbook prior to start of I&T***
  - ***Needed additional documentation on engineering decisions***
- ***You cannot force 6 months of I&T into two months***
  - ***An aggressive schedule that does not contain contingency time is only viable for well-tested components, that is, for repeated tests or integration***

Electrical Systems

Bruce Zink
EO-1 Electrical Systems Lead, Swales Aerospace

Agenda

- Electrical Systems Performance
- Anomalies / Unexpected Events
- Configuration Changes since Launch
- Lessons Learned

Electrical Systems Performance

- ***1773 Data bus performing flawlessly***
  - ***No SEU's***
  - ***No data corruption***
- ***No harnessing issues***
  - ***Power distribution nominal***
  - ***Internal data communication nominal (wrt wiring)***
- ***Power system nominal***
  - ***Solar array deployed on schedule and performing within predictions***
  - ***Power balance following predictions***
    - *Early operations put peak loads on power bus causing some bus voltage issues*
    - *Off pointing array due to burns and slews causes brief balance issues, which are recovered within one orbit (typically)*
  - ***Battery performing nominally***
    - *Battery age possibly showing up in EON voltages as battery "breaks in"*
    - *Bus voltage within acceptable parameters (modified expected values to reflect battery performance)*

Electrical Systems Performance *(CONTINUED)*

- ***RF S-Band communications nominal***
  - *See Comm presentation for details*
- ***RF X-Band communications still in checkout***
  - *Ground station / Spacecraft interaction still being explored with respect to NMP XBPAA*
- ***C&DH subsystem performing nominally***
  - *Single bit errors occurring in memory (assumed due to SEU's)*
  - *Memory scrub task rate increased to compensate*
  - *CPU utilization with respect to EFF still to be determined*
  - *GPS interface SW issues (see ACS and Flight SW sections)*
- ***LFSA deployed successfully and data collection taking place***
  - *Performance within predictions of manufacturer*
  - *One thermistor (of two) has gone "open circuit" following several days of operation*
  - *Thermistor's "bottom out" at -36C (capability of spacecraft acquisition system)*

Anomalies / Unexpected Events

- ***LFSA deployment caused S/A to go to index***
  - *TSM's (71 and 72) for separation and deployment tripped when launch packet enabled*
  - *TSM's accidentally enabled prior to LFSA deployment*
  - *Caused S/A to go to index (part of launch sequence RTS 34)*
  - *Re-enabled S/A tracking on next command pass. Disabled relevant TSM's. Disabled launch packet.*
- ***Yoke (deploy) hinge pot drifted from 99% following deployment (day 326) to 94.7% (day 331)***
  - *No indication of actual movement on S/A power output (cosine function would preclude measurement)*
  - *No indication of any other telemetry points using same current source and A/D drifting*
  - *Total change was 9 A/D counts (or 45mV)*
  - *Potentiometer settling and A/D "misbehavior" suspected as cause*
  - *No action required*

Anomalies / Unexpected Events *(CONTINUED)*

- ***LFSA thermistor "open circuit"***
  - ***Following several days of operation one of the LFSA panel thermistors "stuck" at -36C, indicating an open circuit condition***
  - ***Previous to failure both thermistors "bottomed out" at -36C, which is the minimum temperature measurement of the sampling system***
  - ***Cold end predictions of LFSA exceed manufacturers specifications***
  - ***Most likely thermal stress (see thermal presentation)***

Configuration Changes since Launch

- ***None in Electrical Systems***

Lessons Learned

- ***Nadir Deck Heater Short (discovered in TVAC 1)***
  - ***Wire lists should be used for complex circuits instead of schematics***
  - ***Circuits should be tested exactly as expected in flight***
- ***Cable Wrap Wiring Damage***
  - ***Identify "at risk" harnessing and protect it!***
  - ***Implement "spares" in areas which cannot be supplemented (done in cable wrap as part of design)***
  - ***Keep margin in all areas to accommodate potential repairs***

Lessons Learned *(CONTINUED)*

- ***EGSE "robustness"***
  - ***Build EGSE to withstand travel and extended use (spend your time up front)***
    - *Equipment racks*
    - *Cabling*
  - ***Do not let "quirks" of EGSE performance to propagate too long following discovery***
    - *Umbilical GPIB*
    - *APTS to ASIST link*
- ***ETU's / FLATSAT***
  - ***Build and use necessary ETU's early***
  - ***Minimize "development" on flight hardware***
  - ***Integrate complex interfaces early as they are identified***

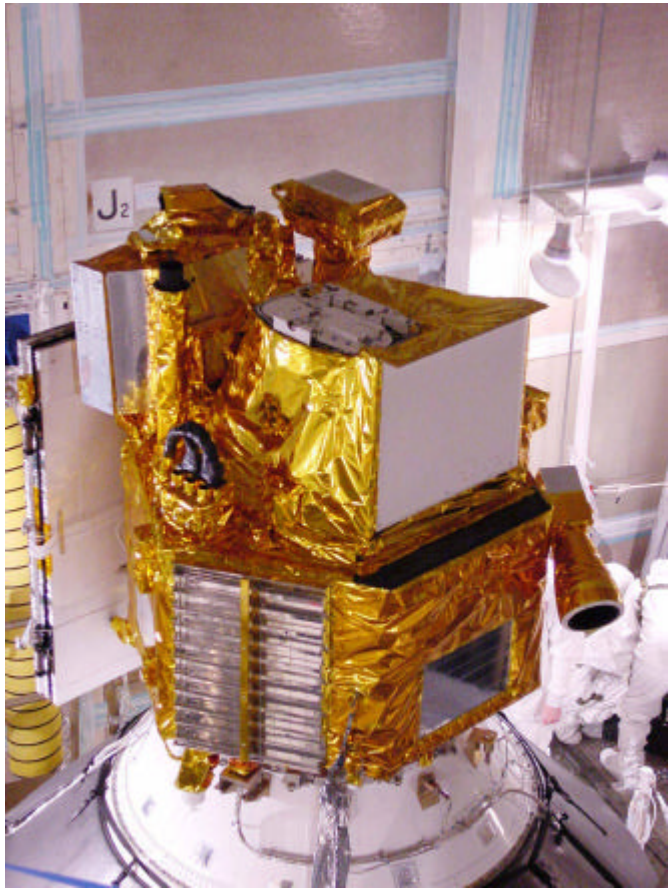
Mechanical System

Pete Alea
EO-1 Mechanical Systems Lead, Swales Aerospace

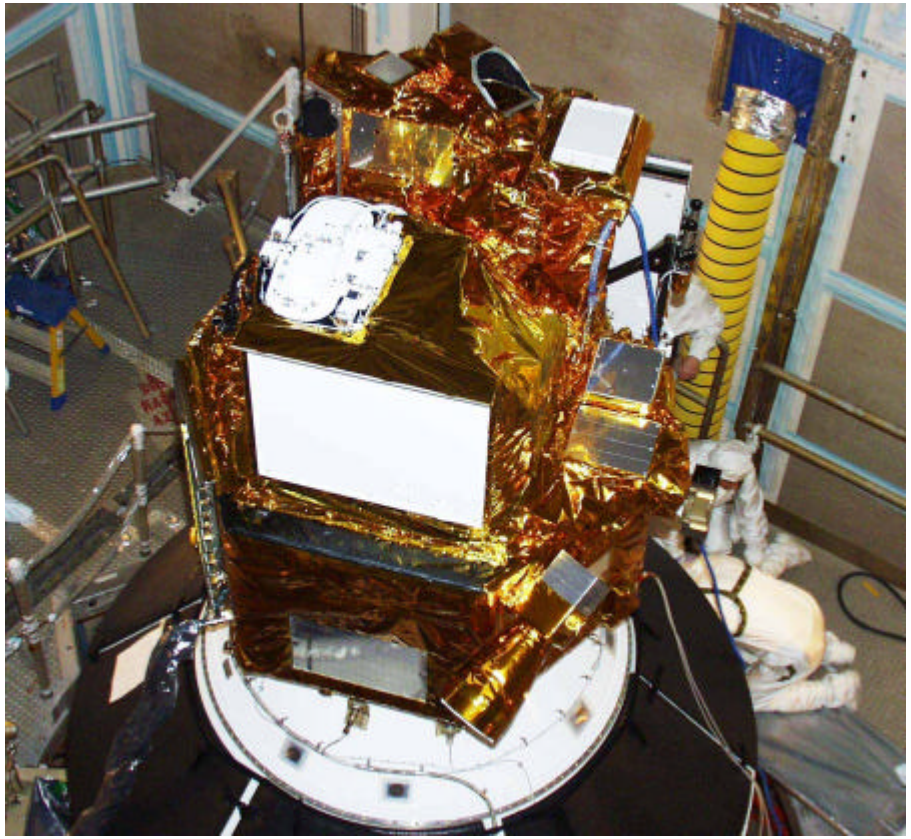
Agenda

- Satellite Launch Configuration
- Final Mass Properties
- System Tests Performed
- Mechanical System Performance
- Lessons Learned

Satellite Launch Configuration



EO-1 View From Bay 2/3

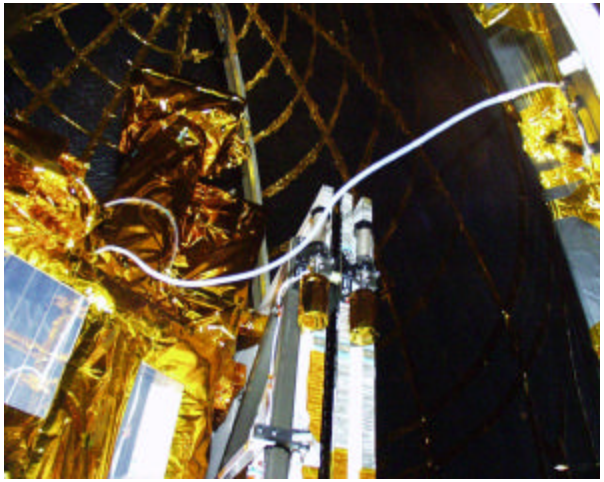


EO-1 Nadir View

Satellite Launch Configuration

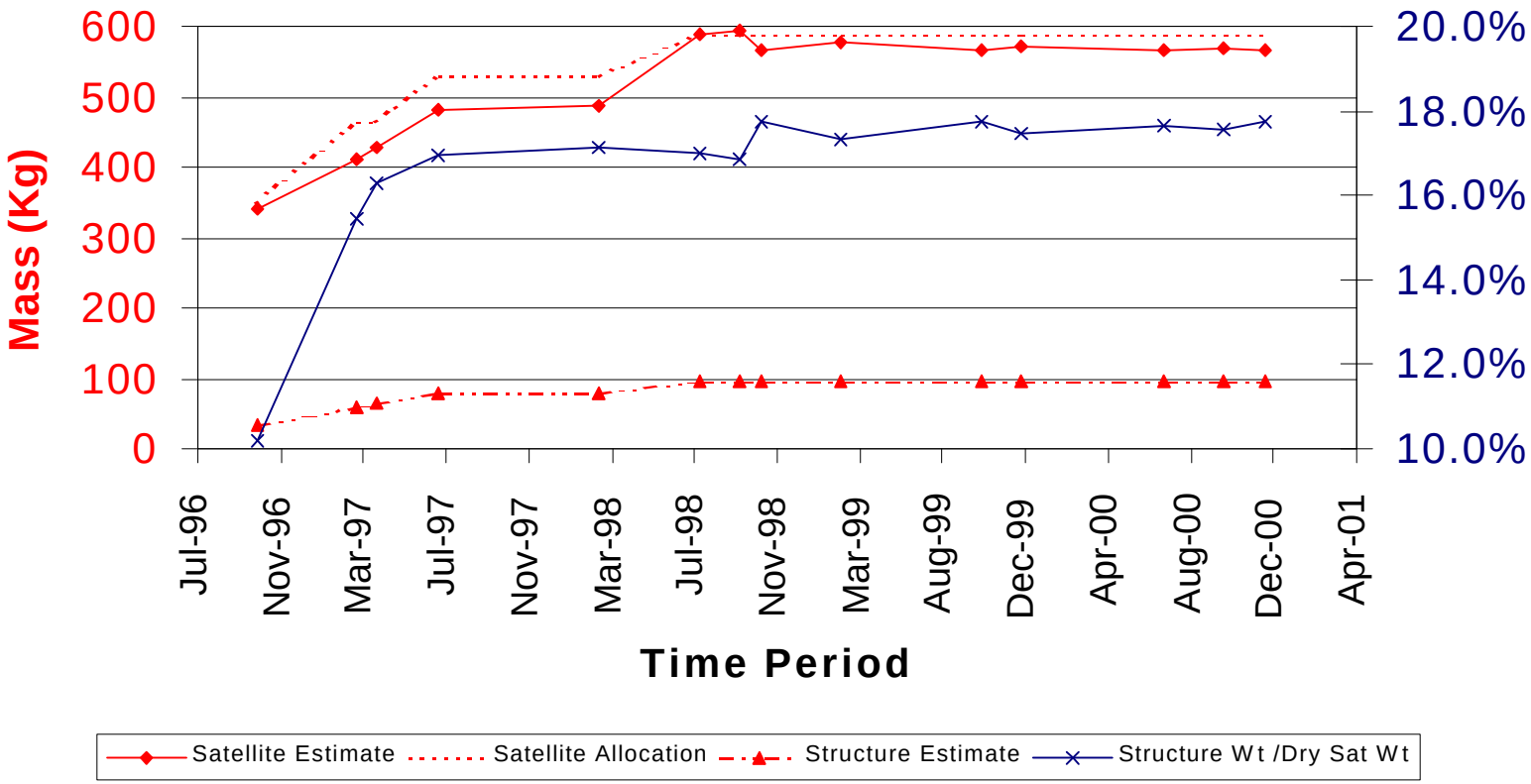
- *There were no open PRs or deviations to the nominal satellite mechanical flight configuration at launch*
- *Most red tag items were closed out at Astrotech or SLC-2 prior to fairing installation*
- *The A/C vent and purge line c/o was completed during fairing finalization*

A/C Vent Closeout



Purge Closeout

EO-1 Mass Growth



Final EO-1 Mass at Launch was 566 Kgs, 22 Kgs under allocation of 588 Kgs!

System Tests

- The following Satellite level environmental tests were performed:
  - Modal Test, 7/1999
  - Shock Test, 8/1999
  - Vibration Test, 8/1999
  - Acoustic Test, 8/1999
  - Mass Properties, 9/2000
- For all tests, the primary objectives were successfully achieved without any observed failures
- Retesting of the satellite system was not required after reworking the WARP, ACDS and S-Band avionics due to the proven integration process used

Mechanical System Performance

- *Final launch loads should be enveloped by the VLA*
- *Final report to be provided by Boeing for Delta 282 Mission*

	Design Loads	Final VLA 8/99
EO-1 S/C		
Lateral LC1	±4.7	±4.0
Axial LC1	+9.0	+2.7
Lateral LC2	±4.7	±0.22
Axial LC2	-1.0	+8.1
ALI		
Lateral LC1	±7.3	±4.3
Axial LC1	+9.1	+2.7
Lateral LC2	±5.6	±0.45
Axial LC2	-1.0	+8.1
HSA		
Lateral LC1	±7.3	±6.8
Axial LC1	+3.8	+2.8
Lateral LC2	±7.3	-
Axial LC2	-1.0	-
Lateral LC3	±1.1	±1.1
Axial LC3	+8.1	+8.1

Note: For axial cases, "+" indicates compression and "-" indicates tension

Mechanical System Performance

- ***Solar array deployment observed from telemetry data:***
  - ***HOPAs Powered Up at 326-19:24:25.3***
  - ***Solar Array Release at 326-19:27:16.8***
    - *Nominal Time Expected from Ground Deployments 3 mins*
    - *Actual Time 2 mins 51 secs*
      - *HOPA Performance Nominal !*
  - ***Full Deployment at 326-19:28:24.6***
    - *Nominal Time Predicted 90 secs*
    - *Actual Time 68 secs*
      - *Deployment time somewhat less then predicted from kinematics model due to effects from S/C tumbling*

Lessons Learned

- ***A Gr/E composite structure would have been lighter weight then our baseline aluminum structure, however, for a technology driven satellite like EO-1, there are undesirable limitations imposed by a Gr/E structure:***
  - ***The addition of the Hyperion Instrument could have compromised the existing Gr/E S/C structure. The Al structure was far more forgiving and easier to interface.***
  - ***The addition of last minute components such as the AST TSA and WARP Filter Box would have been difficult and costly to implement***
  - ***Damage tolerance is far greater with an Al structure then Gr/E. De-integration and re-integration subsystems would have been more time consuming with Gr/E structure and panels.***
  - ***The mass allocation was adequate for the aluminum structure***

Lessons Learned *(CONTINUED)*

- ***Minimizing the existing S/C interior volume is undesirable for new technology satellite***
  - ***Addition of unforeseen components would not have been possible (fuse plugs, SADA rework bracket, filter box,..)***
- ***Re-integration of avionics would have been far more difficult without the addition of the GSE hinges***
  - ***Even thorough the S/C interfaces were planned into the structure early on, the actual hinge design and fab were not approved until after Hyperion was added to the program***
- ***Requirements for all GSE hardware need to be clearly defined during the initial program study phase and revisited when program changes are made***

Lessons Learned *(CONTINUED)*

- ***The EO-1 environmental specification should included guidelines for testing reworked hardware to streamline the decision making process. Similar guidelines should also exist in the GSFC GEVS document.***
- ***Spacecraft deintegration/reintegration activities required the repeat or performance of all alignment measurements six weeks before launch***
  - ***Future efforts should provide adequate time for both the acquisition and processing of instrument and spacecraft metrology data***
- ***We were partially prepared with spare wires for the solar array cable wrap damage***
  - ***The termination of the spare cable wrap wires could have been placed in a more effective location to play a greater role in solving the problem***
  - ***Spacecraft harnesses which are susceptible to damage or difficult to repair/rework should be protected during all phases of I&T***

Good Lessons Learned

- *Mechanical design team staffing was appropriate. Small group in a "Skunk Works" type environment. Corporate support was consistent with final result.*
- *Direct fabrication of primary structure components from Pro/E database worked well for decks and radials to reduce design/manufacturing cost. Not as effective for mechanism components were interface checks must be performed with detail drawings.*
- *Manufacturing tool design and fab should be worked in parallel with final phase of flight hardware design to minimize fab schedules*
- *One mechanical team following the hardware from "Cradle to Grave" works well for EO-1 type program. This approach allows for quick response to issues that come up during I&T.*

Good Lessons Learned *(CONTINUED)*

- ***EO-1 success was due to a team of individuals from all aspects of the Swales' including engineering, purchasing, receiving and manufacturing. Bring everyone into the "Team" was key to our success.***

Attitude Control Subsystem

Paul Sannenman
EO-1 ACS Systems Lead, Swales Aerospace
Kathie Blackman
Jeff D'Agostino
Teresa Hunt
Dave Speer
Seth Shulman

ACS Summary

- Initial Acquisition Performance Summary
- Attitude Control Electronics
- AST Performance
- IRU PDV Trend
- Attitude Determination - Kalman Filter & Alignment
- Magnetic Calibration Results
- ACS Flight Software
- ACS FDC Trips
- ACE Safe Hold Mode Test
- Delta-V Attitude Control Performance
- Science Pointing Accuracy Assessment
- Anomalies
- Lessons Learned Summary

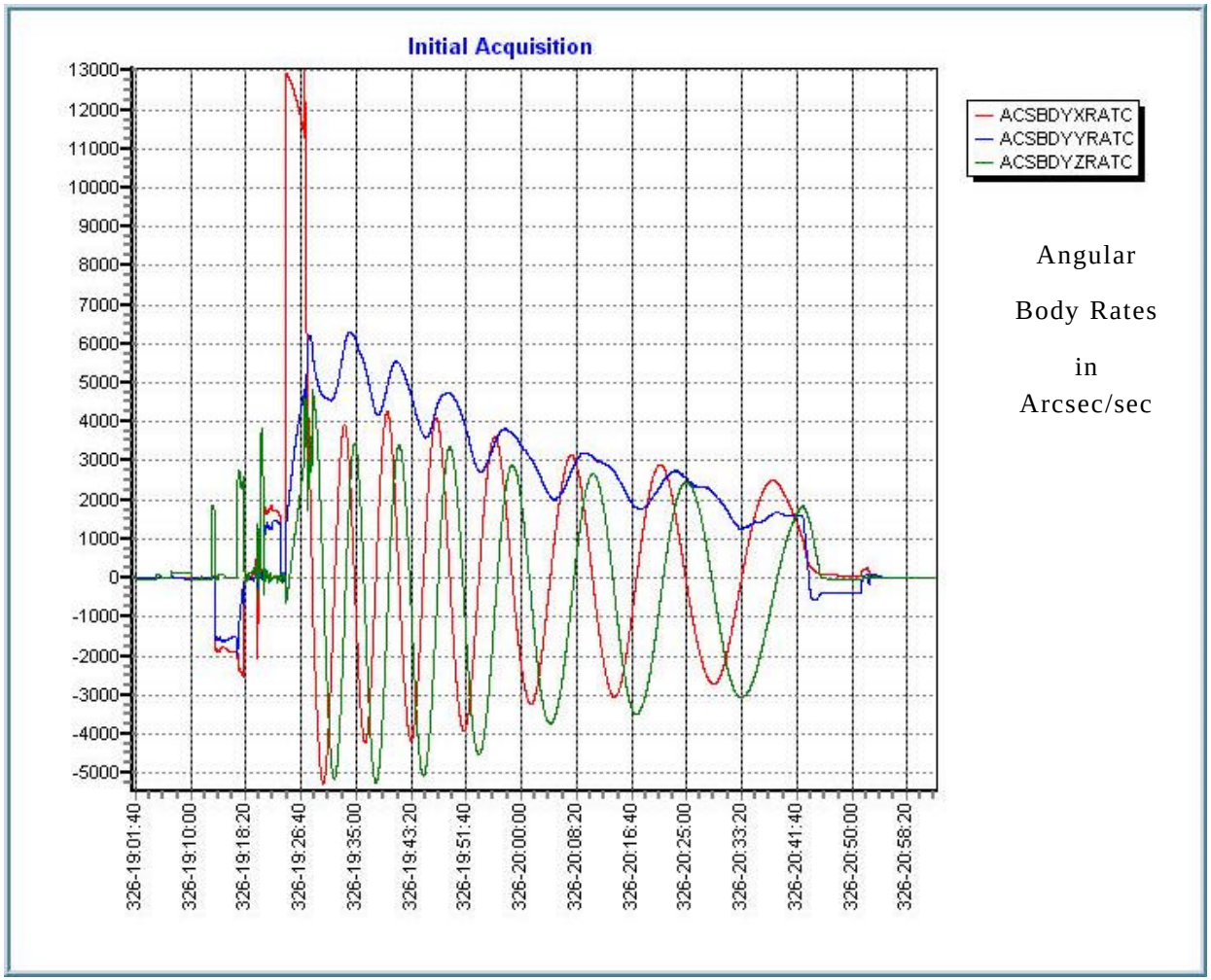
ACS Chronology Highlights

UTC	Activity
00-326 18:24	Launch
00-326 19:24	Separation
00-326 19:35	Solar Array at Index
00-326 20:42	Transition to SunAcq Mode
00-326 22:00	SunAcq complete
00-327 15:35	Safe Hold Test Started
00-327 18:47	Upload AST alignment (cube data)
00-327 18:53	Safe Hold Test Completed
00-327 20:25	First Earth Acquisition
00-327 20:40	Earth Pointing in IDLE Mode
00-328 06:21	Restore original AST alignment
00-328 08:01	Enter SunAcq due to FDC #79
00-328 09:42	Earth Acquisition
00-328 14:37	Mark KF as Not Converged
00-328 15:41	Pitch Axis Gyro Cal Maneuver
00-328 18:59	Roll Axis Gyro Cal Maneuver
00-328 22:16	Yaw Axis Gyro Cal Maneuver
00-329 15:19	Delta-V Mode for 60 sec

00-330 20:55	First yaw maneuver image prep
00-331 13:49	Delta-V Mode for 514 sec (INC)
00-331 14:07	Enter SunAcq due to FDC #5
00-331 16:40	Earth Acquisition
00-331 18:19	Enable GPS Navigation updates
00-332 19:03	Upload Magnetic Cal. Results
00-333 15:03	Delta-V Mode for 831 sec
00-335 14:10	Delta-V Mode for 901 sec
00-339 16:35	Upload IRU Calibration results
00-340 17:03	Upload new KF Residual Tol.
00-344 13:24	Delta-V Mode for 430 sec
00-345 15:04	AST transition to STANDBY
00-345 19:10	Recovery from AST outage
00-346 03:36	Delta-V Mode for 1015 sec
00-346 18:??	Upload GPS outage persistence to 120 s
00-348 14:08	Delta-V Mode for 75 sec

Initial Acquisition Performance 00-326

- **Separation Rates [3.61, 0.42, -0.19] deg/sec**
- **Angular Rates after Solar Array Deployment [1.11, 1.72, 1.0] deg/sec**
- **Bdot Magnetic despin Duration of 78 minutes**
- **Initial Sun Acquisition**
  - Initiated at 20:42 just prior to orbital eclipse period
  - Performed angular rate damping and RWA momentum dumping during eclipse
  - Initiated pitch flip after entering into orbital day
  - Completed at 22:00
- **RWA Momentum Unload Completed by 23:00**



Attitude Control Electronics

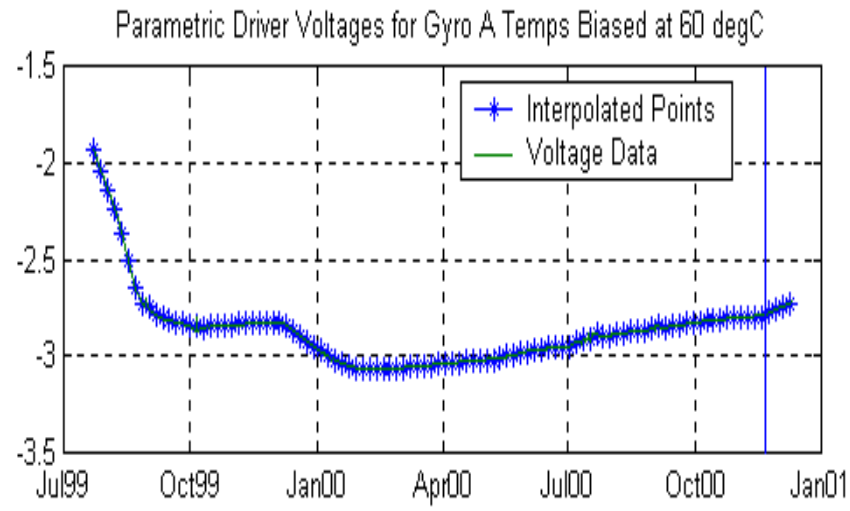
- *Overall operation of Attitude Control Electronics has been nominal*
- *No observed anomalies in power supply voltages, ACE total current, or calibration/reference signals (but much more analysis to be done). ACE card temperatures very comfortable in +25°C to +35°C range. A-to-D converter on ACE RSN card still skipping codes (known issue).*
- *All ACS component power, command, data and telemetry signal interfaces being continuously exercised and working as expected, including CSS's, TAM, MTB's, IRU, AST and RWA's. Subset of PPT signals are working, but PPT Fuel Gauge 1 signal is very noisy (known issue) and PPT charge/fire commands not used.*
- *Solar Array Drive systems working very well after 300+ track/rewind cycles. Redundant drive verified briefly during Safe-Hold test, & secondary encoders turned on & used for two orbits (then turned back off).*
- *RCS/Propulsion system function was excellent during the first 6 delta-V maneuvers, but analog current sum signal hard to use due to heating*
- *No SEU's observed in digital electronics (including FPGA's) after 500+ hours in space and 100+ passages through South Atlantic Anomaly*
- *Comprehensive analysis and trending of ACE signals and parameters planned for the written report (and after DTAS upgrades)*

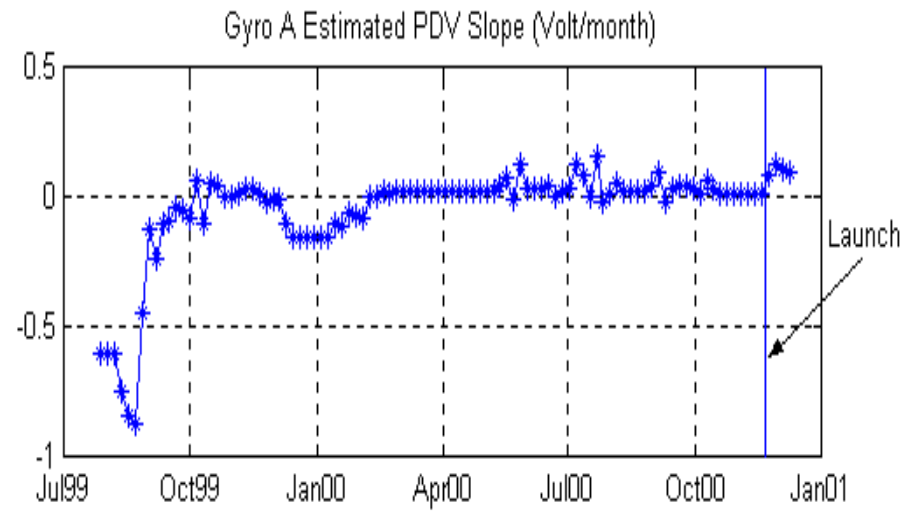
AST Performance

- **Overall Autonomous Star Tracker performance has been excellent**
- **Tracking from 14 to 40 stars, all initial attitude acquisitions successful**
- **RMS error based on AST calculations ~ 10 to 15 arcsec**
  - **Ground processing indicates approximately 30 arcsec, 3-sigma**
  - **At least two occasions of RMS error spikes under investigation**
- **Effective Focal Length indicates <10 um error - no update needed**
- **Baffle protection**
  - **Earth Limb: 6 to 18 degrees depending on Earth illumination**
  - **Moon: 12 to 15 degrees**
  - **Sun: 65 degrees (3 occurrences) -**
    - *Expected 20-30 degrees*
    - *Other LMMS AST baffles have also exhibited less protection than specification*
    - *Impact to mission planning and expect to update ACS Table*
- **No Reboots while in the SAA**
  - **00-345 anomaly near south pole caused AST to enter STANDBY mode**
- **Several transitions to COAST mode without loss of Track**

IRU Performance

- ***PDV Trends still improving - no sign of helium exposure on launch pad***
- ***Initial calibration of gyros based on 00-328 Gyro cal maneuvers***
  - ***Estimated IRU Drift Biases of [1.02 0.08 1.58] deg/hr in [X,Y,Z]***
  - ***Most important, these values have remained constant***
  - ***[1.0 0.0 1.5] deg/hr in [X,Y,Z] on 00-347 from ACS Kalman Filter***
- ***Calibration identified negligible scale factor error***
- ***IRU-to-AST on-orbit alignment calibration resulted in less than 0.2 degree (720 arcsec) change***





GPS Performance

- *Two cold start acquisitions in Sun Pointing orientation*
- *Remained in track "POS FIX IN PROC" during all gyro cal slews, Delta-V slews and imaging slews*
- *Started GPS updates to ACS on 00-329 16:55 after two days monitoring the performance compared to ACS propagated and ground solution*
- *Navigation vectors (S/C position and velocity) performance has been well within specification - within 100 meters*
- *GPS data interface to HK RSN has encountered some outages due to packet validation algorithm and data format anomalies*
  - *Some are predictable at this point, while others are still being investigated*
  - *Tuesday night issues due to A1 (hex) packet 'milliseconds into week'*
    - *00-334 02:37 65 second outage caused drop in ACS processing*
  - *00-341 00:14 Longer outage due to packet 41 (hex) data values corrupting the packet recognition algorithm in the HKRSN in conjunction with the A1 (hex) packet 'milliseconds into week'*

Attitude Determination

- Kalman Filter operations commenced Day 1
- Slew maneuver performance not as expected starting with first EarthAcq
- AST alignment update based on alignment cube measurements
  - 3+ deg offset from ALI based on cubes - not valid; restored original
  - Decided to keep to plan for using IRU alignment calibration results
- Continue to operate in 'Not Converged' state
  - Misnomer for residual error tolerance limit (multiplier)
  - Updated value from ~40 to ~450 arcsec tolerance on day 340 17:04
- IRU alignment matrix updated on 00-339 21:01
- Problems during slews prior to science images and delta-v burns
  - Affected both Delta-V and imaging DCE accuracy ~ 1 Deg
- Kalman filter tuning analyses underway
  - Will result in update to KF noise parameters to effectively reduce gain associated with IRU drift bias estimation
- FDC Test 79, Kalman Filter divergence test, has tripped more than once
  - Currently disabling test when AST updates not available for extended period, such as Earth/Sun occultation, anomalies, etc
  - Will no longer be necessary once KF tuning update is completed

Magnetic Calibration

- Day 1 FDC test 75,76,77 trips indicated some magnetic field issues
- FDC Test 5 Trip after Inclination Delta-V was a surprise and caused transition to SunAcq mode
- S/C Residual dipole creates [-1.53 1.02 -1.32] uTesla field at TAM
  - Static compensation values updated on 00-332 (ACS Table 57)
- MTB-to-TAM compensation matrix updated based upon on-orbit data
  - I&T data known to have some corruption due to facility issues I.e. REE-bar in flooring and clean-tent structure
  - Compensation matrix values updated on 00-332 (ACS Table 67)
  - At full MTB dipoles, the miscompensation was near 5 uTesla
- Based on this calibration, ground-based attitude determination software using TAM and gyro data is providing better than 1.0 deg accuracy

ACS Flight Software

- ***M5 ACS FSW performing nominally***
- ***All control modes except Science Imaging Mode have been exercised***
  - ***No plan to use Science Imaging Mode on-orbit***
  - ***Science Imaging Mode uses same controller as Mission Idle Mode***
- ***No code patches have been implemented on ACS FSW***
  - ***One patch developed (Replace IRU rate data with AST rate data) before launch***
    - *Not needed*
  - ***One patch is under development (algorithm correction for Yaw Steering capability)***
    - *Yaw Steering is currently disabled and not required*

ACS Flight Software Tables

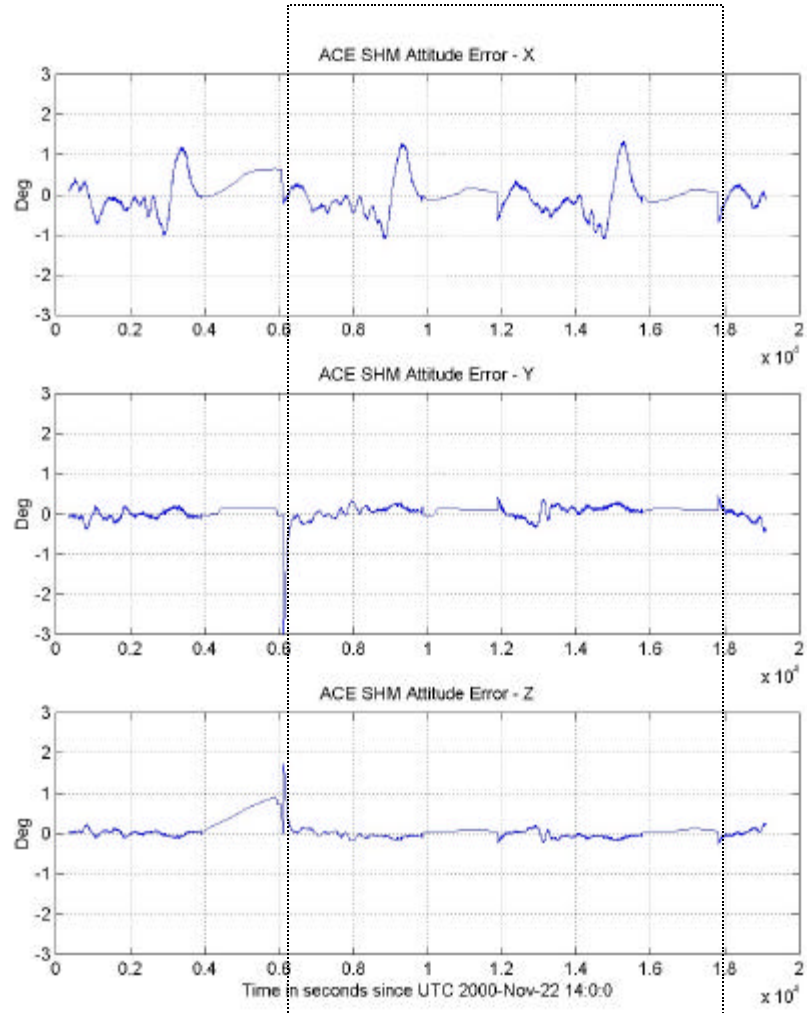
- **Five ACS tables modified prior to launch**
- **ACS table modifications since launch:**
  - #65 (AST Alignment) on 00-327 to correct possible misalignment; restored from EEPROM on 00-328 (correction not needed)
  - #57 (TAM Parameters) on 00-332 to help reduce FDC trips
  - #58 (TAM Transformation) on 00-332 to help reduce FDC trips
  - #67 (TAM Contamination) on 00-332 to help reduce FDC trips
  - #56 (IRU Transformation) on 00-339 to improve Kalman Filter attitude and gyro bias estimation accuracy
  - #73 (Thruster Parameters) multiple times to modify max burn time; restored from EEPROM after each Delta-V
  - #85 (Ephemeris Limits) on 00-346 to widen “bad GPS” timeout
- **Pending ACS table modifications**
  - #90 (Control Mode Configuration) and #97 (ACS RTS List) under investigation for possible addition of RTS upon Sun Acquire mode entry
  - #61 (Coarse Sun Sensor Parameters) to update for peak output value
  - #76 (Solar Array Control Parameters) to improve track acquisition rate
  - #64 (Star Tracker Parameters) AST/Sun Interference Angle and AST/IRU FDC Rate Limits

ACS FDC Trips

- Tests 75,76,77,5 - due to magnetics
- Tests 1 due to pitch slew rates and AST Z-axis rate accuracy
- Test 79 KF divergence
- Test 24 (GPS Data Invalid) was disabled during 00-341 long-term outage
  - Plan to re-enable pending resolution of long-term outage issue
- Test 6, 7 and 8 MTB Dipole Cmd vs Measured during SHM
  - Need to disable FDC during SHM
- Test 84 HW/SW Eclipse mismatch due to CSS normalization issue
- Test 64 Disabled for Delta-V on 00-346 due to duration > 1000 sec
  - Re-enabled after Delta-V

ACE Safe Hold Mode Test 00-327

- Safe Hold Mode control test included as part of Day 2 activities
- Ground commanded entry via same method as fault trip - RTS 2
  - Load shed commands all executed, but many services had not yet been ON
- Excellent attitude control performance for Sun Pointing the solar array
  - Spec of 25 deg, 3-sigma
  - Performance 3-5 deg, 3-sigma, including CSS albedo errors
- Autonomous switch to redundant side of SAD/ECU and drive to Index successfully demonstrated
- SHM Recovery procedure validated



SHM Control

Delta-V Performance

- ***Attitude control performance during thruster-based delta-v mode has been excellent***
  - ***Phase plane plots indicate expected trajectories***
  - ***Attitude errors have steady-state values near [1.6 -1.0 0.0] deg, XYZ***
  - ***Indicates very good correlation between RCS fab/test, mechanical mass properties tracking and ACS controller design***

Mission Day	UTC Day	UTC Start	Dur. Sec	Burn Type	Delta-V m/sec	Fuel kg	Error % DV
4	00-329	15:19:39	60	ALT+	0.21	0.058	+1.0
6	00-331	13:49:04	514	INC	1.81	0.491	+1.4
8	00-333	15:03:09	831	ALT+	2.71	0.735	+0.11
10	00-335	14:10:09	901	ALT+	2.77	0.743	+1.4
19	00-344	13:24:14	430	ALT--	1.32	0.342	-1.0
21	00-346	03:36:37	1015	ALT--	2.83	0.759	+1.1
23	00-348	14:08:09	75	INC			
25	00-350						
25	00-350						

Science Pointing Accuracy Assessment

- **Attitude Control [30, 30, 30] arcsec, 3-sigma budget allocation**
  - X & Z consistently under 30 arcsec, Y varies 0 to 50 arcsec depending on settling time
- **Attitude Knowledge [54, 108, 54] arcsec, 3-sigma budget allocation**
  - All axes consistently under 36 arcsec, 3-sigma during normal nadir-pointed operations
- **Navigation Accuracy [130 m Cross-Track, 100 m Along Track] 3-sigma**
  - Cross-track 45 m, 3-s; Along-Track, 55m 3-s; Radial, 30 m, 3-s
- **Jitter/Rate Stability**
  - Better than 0.5 arcsec/sec, 3-sigma during imaging
- **RWA Zero Speed crossings**
  - [45,120,35] arcsec peak transient with 2 minute width
- **Thermal Snap transients**
  - 40 to 80 arcsec peak transient per axis with 2 minute width
- **ALI Cover open transient**
  - 300 arcsec peak transient in pitch axis - zero'd within 2 minute prior to DCE at 3 minutes (even when RWAs are biased near 1000 RPM as evidenced by 00-347 Cape Canaveral DCE)

ACS Anomalies

- AST alignment based on optical cube data was not accurate
- Kalman Filter performance during attitude slew accelerations
  - Need to modify gains to improve IRU Drift Bias estimation accuracy
  - Should also prevent FDC Test 79 trips due to KF divergence
- FDC Test 5 trip caused transition to SunAcq - MTB-to-TAM coupling issue
- GPS data interface to HKRSN experiencing outages
  - A1 Packet 'milliseconds into week' causes Tuesday Night outage
- AST sun separation protection from baffle only 65 deg not 30 deg
- AST transition to STANDBY on 00-345 15:04 - expect SEU

Lessons Learned

- IRU Helium protection - GN2 purge from the start; mis-information from launch vehicle personnel a couple years ago caused much agony later
- SHM on-orbit test as part of planned activities worked well
  - ACE telemetry for SHM algorithm validation was designed to be available for scrutiny before pushing 'the button'
- Star tracker light shades are difficult to test on ground - prepare for the worst
- Review all items from ACS FSW test review meetings
  - Had previously warned ourselves about tripping FDC tests 75-77, 5
- Perform more 'What If' test cases for ACS alignment/calibration shifts
  - Alignment data availability and lack of double-check

Lessons Learned

- *Nominal, contingency and auxiliary procedures readiness facilitated ops*
- *Continuity of team members contributed significantly to ACS successes*
- *ASIST/MOC playback and trending not quite ready for full-time ops*
- *Training simulations were very helpful in preparing for launch*
- *Late commitment to ACE ETU fabrication for on-orbit software maintenance had limited impact on program. Earlier commitment would have had a significant impact to hardware/software development.*

EO-1 Reaction Control System On-Orbit Checkout

Michael McCullough
EO-1 RCS Systems Lead, Swales Aerospace

EO-1 RCS On-Orbit Checkout

- Orbit adjust maneuvers well under way
  - 6 Maneuvers Completed
- System performance within ± 1.5% of predicted
- Propellant book keeping yields consistent numbers
  - Total Impulse Approach (3.15 kg to date)
  - Propellant Tank Pressure Approach (3.07 kg to date)
- No Limit Violations
- Thruster alignments yielding excellent control

EO-1 RCS On-Orbit Checkout

- Catalyst bed heater current ~ 900 mA
  - Expected 880 mA
- All temperatures within expected range
- Peak valve soak back temperatures ~ 47 C
  - Arbitrary Yellow Limit - 50C Qualified to 150C
- Tank & Line Temperatures 20-27 C
  - Primary heaters are doing their job

RCS is Healthy & Performing Well!

EO-1 RCS Things We Did Right

- ***Primex provided quality products & services***
  - ***Quality components selected***
- ***RCS GSE borrowed from APL worked well***
- ***RCS integrated with structure well, met required delivery dates***
- ***Alignments controlled by tolerances / assembly***
- ***RCS Enable Plug - Protected system and allowed for thorough testing***

EO-RCS Lessons Learned

- ***Select Good 'ol Nuts & Bolts over Space Age Structural Adhesives (at least when attaching RCS tube standoffs to spacecraft structure)***

- ***Include Catalyst Bed Heater circuits in RCS enable plug - Would have prevented inadvertent cat bed heater operation and subsequent catalyst testing***

Power Subsystem

Allan Billings / Ralph Sullivan

EO-1 Power Lead Engineer / EO-1 Power Systems Engineer, Swales Aerospace

Contents

- Table of Tests and Events
- Overview of Subsystem Performance
- Details of Anomalies or Issues
- Changes to Nominal Configuration Since Launch
- Table of Changes in Database
  - Revised Limits
  - Deleted Commands
  - Revised Calibration Parameters
- Lessons Learned

Table of Tests and Events *(see plot 1 - 3)*

GMT		Battery Settings				Power System Data				
Event	Time	VT	C/D	Ibmax	Itrickle	Tbatt	Ibatt	Vbatt	BSOC	Isolar Arrray
Umbilical Pwr		5	1.05	18A	.3A	20.57C	.38A	30.79V	100.00%	0
Internal Pwr	326 18:13	5	1.05	18A	.5A	20.57C	-3.45	30.02	100.00%	0
Launch	326 18:24	5	1.05	18A	.5A	20.57C	-3.45	29.77V	98.74%	0
Fairing Release	326 18:28	5	1.05	18A	.5A	20.82C	-3.7	29.51V	98.26%	0
Sun on Outer Panel	326 18:44	5	1.05	18A	.5A	20.82C	3.45A	30.02V	96.80%	7.03A (7.5A possible)
1st Eclipse	326 19:13	5	1.05	18A	.5A	19.5C	-4.7	30.79V	99.33%	0
Deploy Array	326 19:25	5	1.05	18A	.5A	19.5C	-6	29.51V	97.66%	0
Sun ACQ	326 22:00	5	1.05	18A	.5A	15.7C	16.7	31.3V	93.39%	22.87
3rd Eclipse	326 22:31	5	1.05	18A	.5A	15.2C	-6.26	30.4V	99.21%	0
During 3rd day EOChg	326 23:36	5	1.05	18A	.5A	14.69C	2.17	31.3V	99.92%	22.87 Estimate

Table of Tests and Events

GMT		Battery Settings				Power System Data				
Event	Time	VT	C/D	Ibmax	Itrickle	Tbatt	Ibatt	Vbatt	BSOC	Isolar Arrray
Test ACS Safehold (Enter)	327 15:40	5	1.05	18A	.5A	15.69	5.5	30.76	95%	23.55
Exit Safehold	327 18:53	5	1.05	18A	.5A	14.82	14.82	29.82	93.07	22
Ramp, Pitch Slew	328 15:41 (start)	5	1.05	18A	.5A	See Plot 4				
Earth Acq	***328 16:16 (start)***	5	1.05	18A	.5A	See Plot 4				
Ramp, Roll Slew, Earth Acq	328 18:49 (start)	5	1.05	18A	.5A	See Plot 4				
Yaw Slew	328 22:16 start	5	1.05	18A	.5A	***See Plot 5***				
Earth Acq	328 22:51 start	5	1.05	18A	.5A	***See Plot 5***				

Table of Tests and Events

GMT		Battery Settings				Power System Data				
Event	Time	VT	C/D	Ibmax	Itrickle	Tbatt	Ibatt	Vbatt	BSOC	Isolar Arrray
ALI Imaging	***330 19:15***	5	1.05	18A	.5A	See Plot 6				
Slew + Delta V (831 SEC)	333 14:50 Start	5	1.05	18A	.5A	See Plot 7 Worst Case BSOC				
LFSA Deployed	334 19:03	5	1.05	18A	.5A	See Plot 8				
Typical Orbits C/D 1.07	340 08:18 start	5	1.07	18A	.5A	See Plot 9				
Thermal Profile Change in VT, CD	See Plot 10									
Dark Image	340 08:18 start	4.5	1.05	18A	.5A	See Plot 11 S/A Tracking Stoped				

Overview of Subsystem Performance

- **Solar Array**
  - Maximum Peak Short Circuit Current = 24.3A Winter Solstice
  - Maximum Steady State Current = 23.1A (at array voltage of 31.5V, Array Temp = 50C)
  - Predicted Steady State = 23.1A (31.5V, 50C)
  - More than Adequate Power for Intended Mission
  - Max Array Temp = 64C
- **PSE**
  - Functioning Normally, There are no Issues
  - Temperature of cards Nominal (see PLOT 12 and PLOT 13)
  - VT, CD and Amp hour Integrator accuracy verified
- **Battery**
  - Battery Performance Nominal (CD of 1.05, 1.07 and 1.1 tested, VT of 5 and 4.5 tested)
  - Abundance of Power Enables Selection of VT 4.5 (was 5) and C/D =1.05 as Baseline (Lower VT will extend life)
  - Battery Temperature 15C to 16C in accordance with Thermal predictions (see PLOT 12)

Details of Anomalies or Issues

- **Need to reduce TSM 50 "Low BSOC" safe-hold threshold from 70% to 60%**
  - Reason: During Delta V we have seen a BSOC as low as 77%. 60% would provide sufficient margin. This is to be reviewed as part of hand-over.
- **Need to periodically adjust battery TSM 60 "Low voltage" threshold as well as FDC Low Battery Voltage thresholds (normal routine adjustment)**
  - Reason: Battery aging. First adjustment may be required in a few weeks.
  - Present Thresholds---Low Battery Voltage TSM 60 event message at 26.8V, safe-hold at 26.3V
  - Low Battery Voltage FDC (load shed) at 26V (actually trips at 25.85V)

Details of Anomalies or Issues *(CONTINUED)*

- ***Battery end of discharge current was 1 amp higher than test battery under similar conditions. Considered benign but under review***
  - ***Prompted shift to C/D of 1.1 and then 1.07 from 1.05 at VT5. We have migrated to VT 4.5 and C/D = 1.05 as mission baseline.***
- ***A few instances of command errors resulted in a less than nominal BSOC***
  - ***This has occurred when the solar array was not restarted after Image taking (for instance)***
  - ***The lowest BSOC recorded was 77%***
  - ***There was no danger posed to the spacecraft or battery health***

Adjustments to Nominal Configuration Since Launch

- ***Pre-Planned Adjustment of VT from 5 to 4.5***
  - ***Reason: With the power available from array we are able to charge battery fully with 30 minutes left in sun period even with VT 4.5. VT 4.5 will put less stress on battery and extend life***

Table of Changes in Database

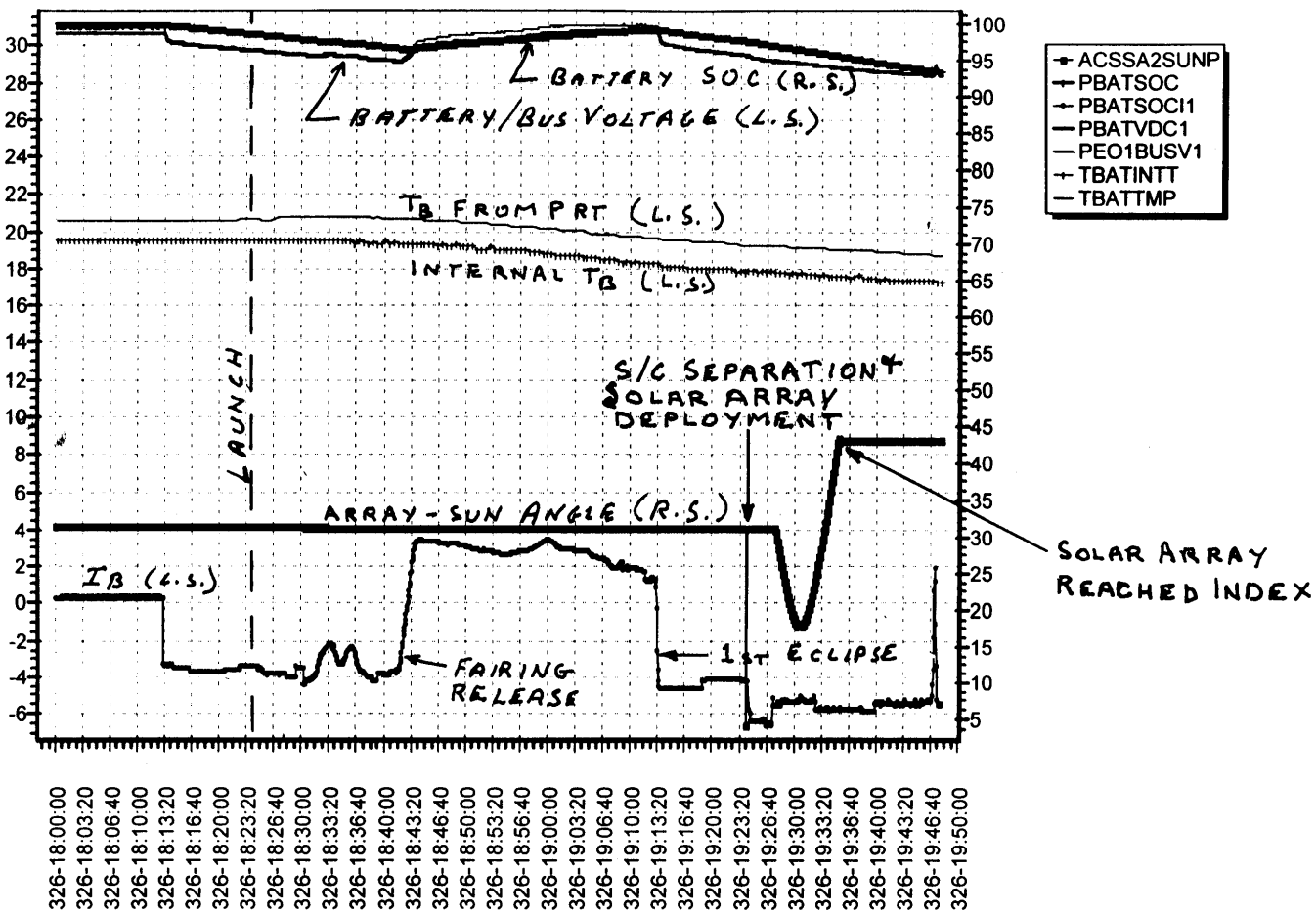
- ***Revised Limits***

New Limits					
Telemetry Nemonic	**Description, Change in Italics**	**RL**	**YL**	**YH**	**RH**
PRSNBUSVFDC	Unfiltered Battery Voltage Used for	***26.5***	***26.7***	32	33
POM1TTLI1	Output Module 1 Total Current	-0.2	0	***10***	13
PBATSOCI1-4	Battery Current Fast Packet	***-18***	***-17***	***17***	***18.5***
PBATI	Battery Current Medium Packet	***-18***	***-17***	***17***	***18.5***
PBATINPLW	Battery Current Long Word	***-18000***	***-17000***	***17000***	***18000***
PEO1BUSV1-4	Bus Voltage	***26.6***	***27***	***33***	***33.5***
PBATVDC1-4	Battery Voltage Filtered	***26.8***	***27***	***32***	***33***
PRSNBUSVFDC	Battery Unfiltered Voltage	***26.8***	***27***	***32***	***33***
PBATEONVDC	End of Night Battery Voltage	***26.5***	***26.7***	***31.5***	***32.5***
PBATCNVDC		***26.8***	***27***	***32***	***33***
PBATVDC	Battery Voltage Medium Packet	***26.8***	***27***	***32***	***33***

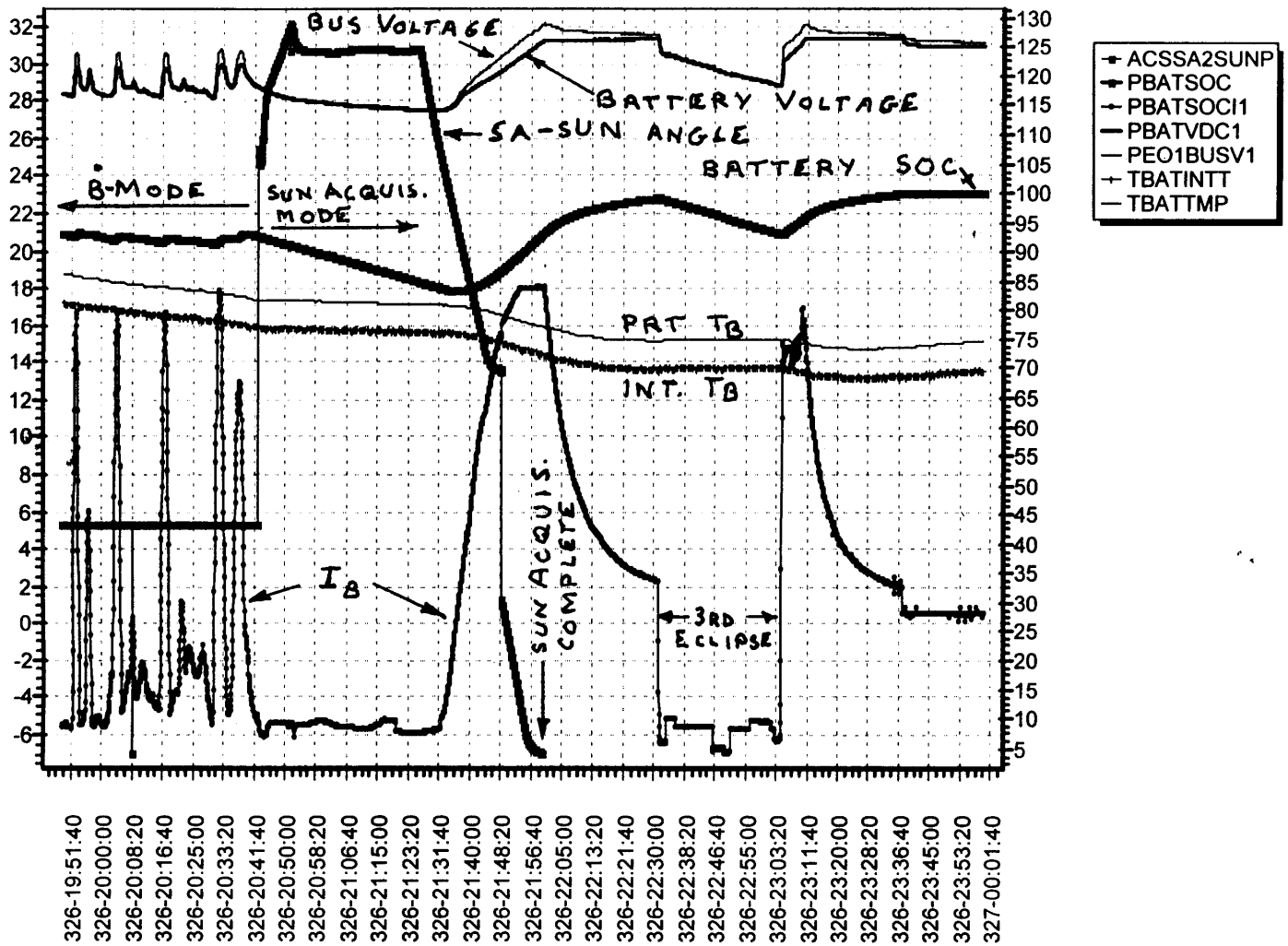
Table of Changes in Database

- ***Deleted Commands---None***
- ***Revised Calibration Parameters----None***
- ***Wish List for Future Programs***
  - ***It would have been desirable to perform "complete" end-to-end telemetry calibrations at the spacecraft level. Time did not permit this.***

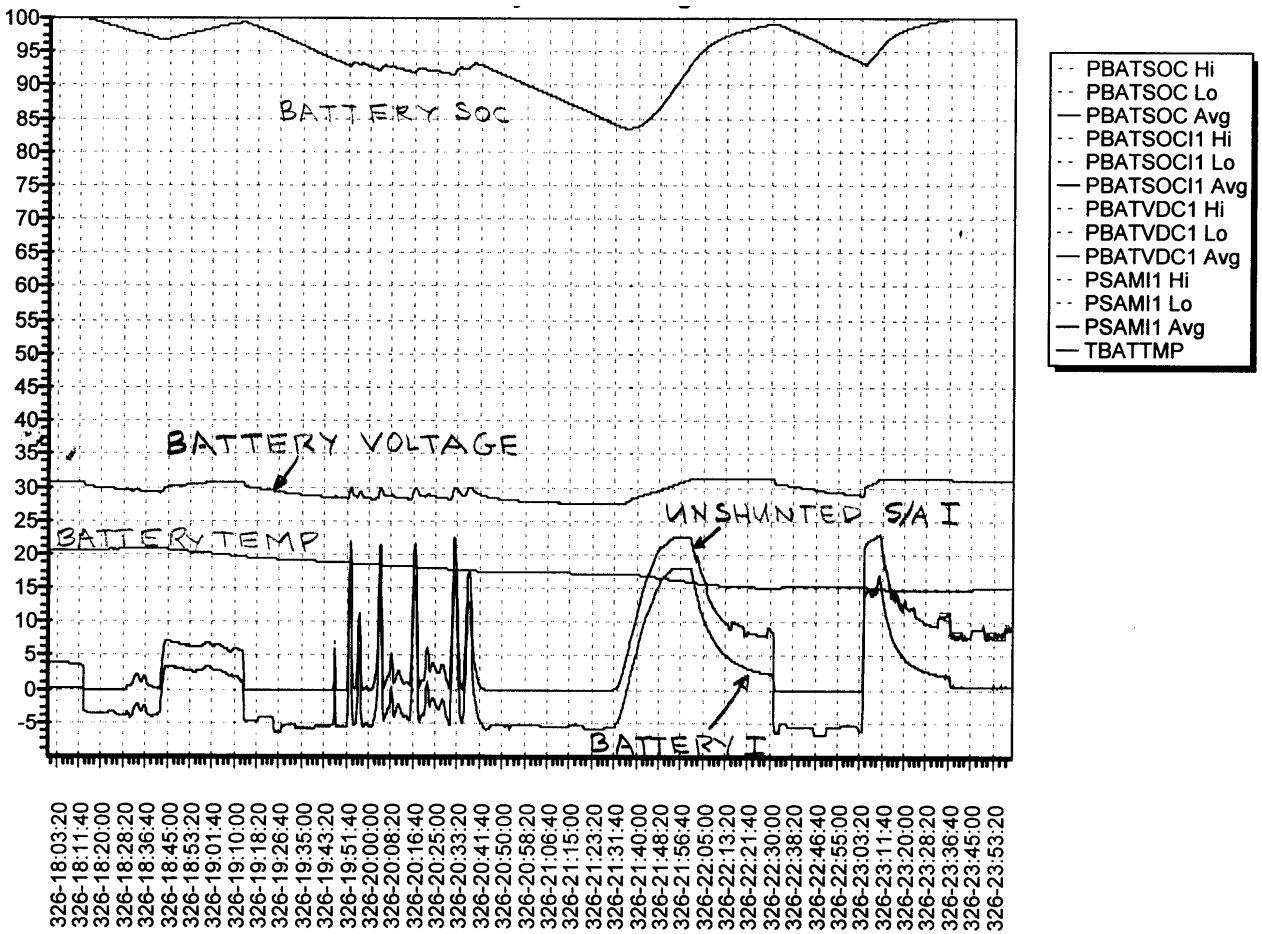
Plot 1 - EO-1 Power Subsystem Parameters
Pre-Launch through 19:48 GMT
Day 326, Year 2000



Plot 2 - EO-1 Power Subsystem Parameters
Launch Day (Day 326)
19:49 to 24:00 GMT

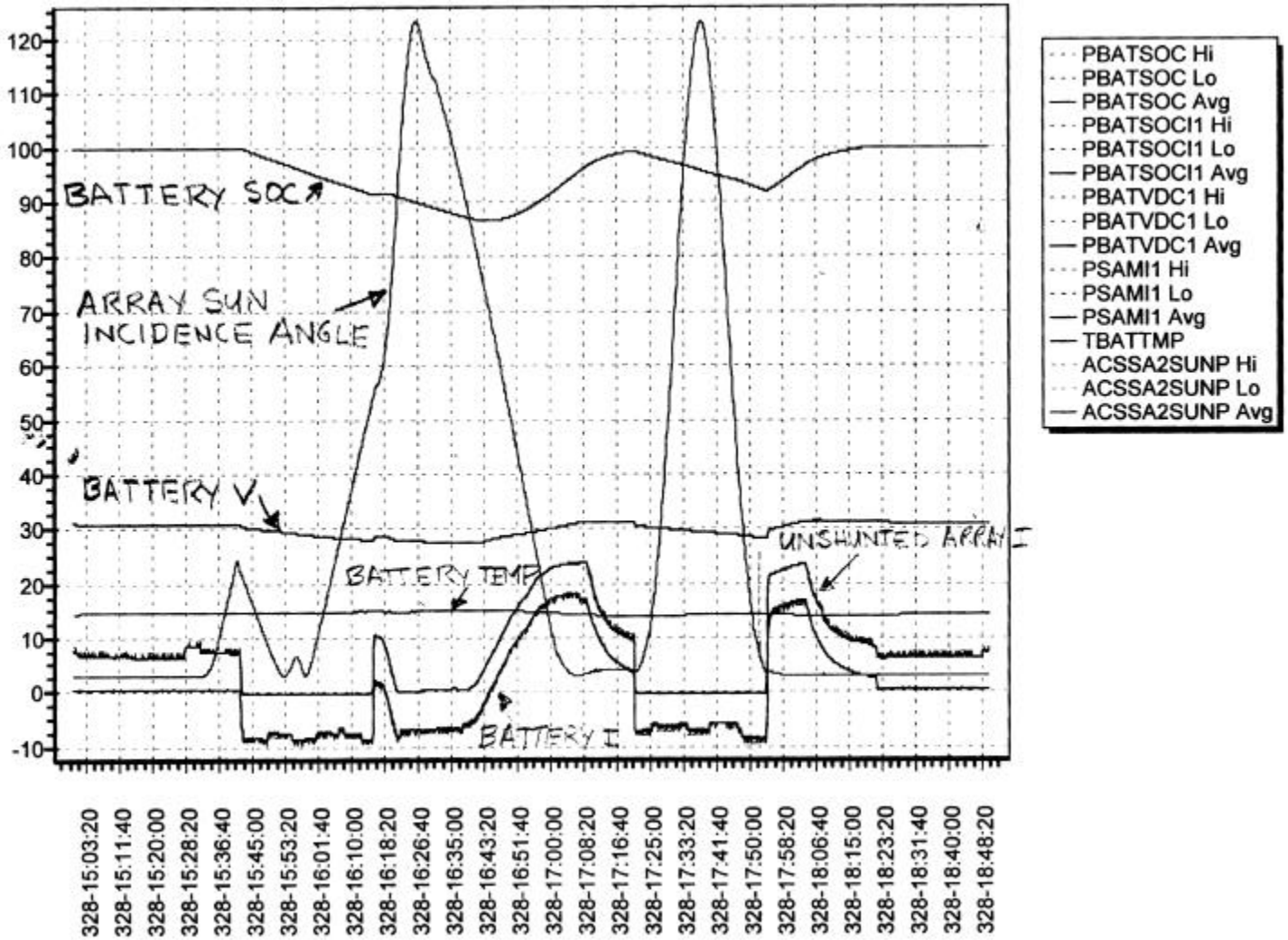


Plot 3
Launch to 3rd Day
End of Charge



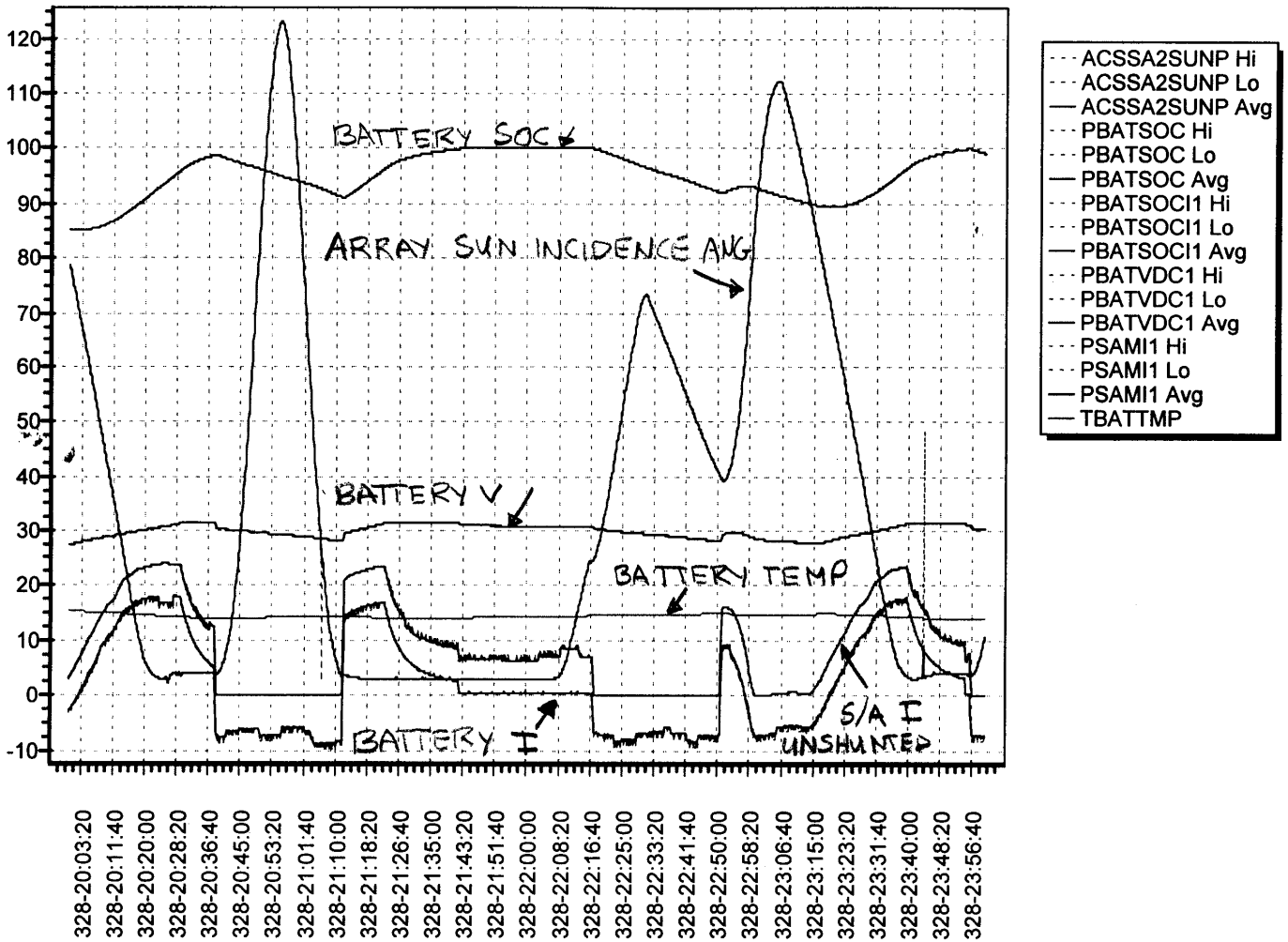
Plot 4

15:31 Solar Array Ramp - Pitch Slew - Earth Acq - 16:16

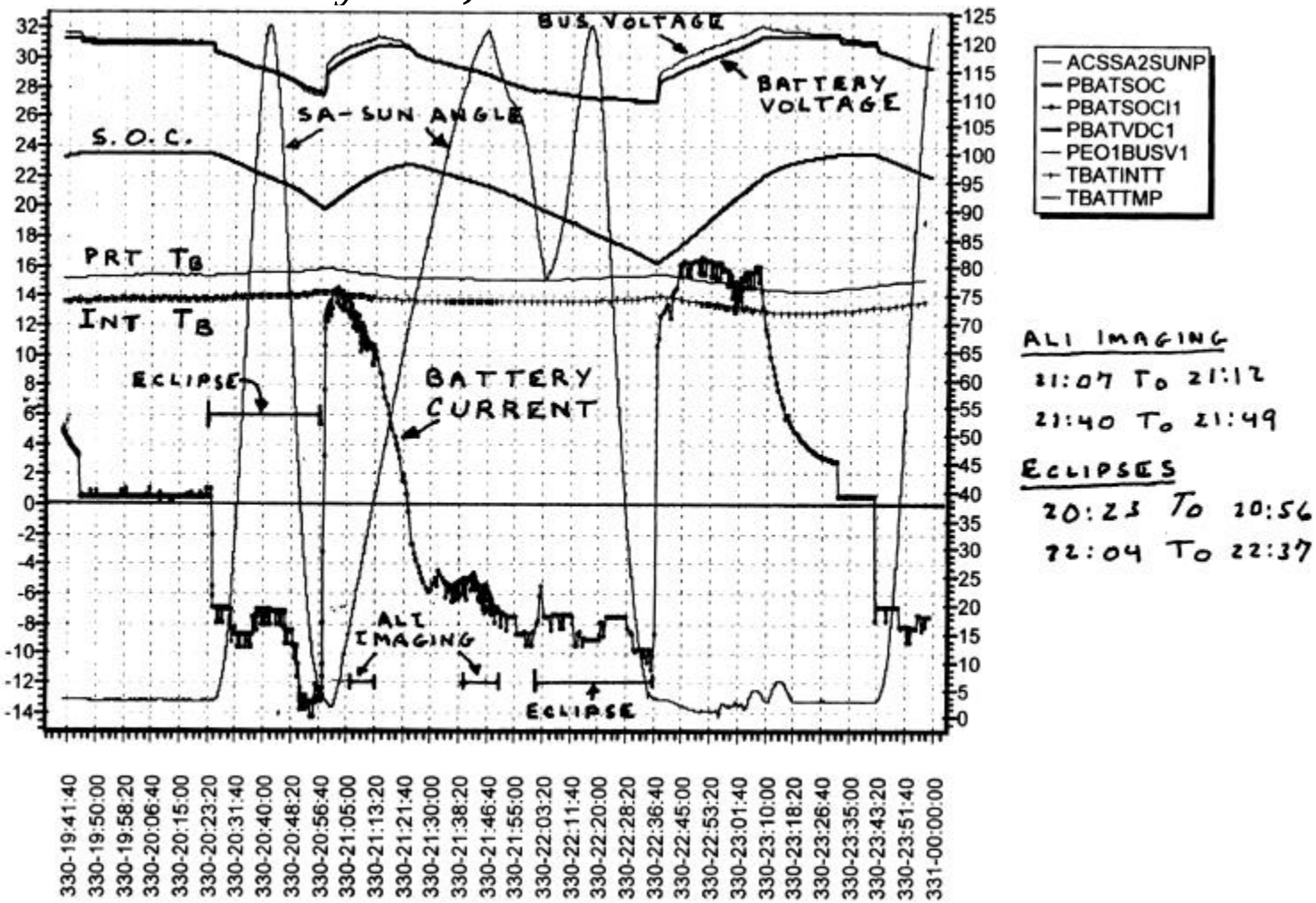


Plot 5

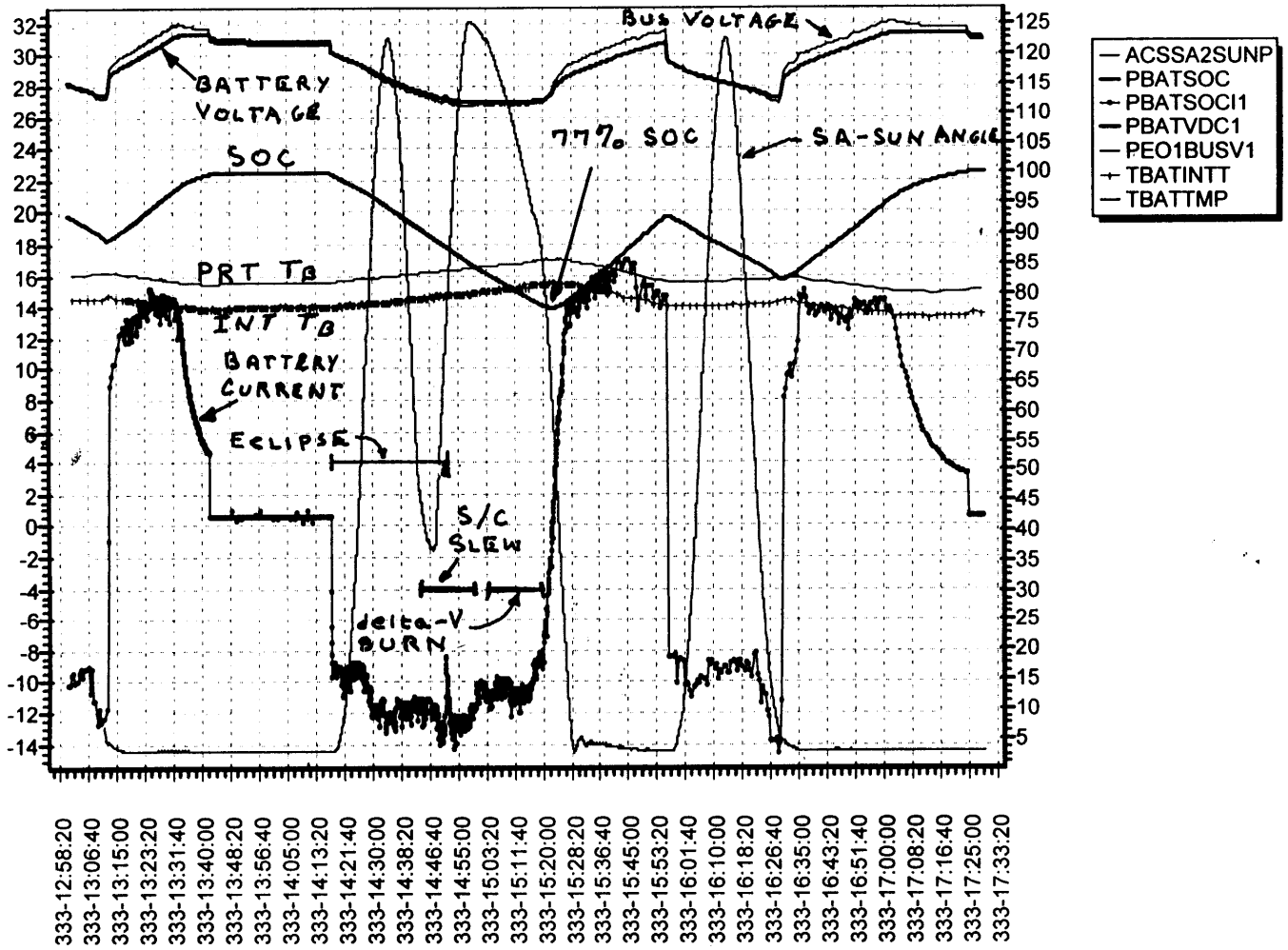
328-22:16 Yaw Slew, Earth Acq 22:51 (start)



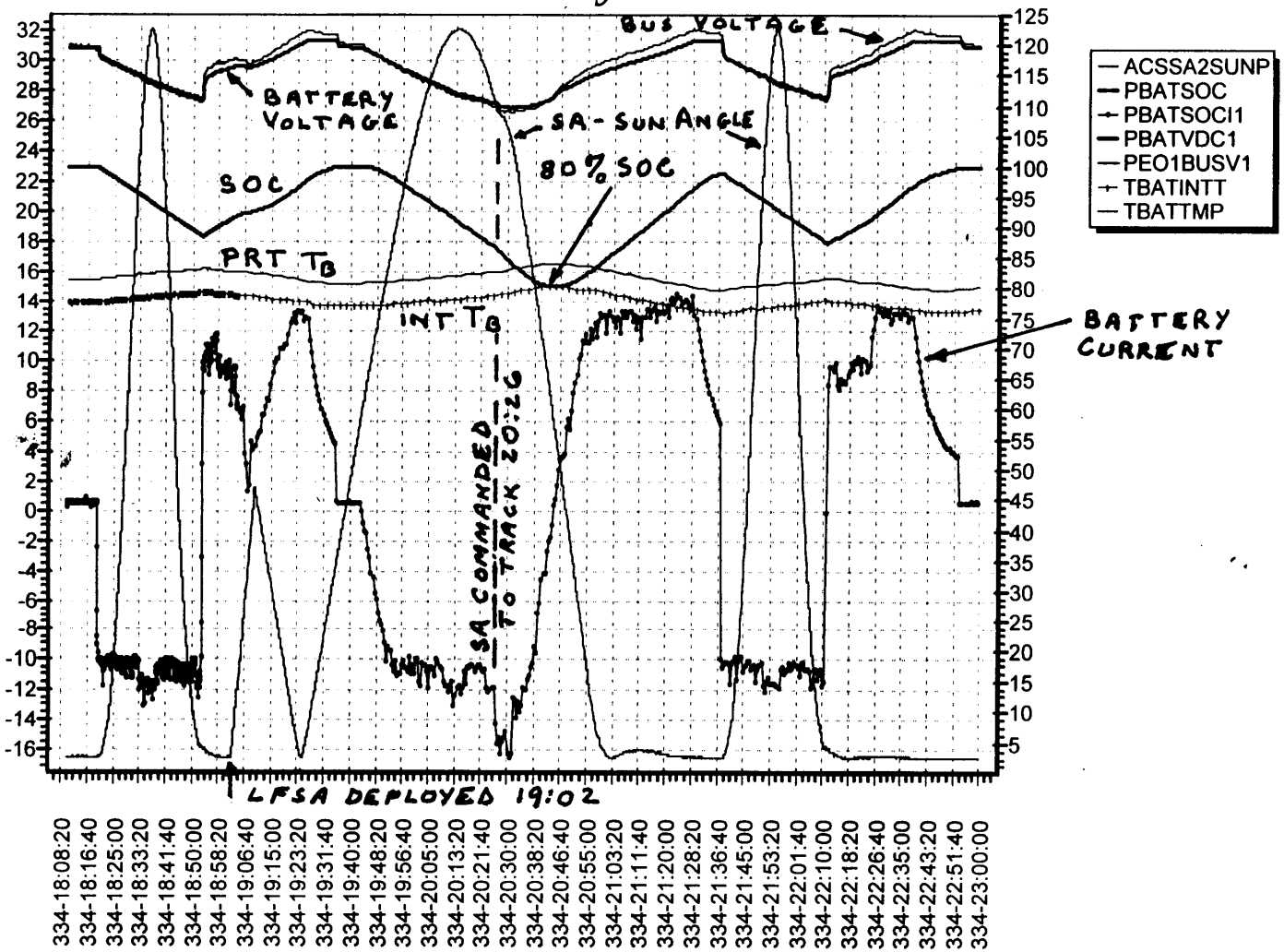
Plot 6 - EO-1 Power Subsystem Parameters with Two Consecutive ALI Images Day 330, 19:40 to 24:00 GMT



Plot 7 - EO-1 Power Subsystem Parameters with Slew and delta-V Burn Day 333, 13:00 to 17:30 GMT



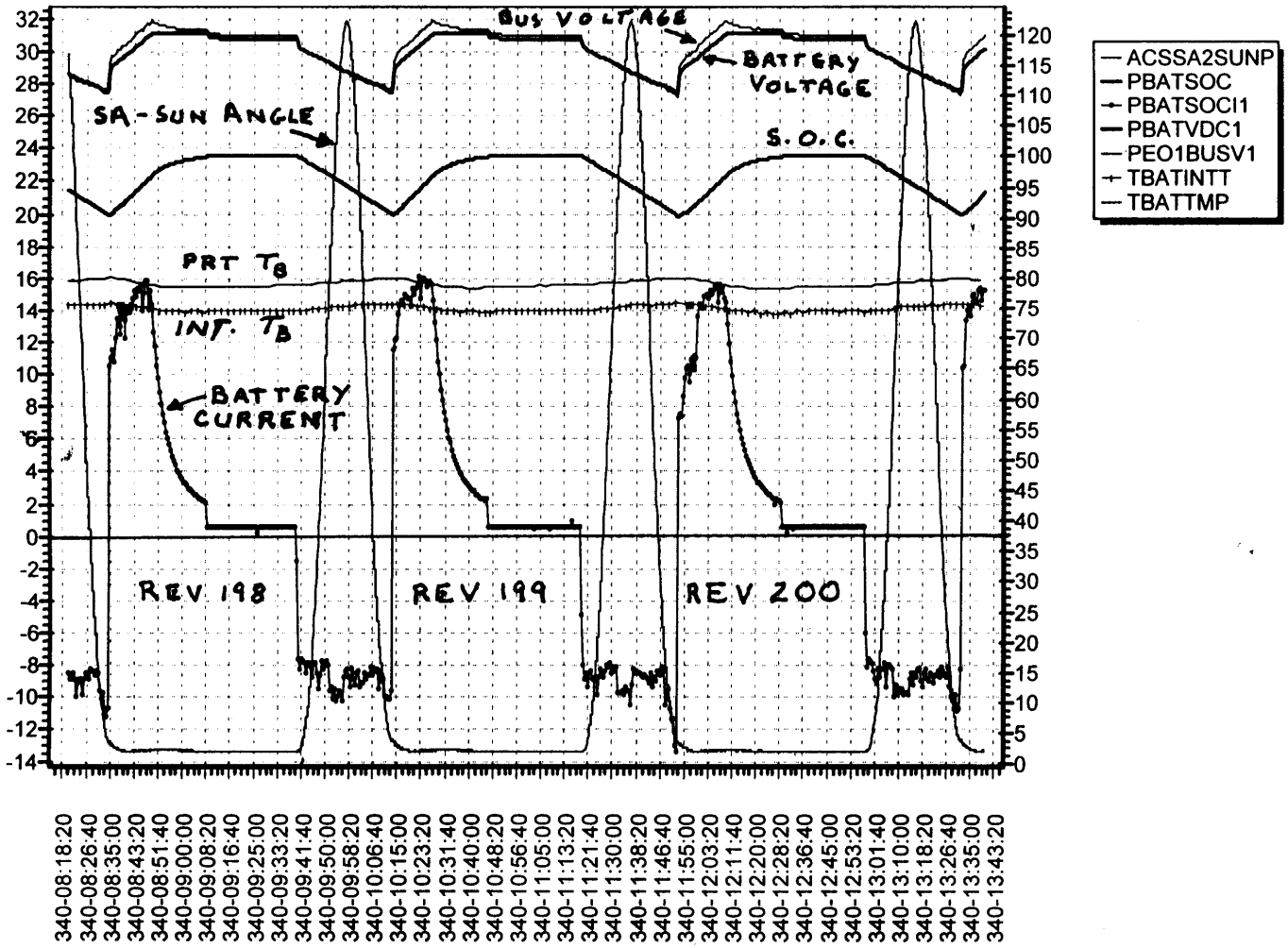
Plot 8 - EO-1 Power Subsystem Parameters as LFSA Deployed, causing the Main Array to Lose Track Day 334



Plot 9

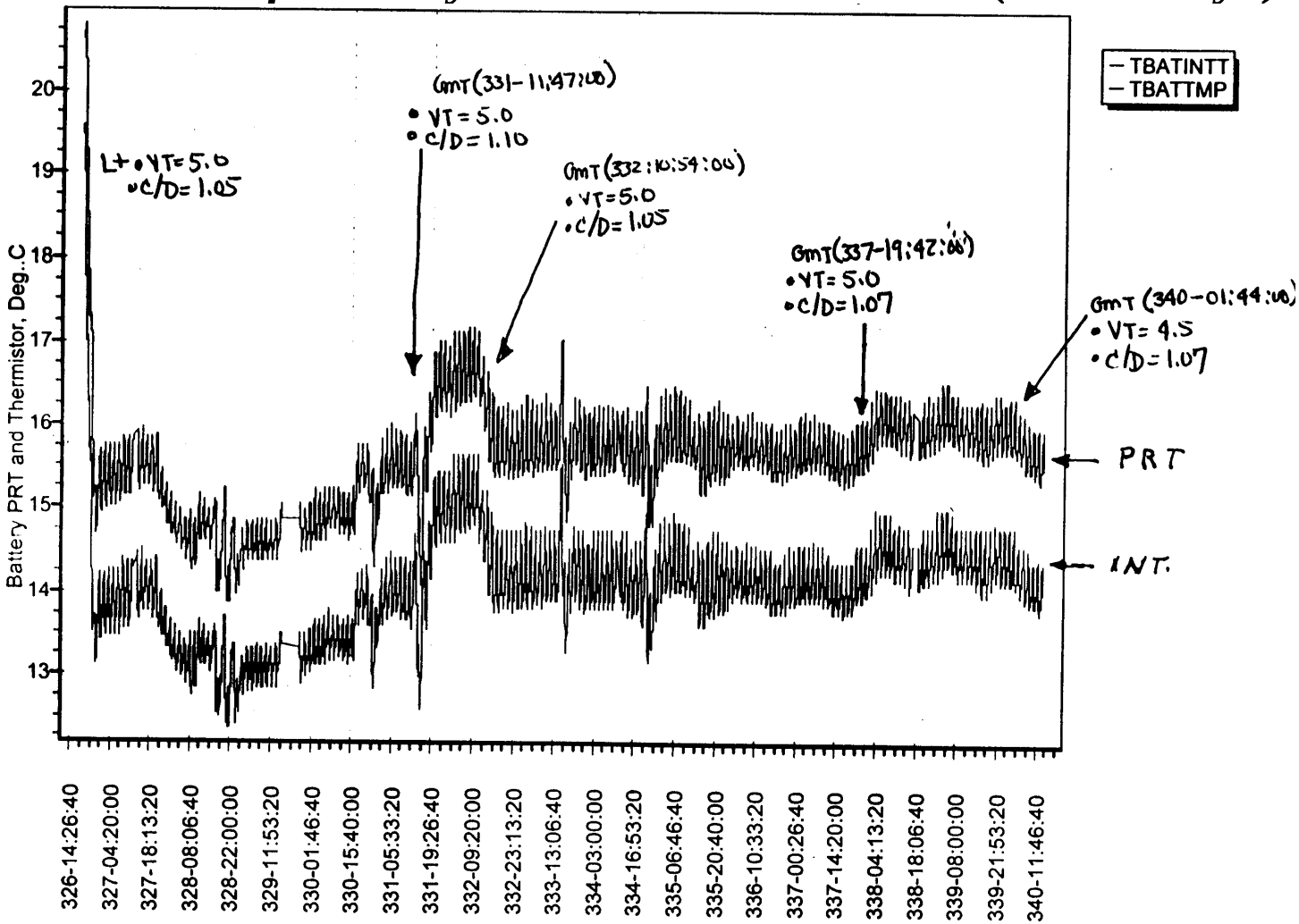
Three Typical Power Profiles

Day 340 (L+14), VT4.5, CD=1.07, trickle=0.500



Plot 10

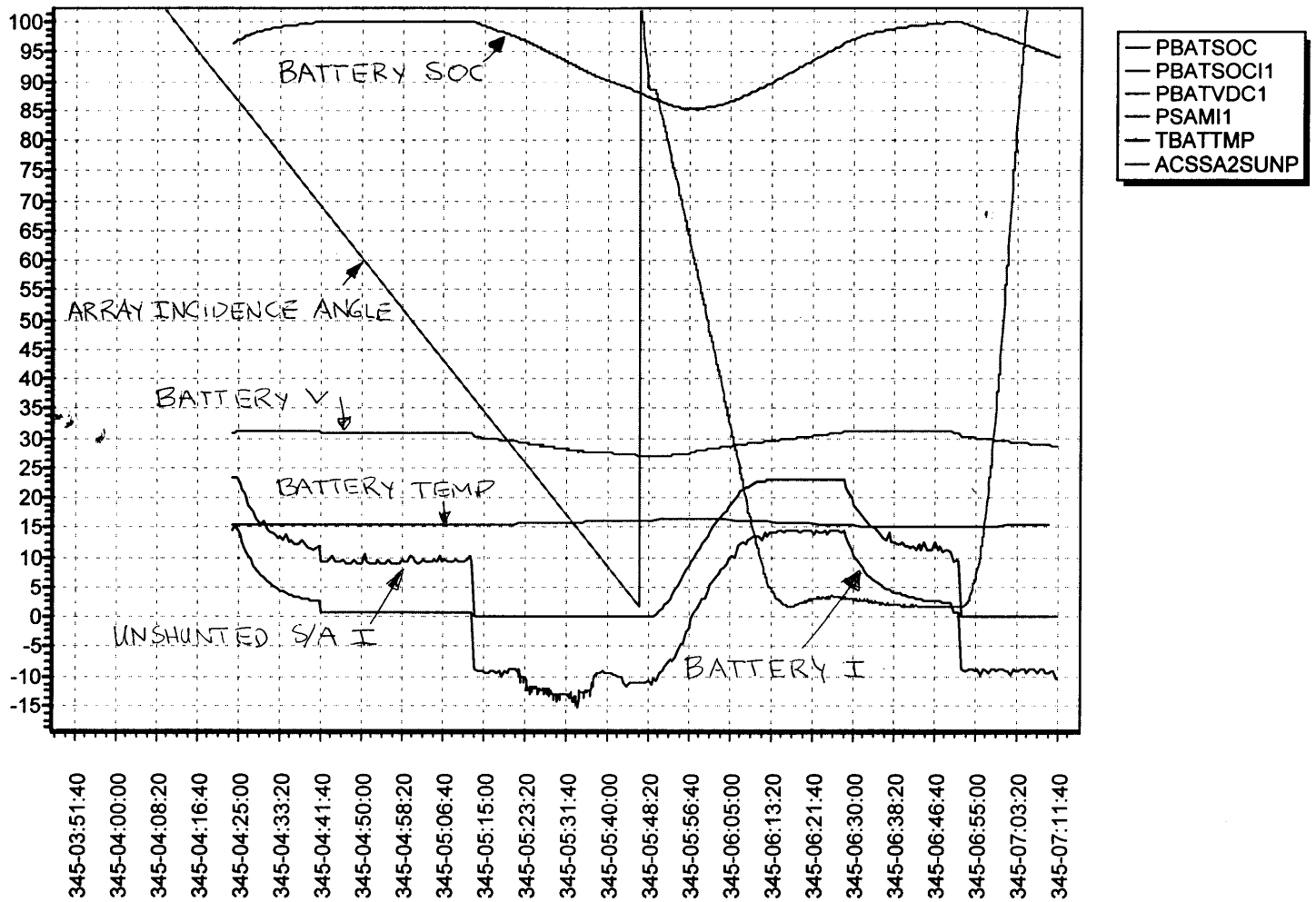
Trend Data of Battery PRT and Thermistor (L+14 Days)



Plot 11

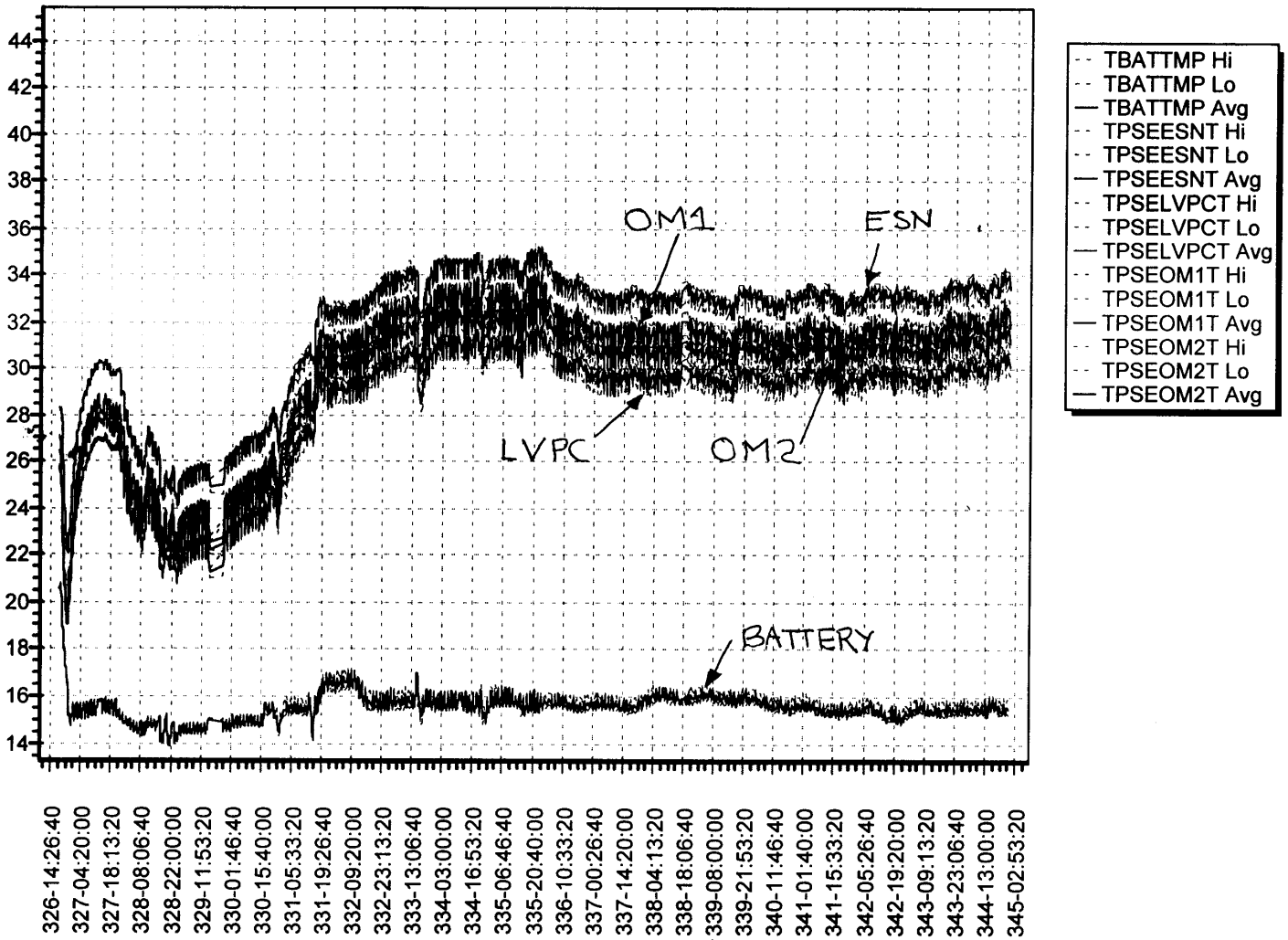
Dark Image, S/A Tracking Stopped during Image

Full Charge End of Sun

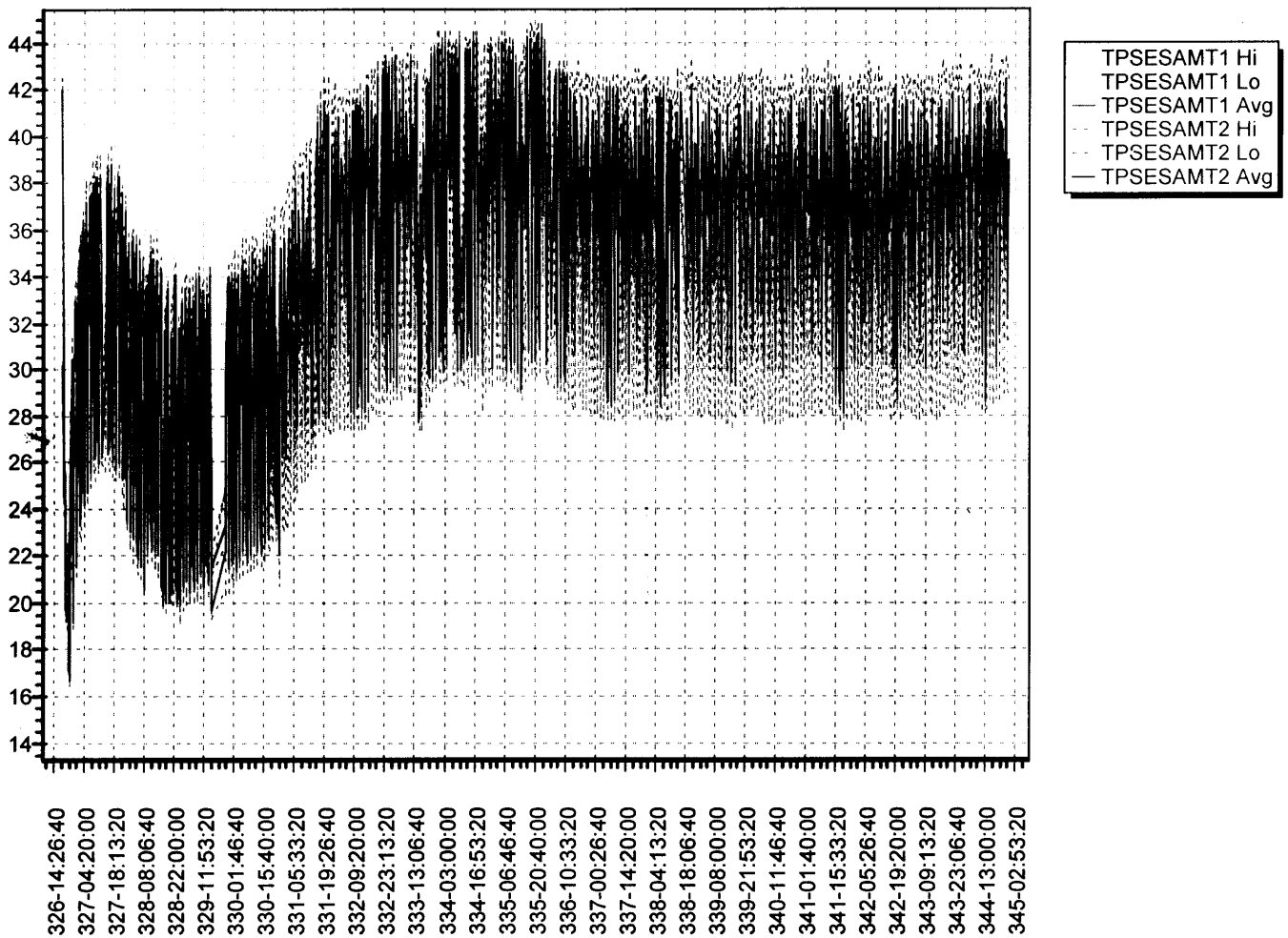


Plot 12

PSE Temperature Profile OM1, OM2, LVPC, ESN



Plot 13
PSE Temperature Profile
Solar Array Module T1, T2



Thermal

Nicholas M. Teti
EO-1 Thermal Systems Lead, Swales Aerospace

Thermal Subsystem Status

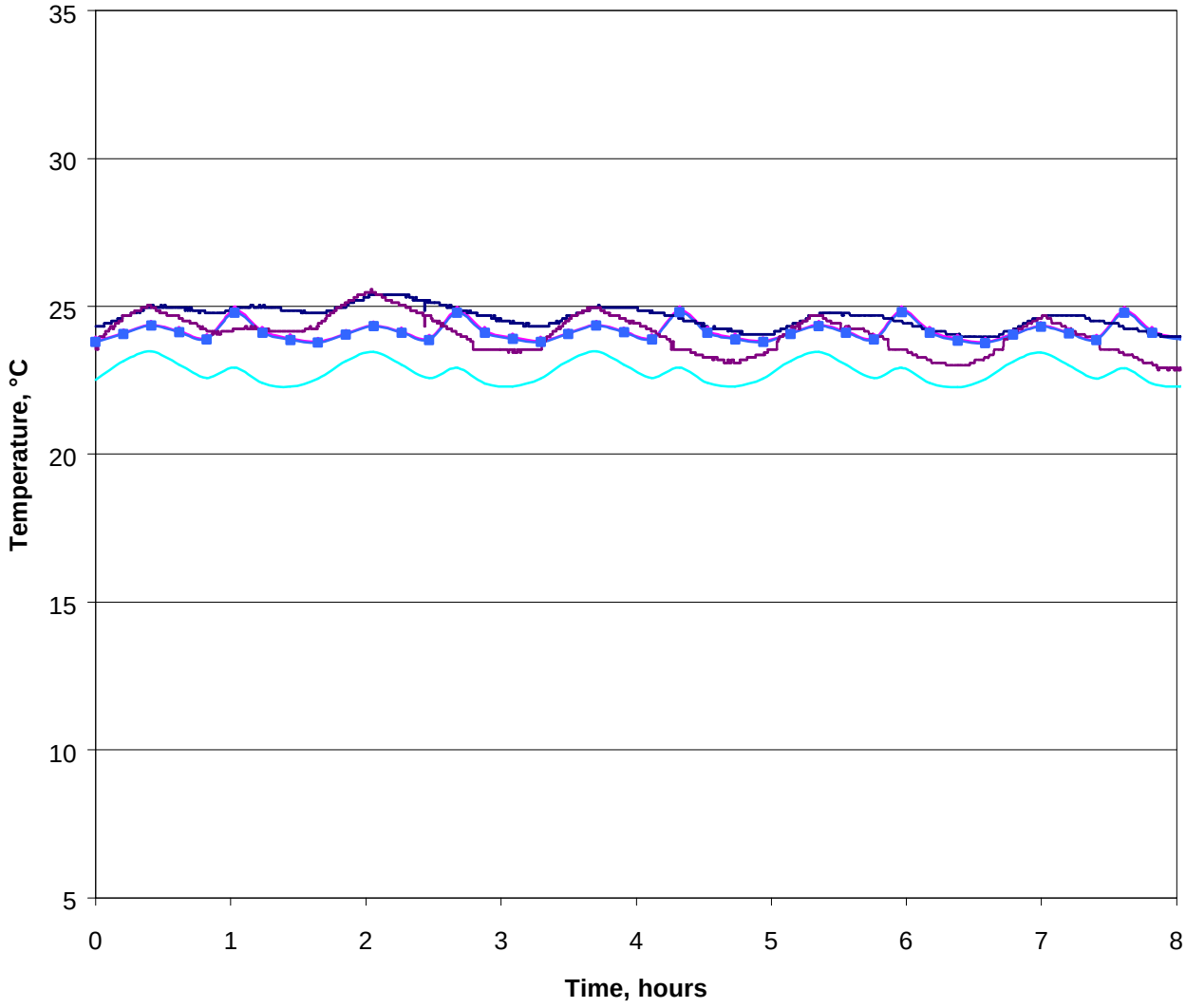
- Launch Conditions Nominal
  - Battery Cooling w/Fairing Air Performed as Predicted
- Post Ascent Nominal
  - Less than 1°C rise in Battery Temperature
- Pre-Solar Array Deployment Nominal
- Sun Acquisition Mode Nominal
- Earth Pointing Mode Nominal

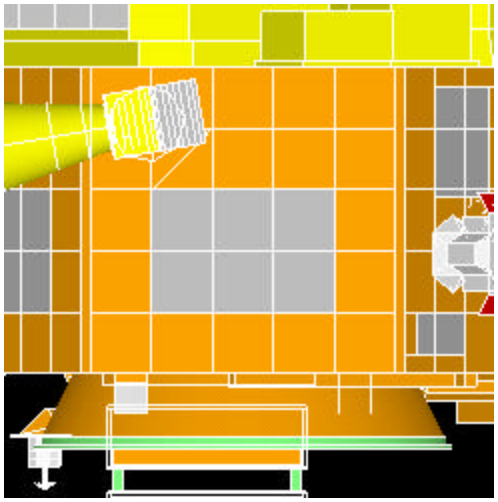
Thermal Subsystem is Nominal !

Thermal Subsystem Status

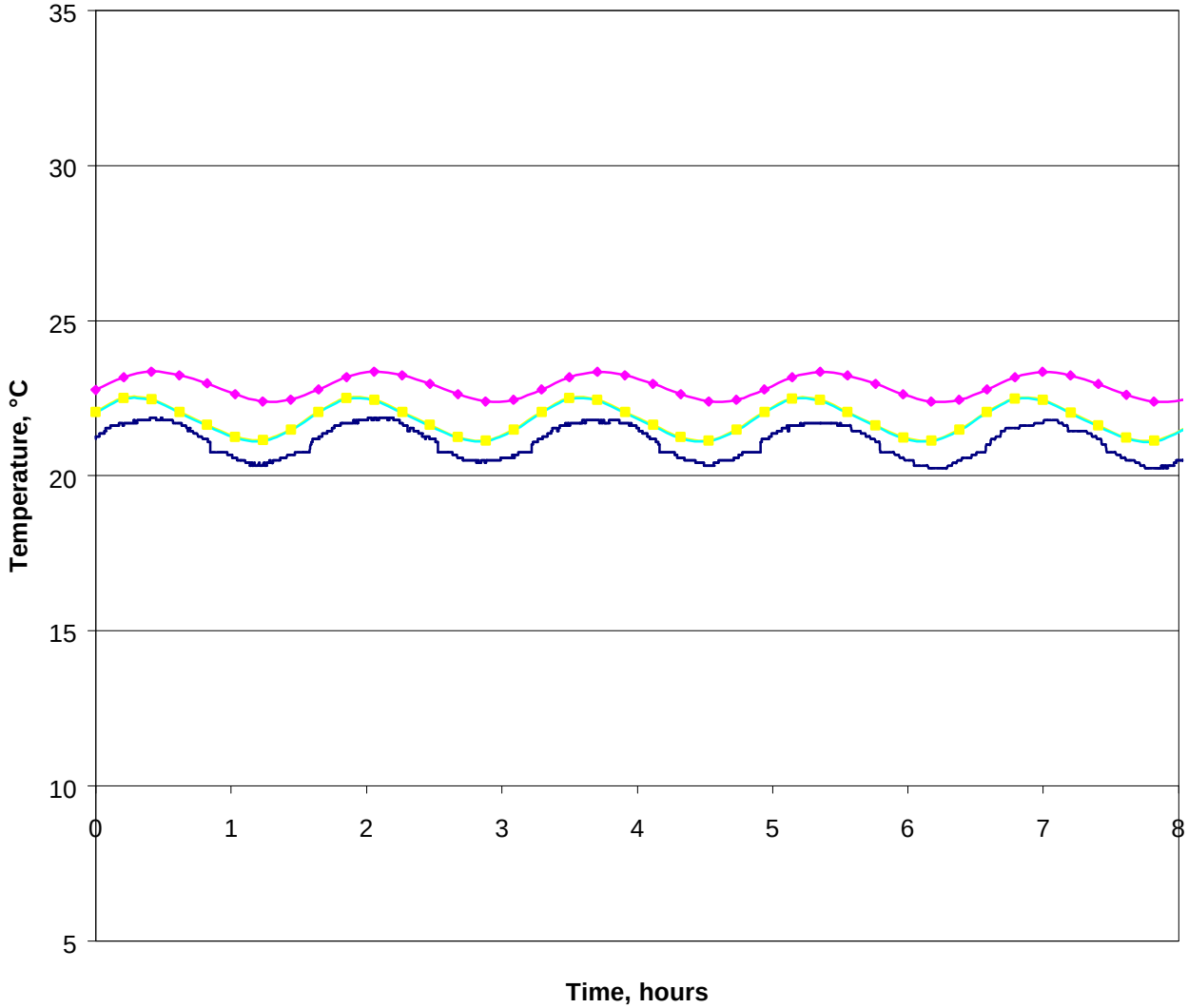
- **No Changes to Nominal Configuration Since Launch**
  - Adequate coverage of Thermistors
  - 0 % Spacecraft Heater Duty Cycle
- **Anomalies or Problems**
  - One LFSA Thermistor (TLFSA1T) not working as of 12/1/00
  - Backside of Solar Array 10 °C cooler than pre-launch predictions
    - Release Rod Capture Canister Conduction Coupling was corrected and post-launch model predictions match flight predictions
- **Revised Limits**
  - Solar Array Drive Assembly (SADA)
    - Yellow High: Changed from 35°C to 36°C based on TV Testing
    - Red High: Changed from 40°C to 41°C based on TV Testing
  - Solar Array
    - Backside Temperature 10°C lower

DCE Thermal Analysis vs. Flight Results (Nominal)

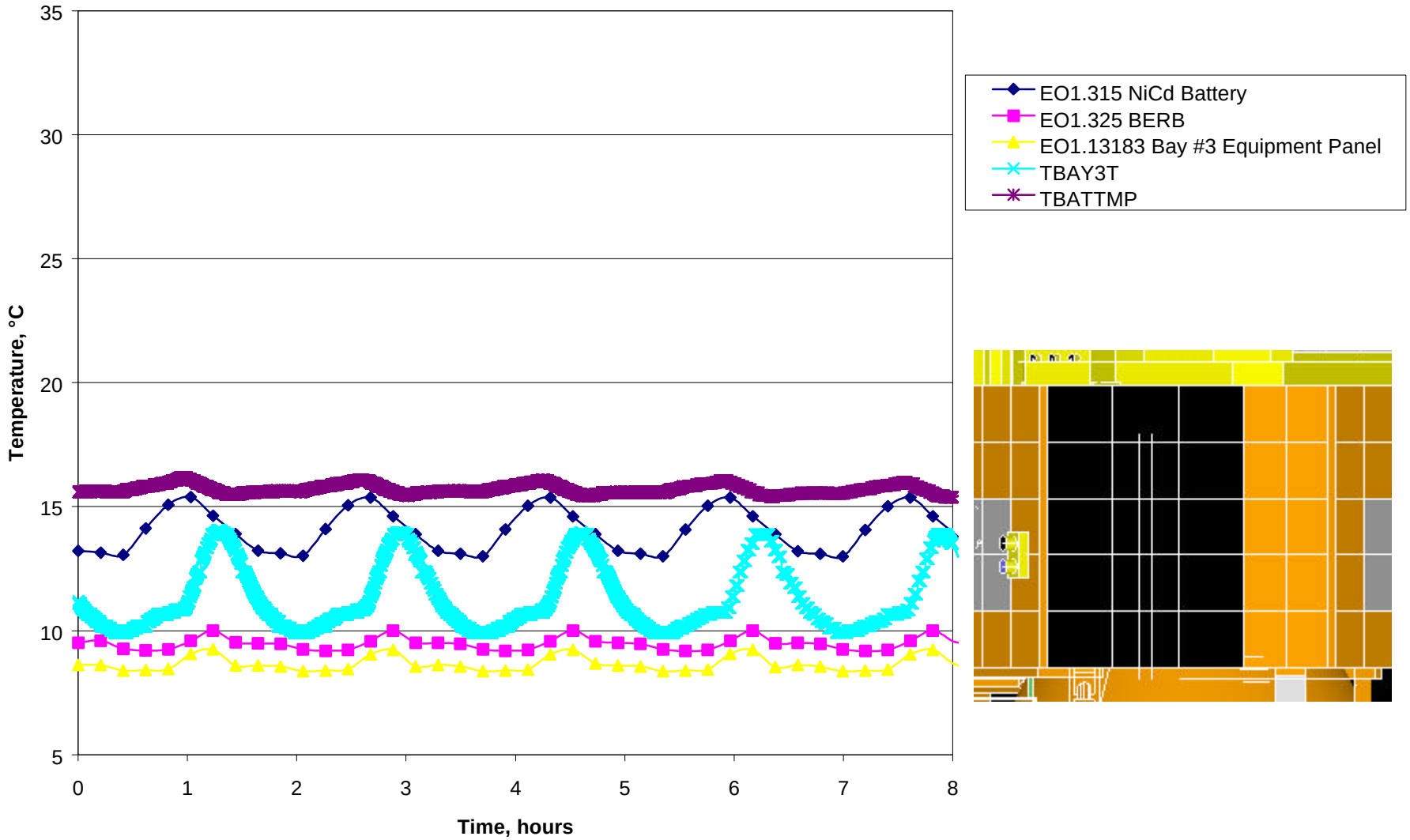




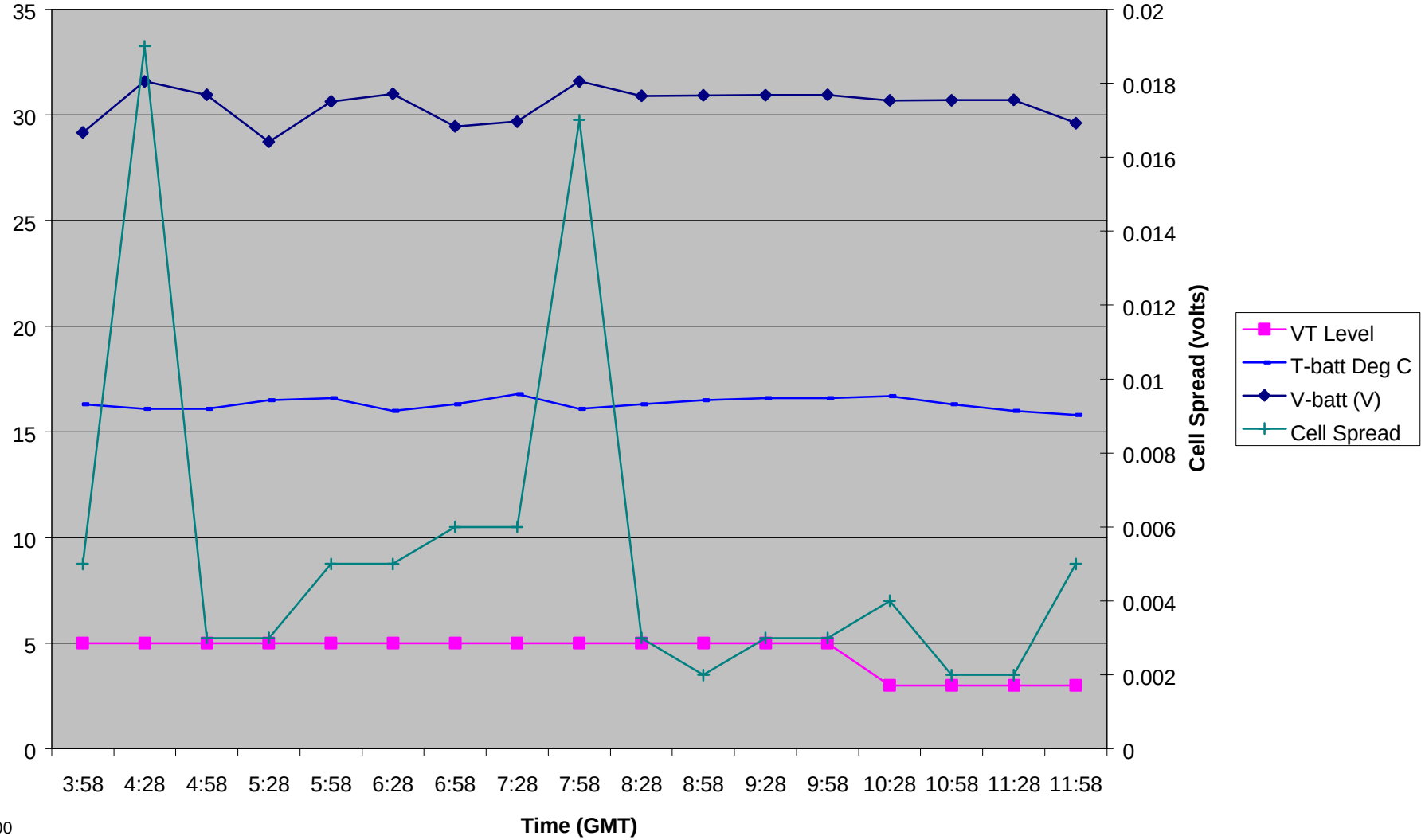
DCE Thermal Analysis vs. Flight Results (Nominal)

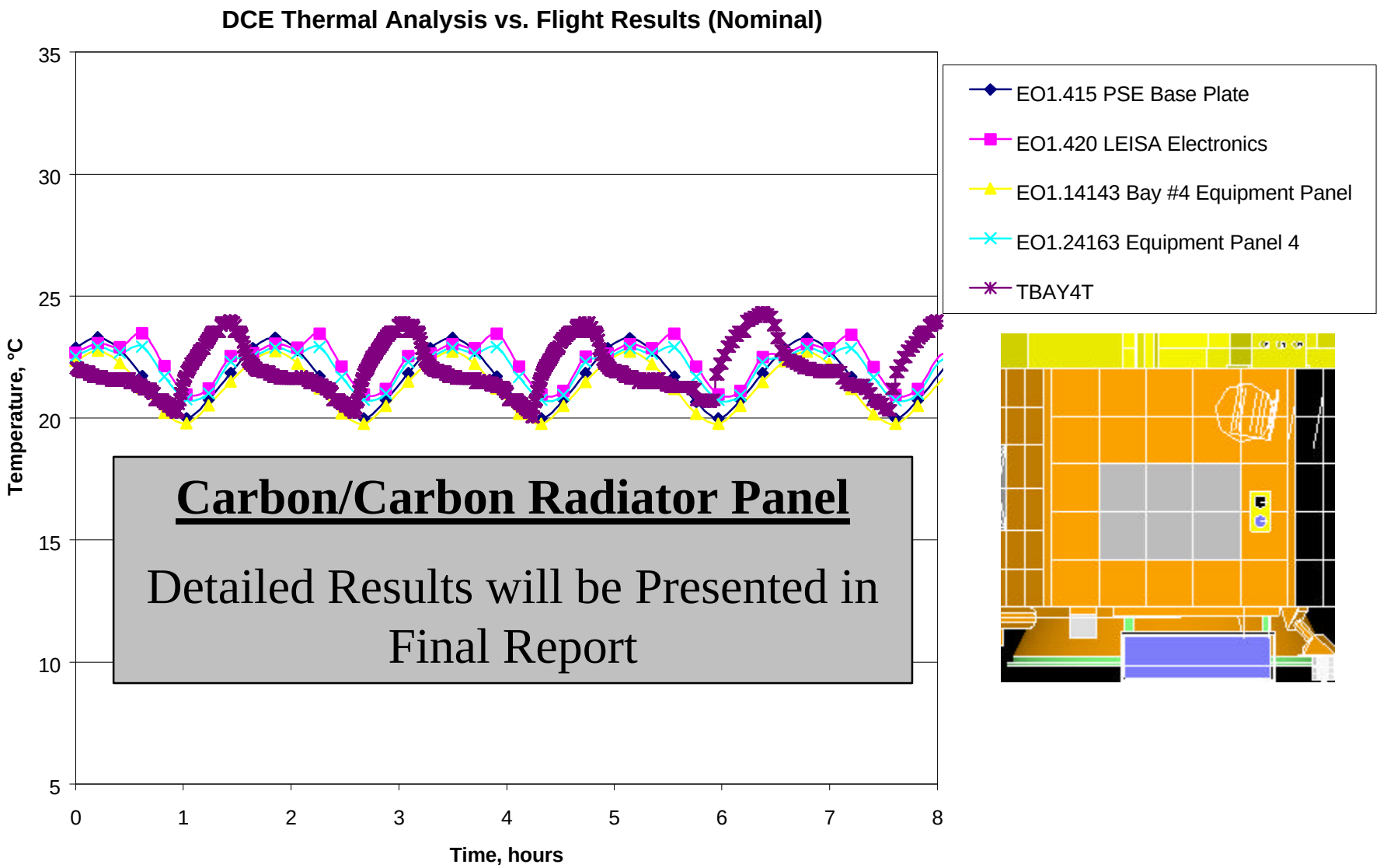


DCE Thermal Analysis vs. Flight Results (Nominal)



Battery Profile S/N-001 During Hot Thermal Balance

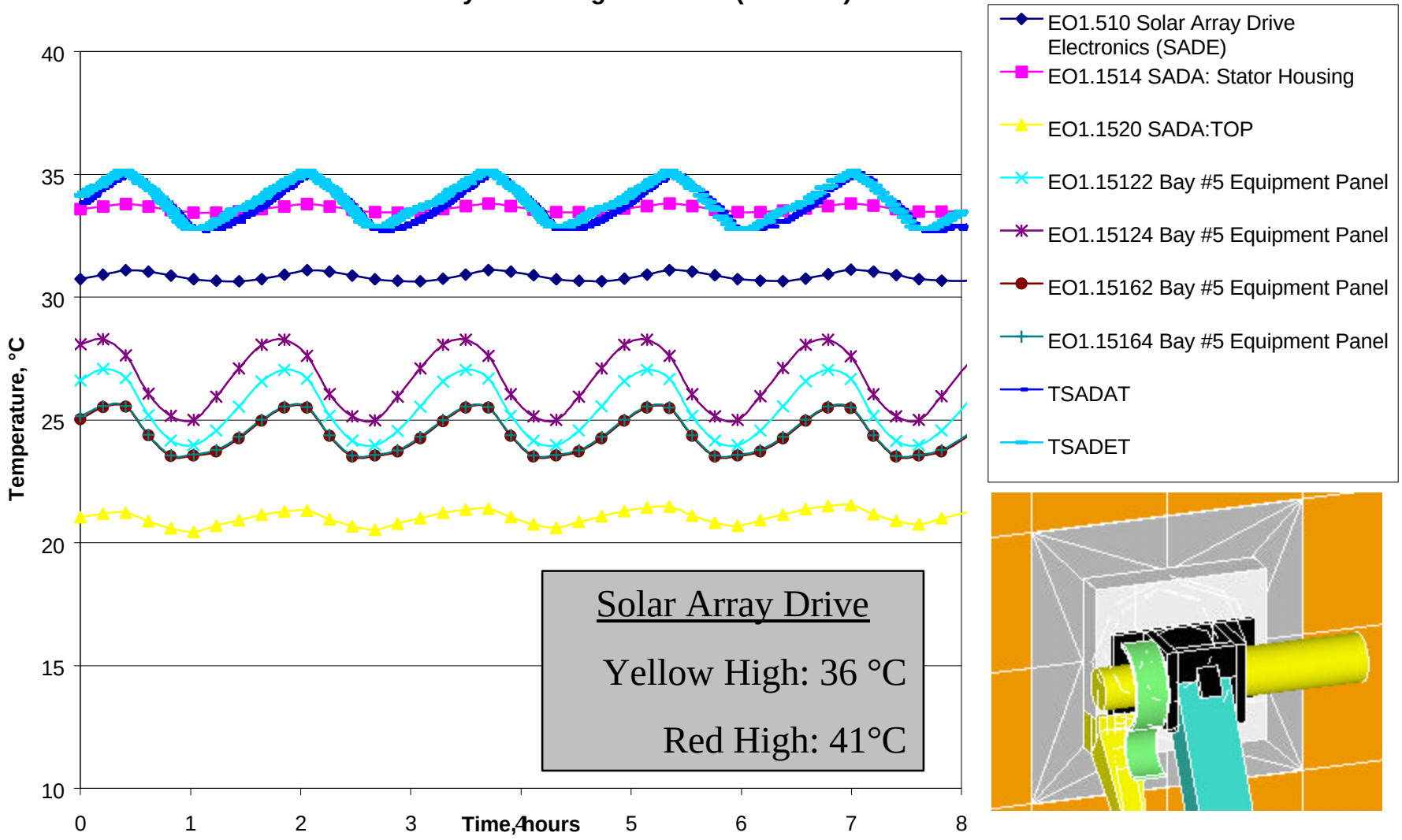




Carbon/Carbon Radiator Panel

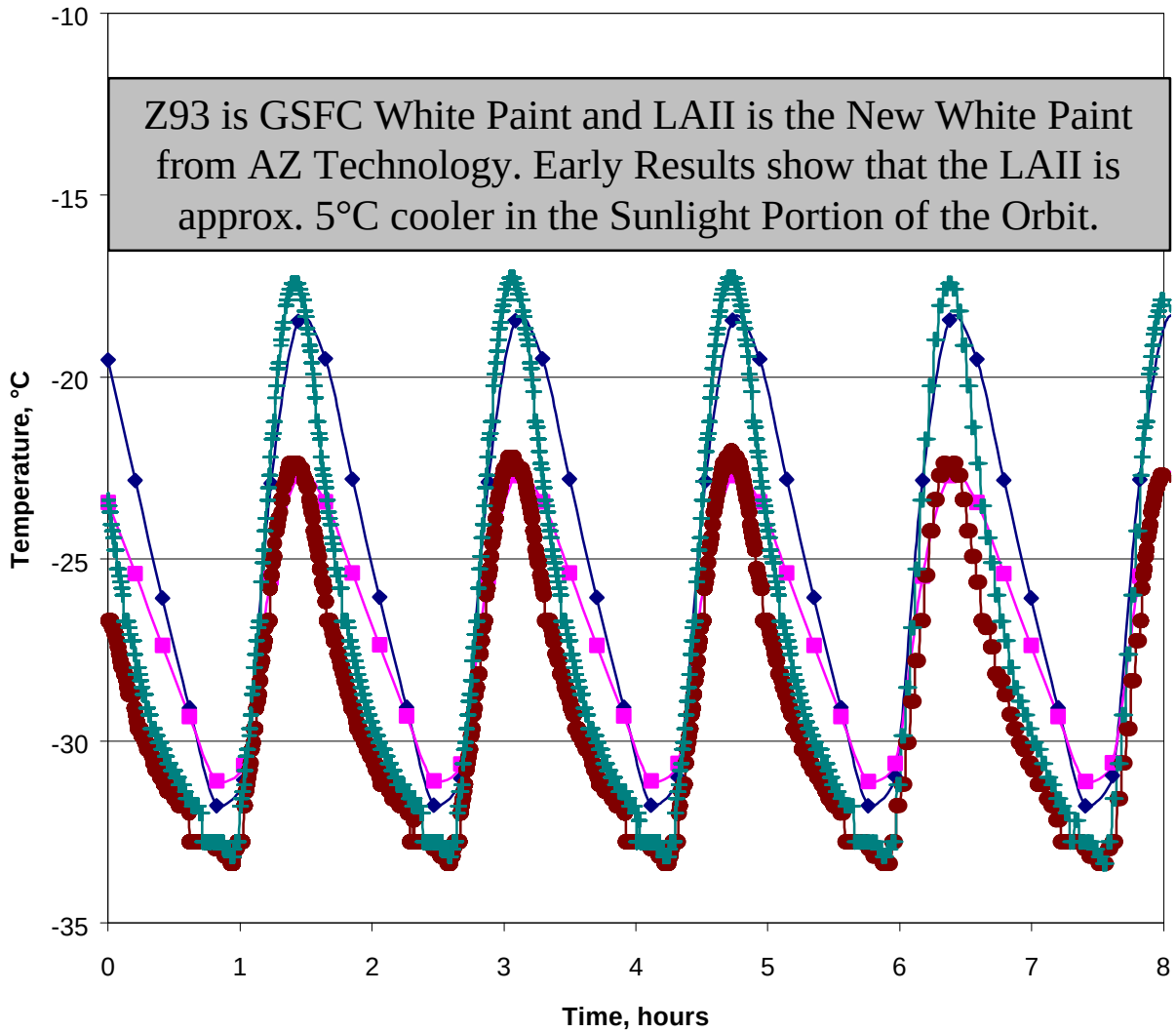
Detailed Results will be Presented in Final Report

DCE Thermal Analysis vs. Flight Results (Nominal)

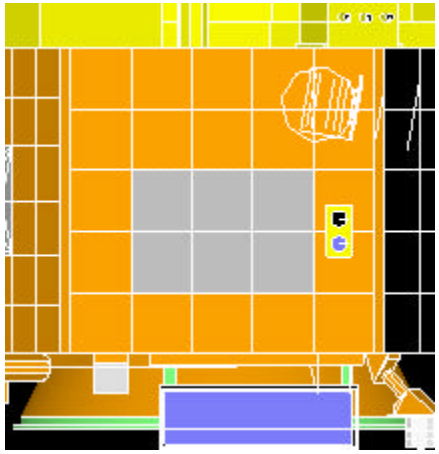


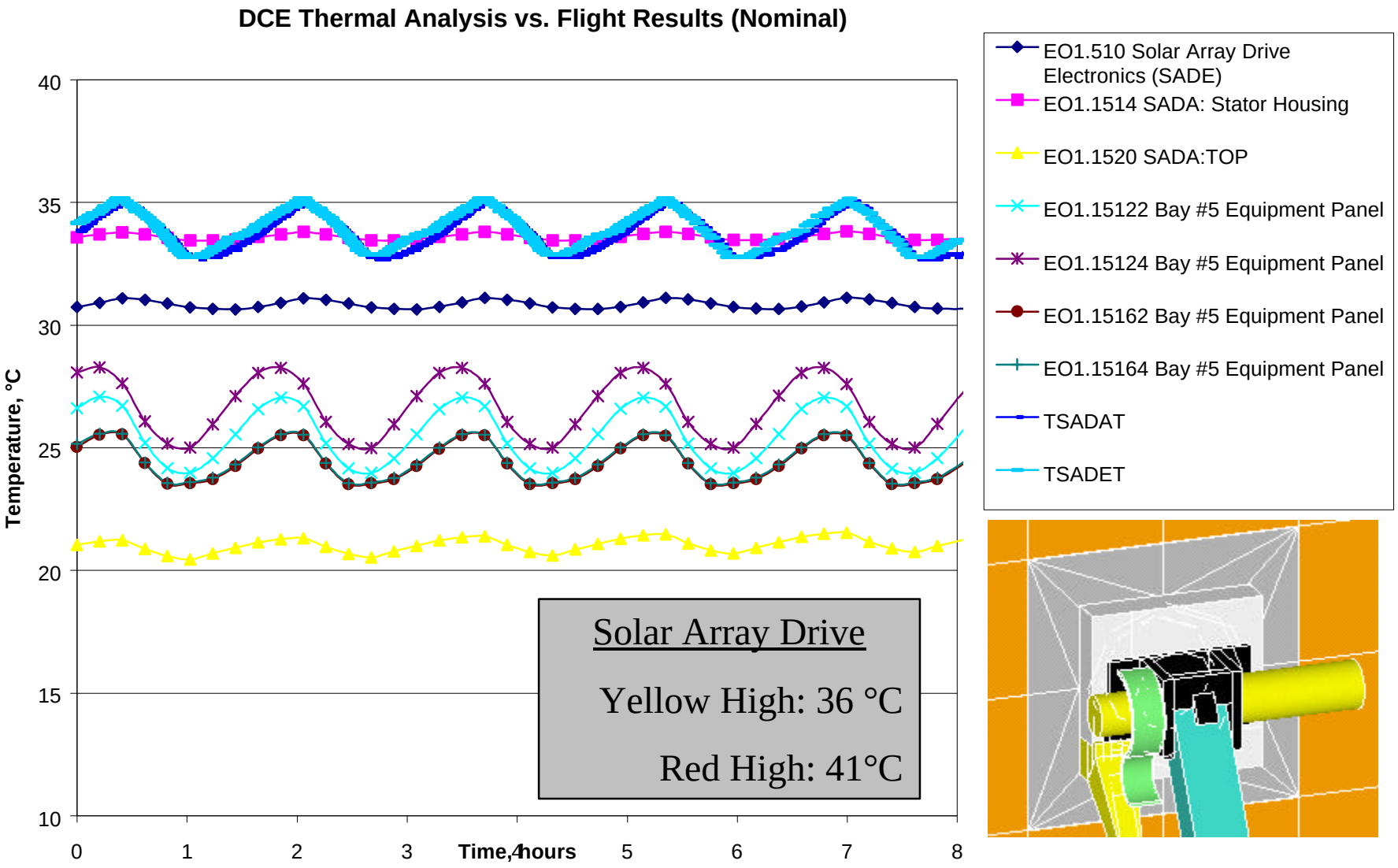
DCE Thermal Analysis vs. Flight Results (Nominal)

Z93 is GSFC White Paint and LAII is the New White Paint from AZ Technology. Early Results show that the LAII is approx. 5°C cooler in the Sunlight Portion of the Orbit.

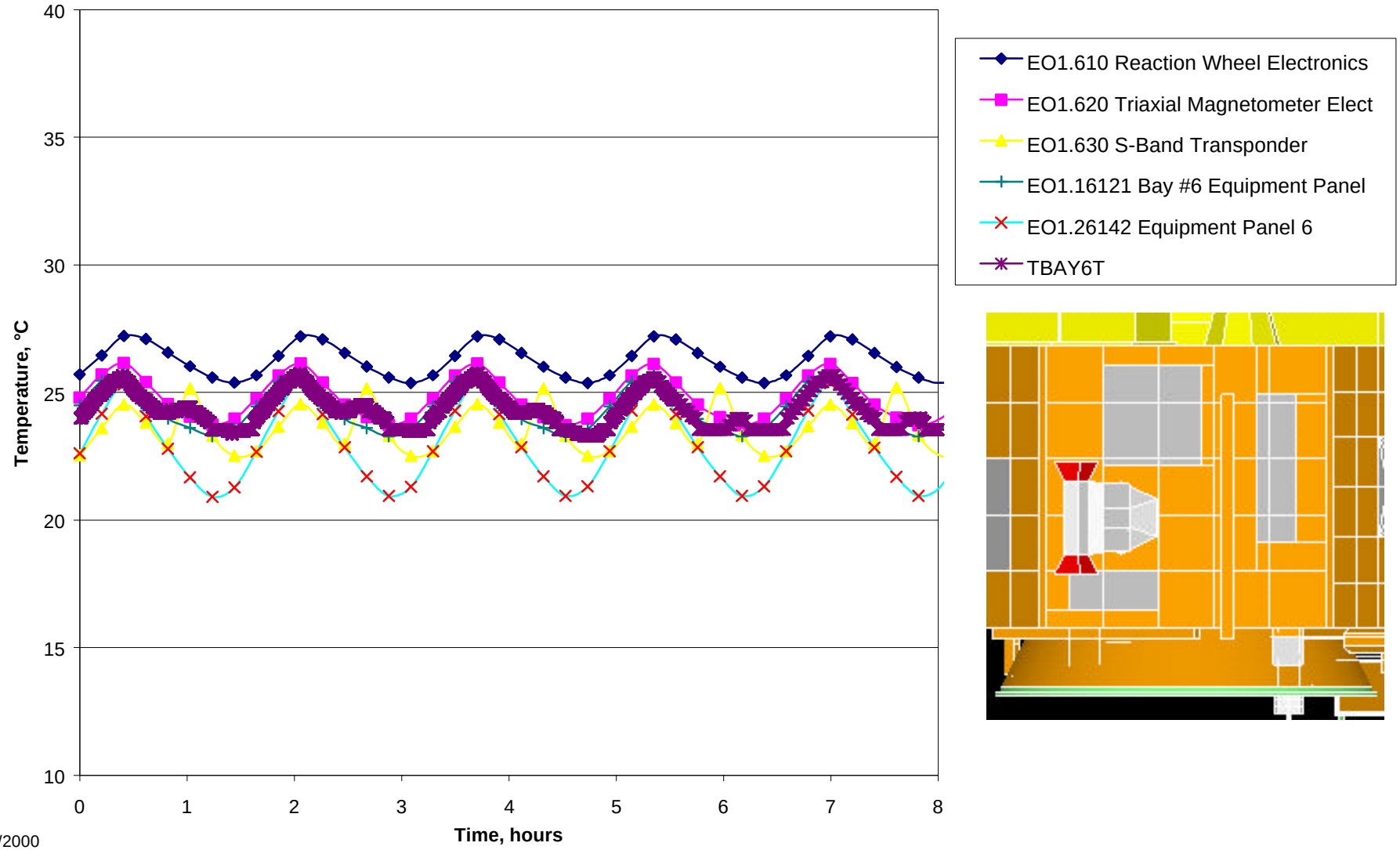


- EO1.1475 Calorimeter: Z93
- EO1.1485 Calorimeter: LAII
- EO1.1470
- EO1.1480
- EO1.1450 Calorimeter Bracket
- EO1.24163 Equipment Panel 4
- LAII
- Z93

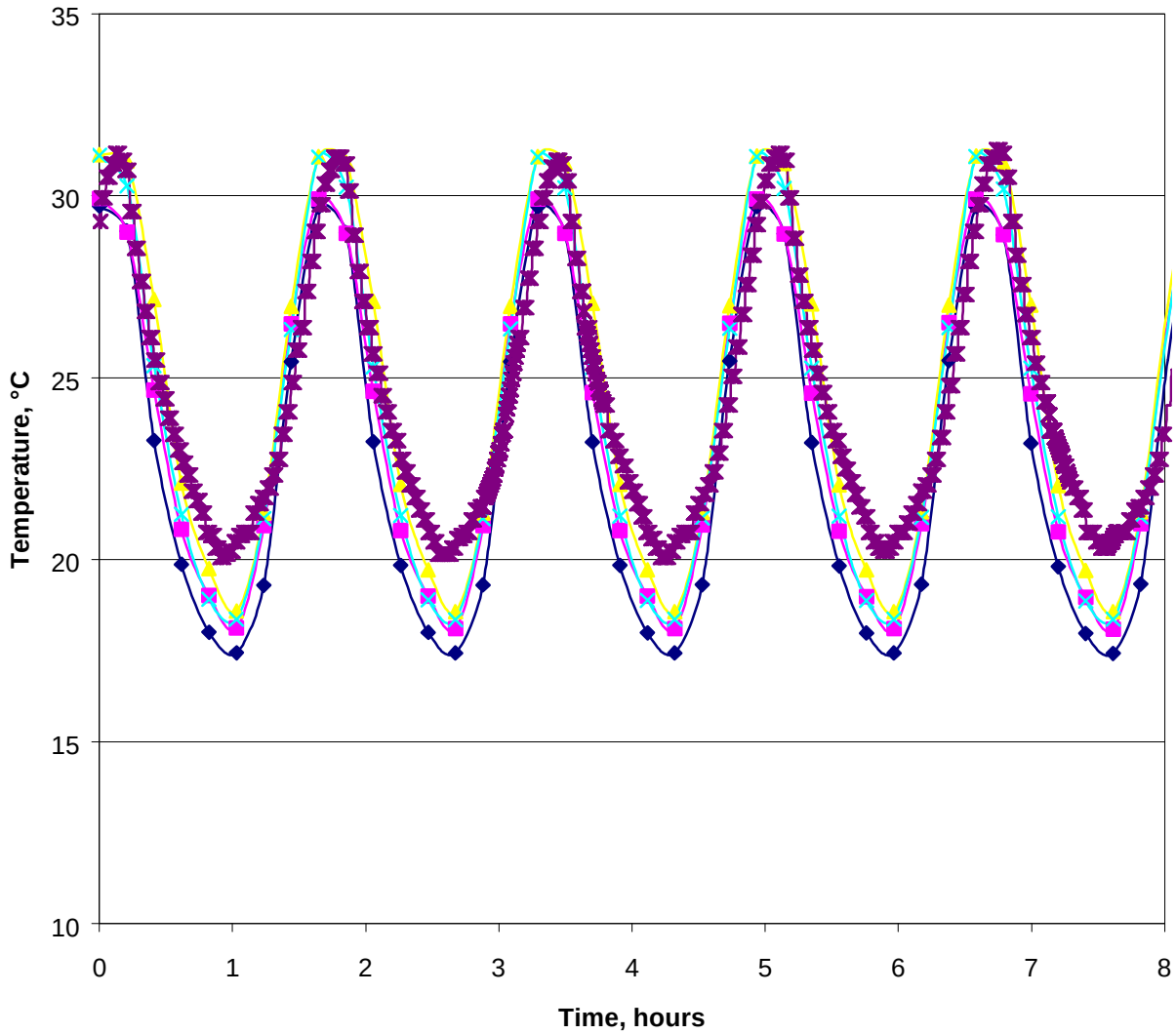


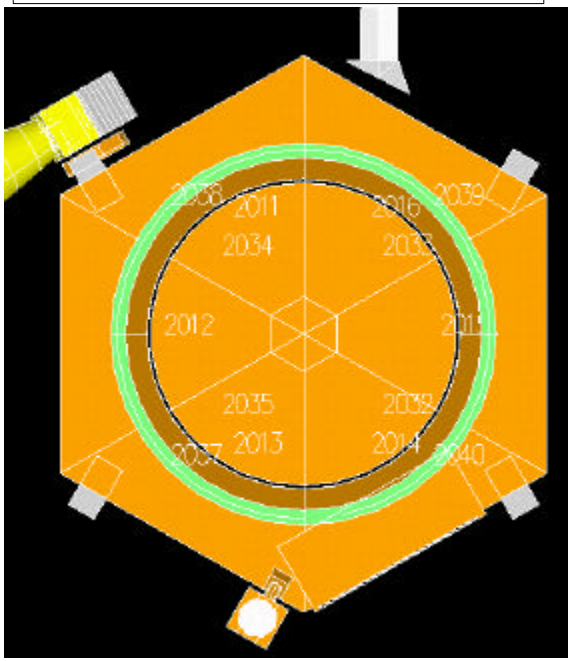

DCE Thermal Analysis vs. Flight Results (Nominal)
Temperature, °C
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
Time, hours
EO1.510 Solar Array Drive Electronics (SADE)
EO1.1514 SADA: Stator Housing
EO1.1520 SADA:TOP
EO1.15122 Bay #5 Equipment Panel
EO1.15124 Bay #5 Equipment Panel
EO1.15162 Bay #5 Equipment Panel
EO1.15164 Bay #5 Equipment Panel
TSADAT
TSADET
Solar Array Drive
Yellow High: 36 °C
Red High: 41°C

DCE Thermal Analysis vs. Flight Results (Nominal)

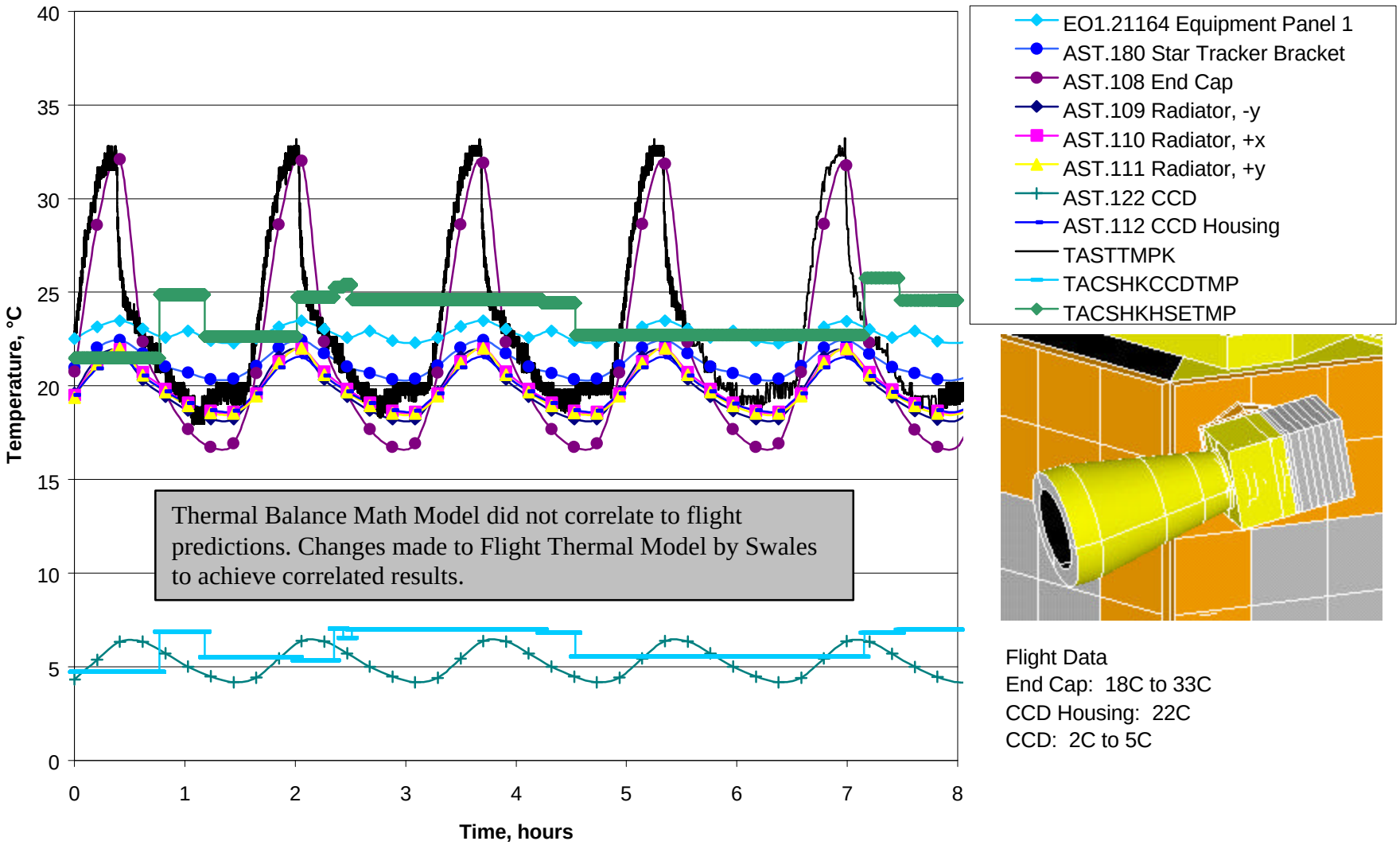


DCE Thermal Analysis vs. Flight Results (Nominal)



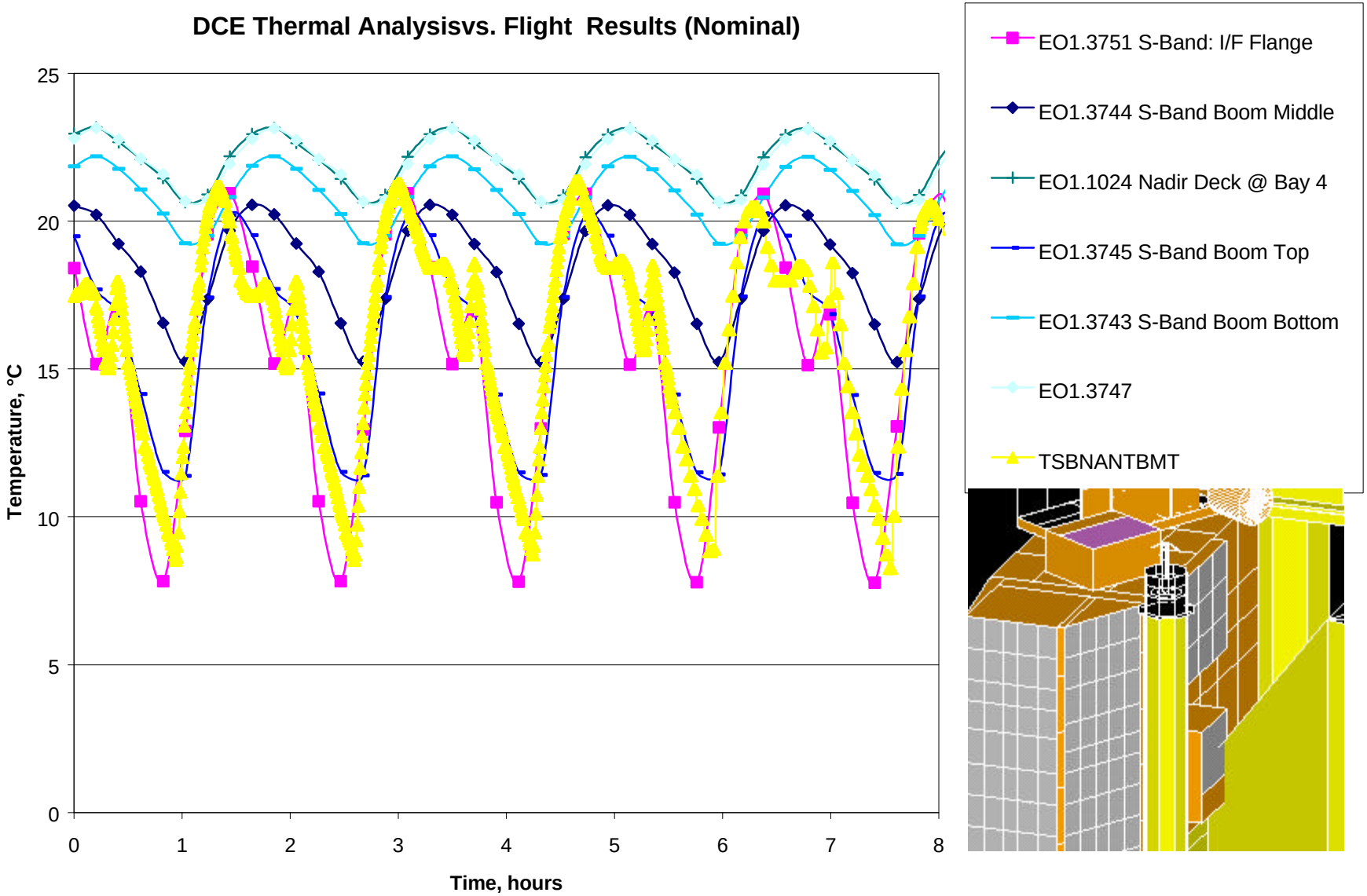


DCE Thermal Analysis vs. Flight Results (Nominal)

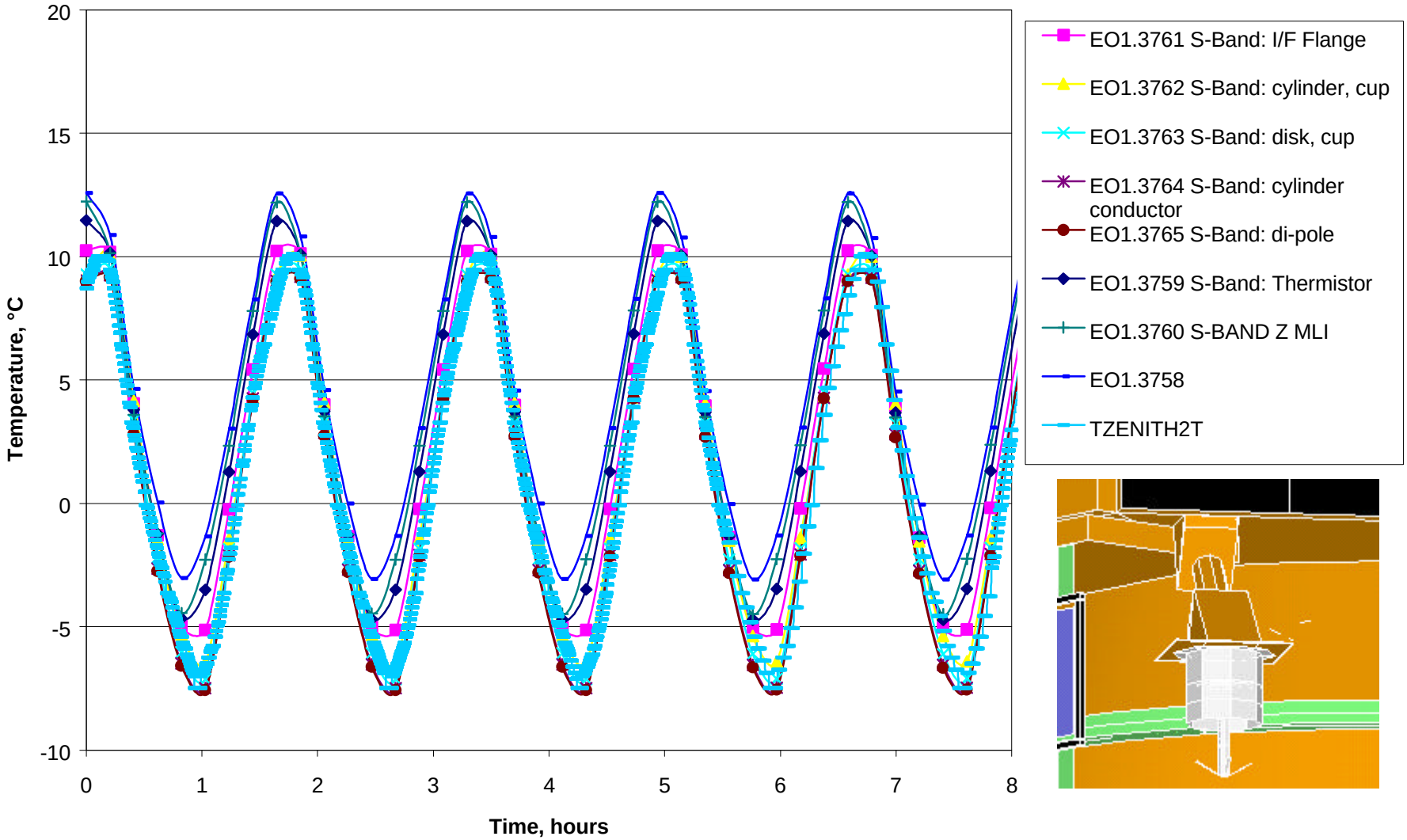


Thermal Balance Math Model did not correlate to flight predictions. Changes made to Flight Thermal Model by Swales to achieve correlated results.

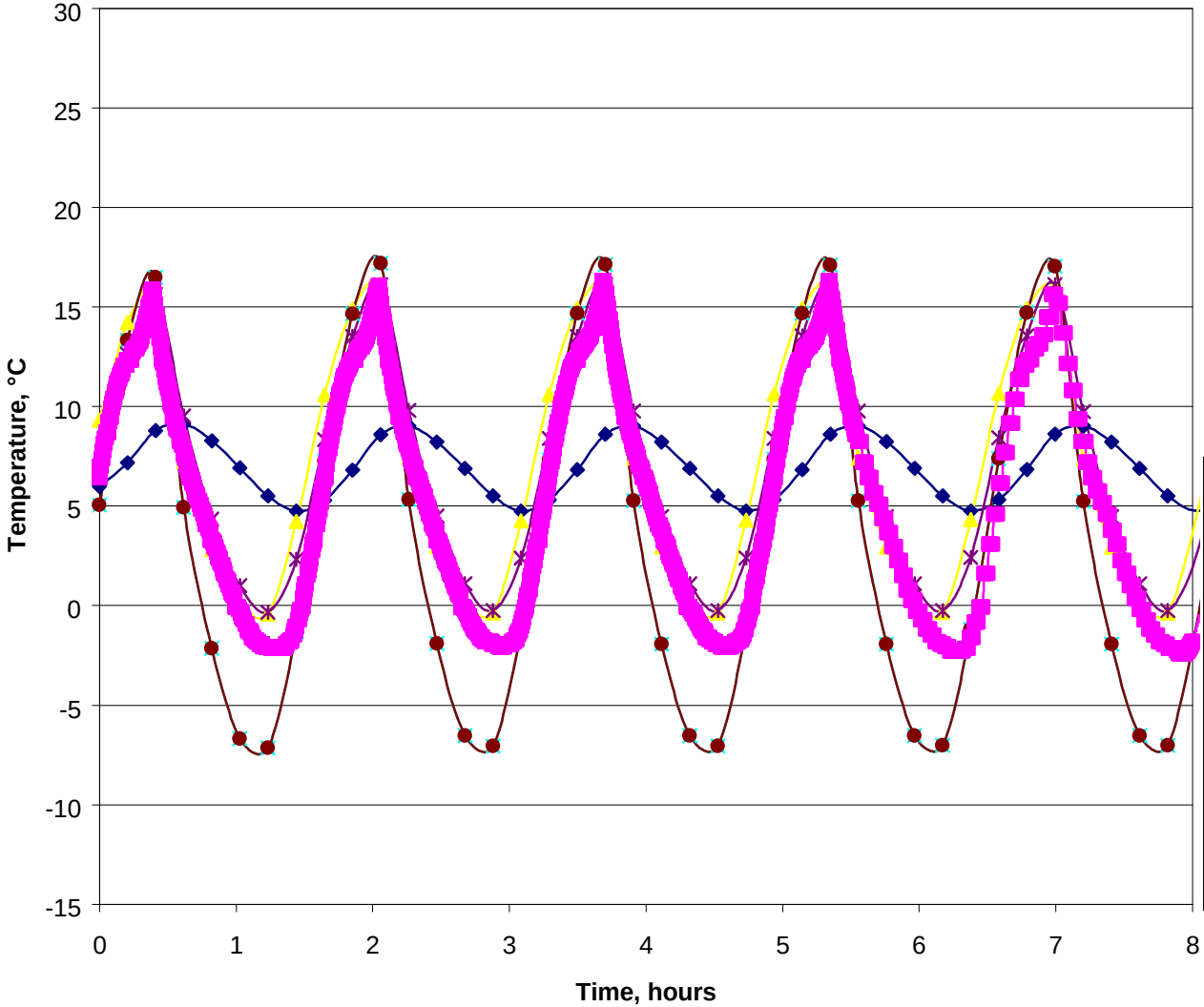
Flight Data
End Cap: 18C to 33C
CCD Housing: 22C
CCD: 2C to 5C

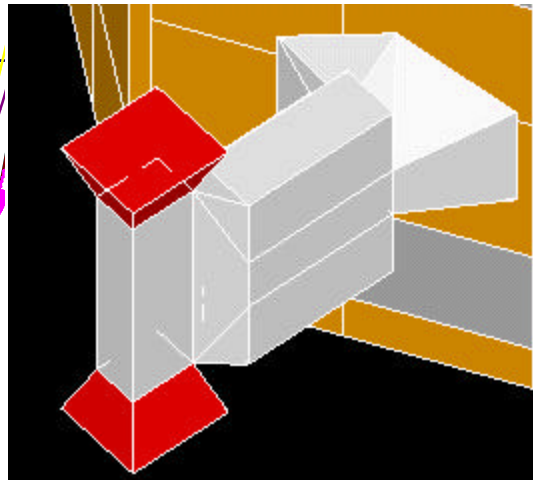

DCE Thermal Analysisvs. Flight Results (Nominal)
Temperature, °C
Time, hours
0
5
10
15
20
25
0
1
2
3
4
5
6
7
8
EO1.3751 S-Band: I/F Flange
EO1.3744 S-Band Boom Middle
EO1.1024 Nadir Deck @ Bay 4
EO1.3745 S-Band Boom Top
EO1.3743 S-Band Boom Bottom
EO1.3747
TSBNANTBMT

DCE Thermal Analysis vs. Flight Results (Nominal)

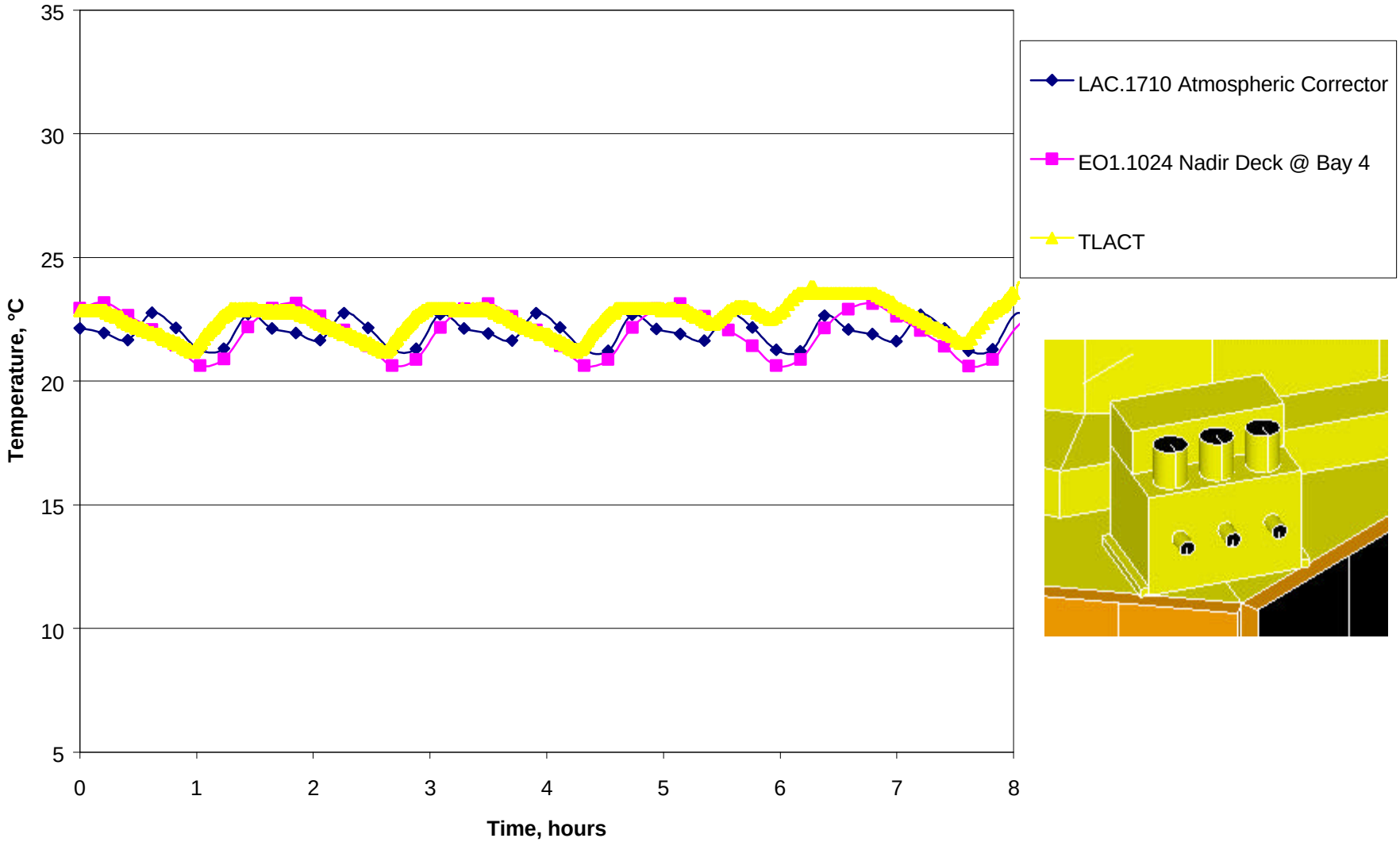


DCE Thermal Analysisvs. Flight Results (Nominal)

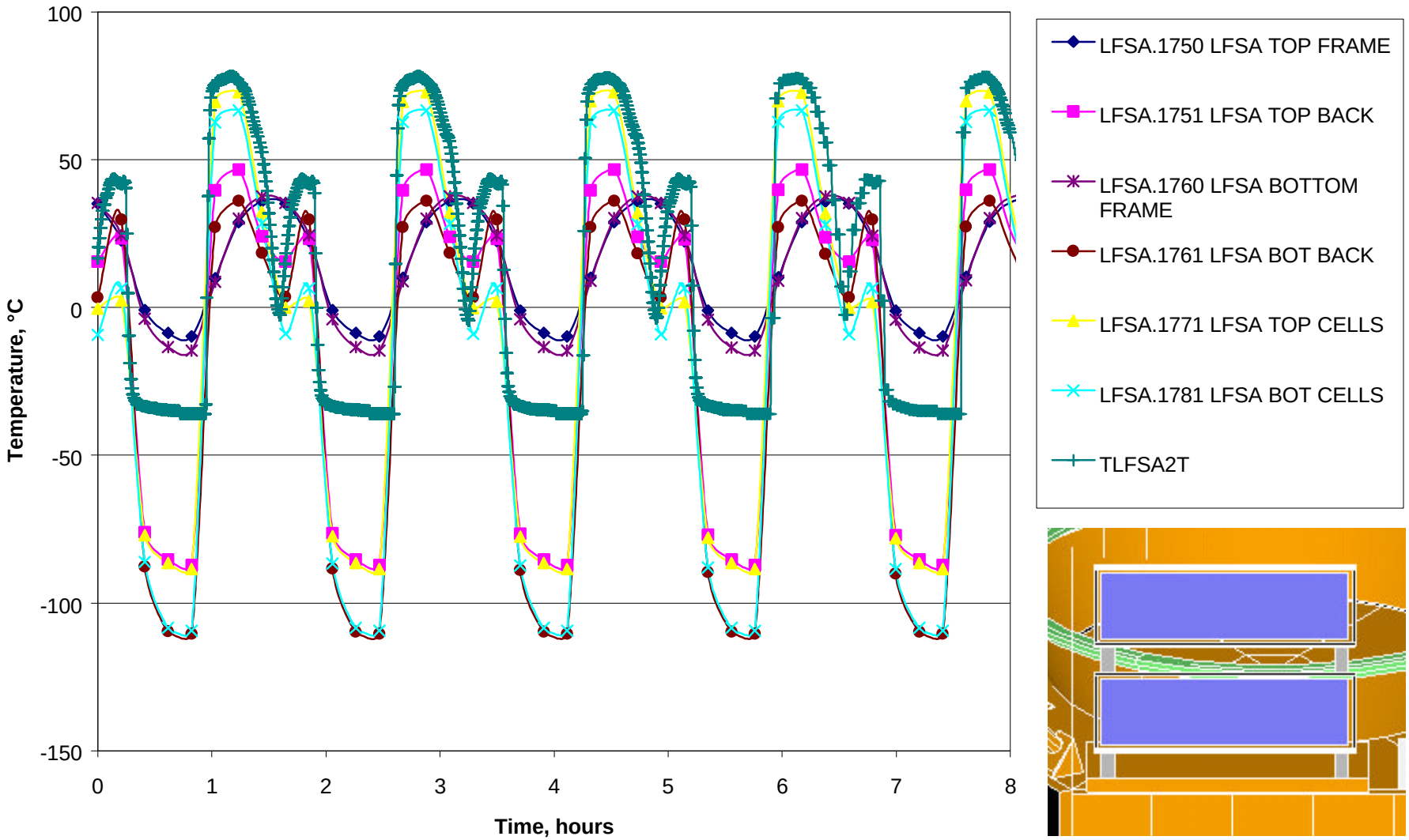




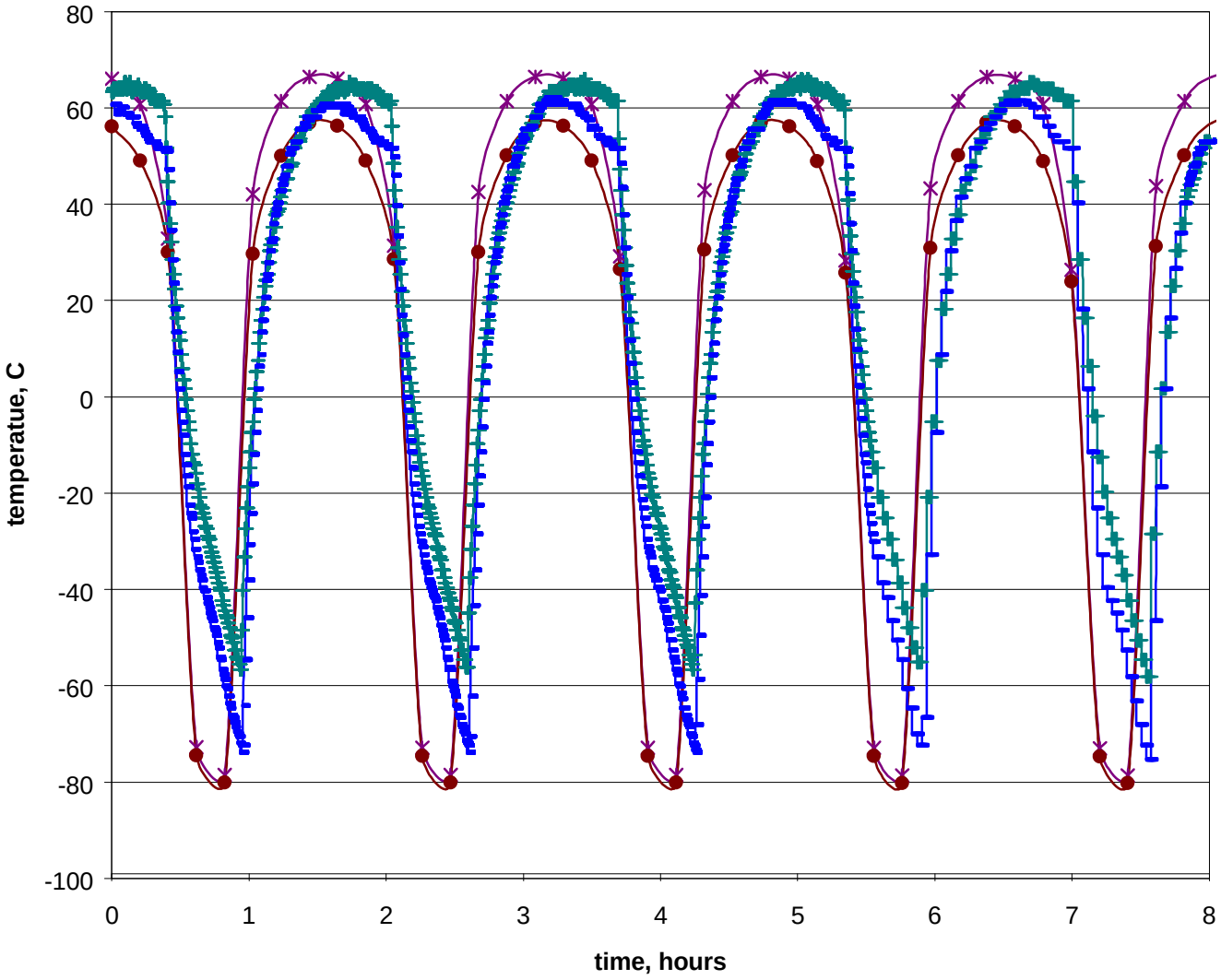
DCE Thermal Analysis vs. Flight Results (Nominal)

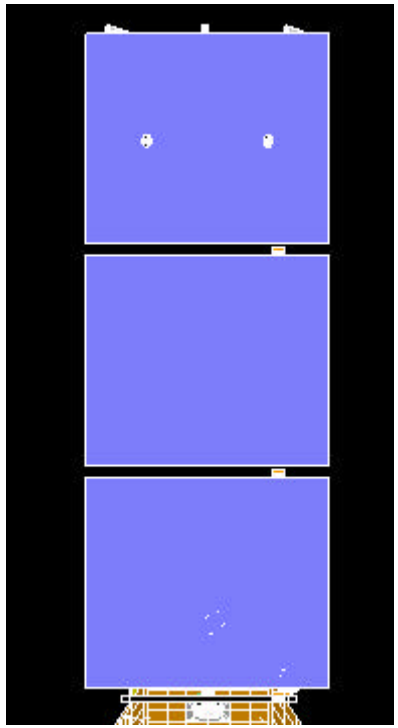


DCE Thermal Analysis vs. Flight Results (Nominal)



DCE Thermal Analysis vs. Flight Results (Nominal)



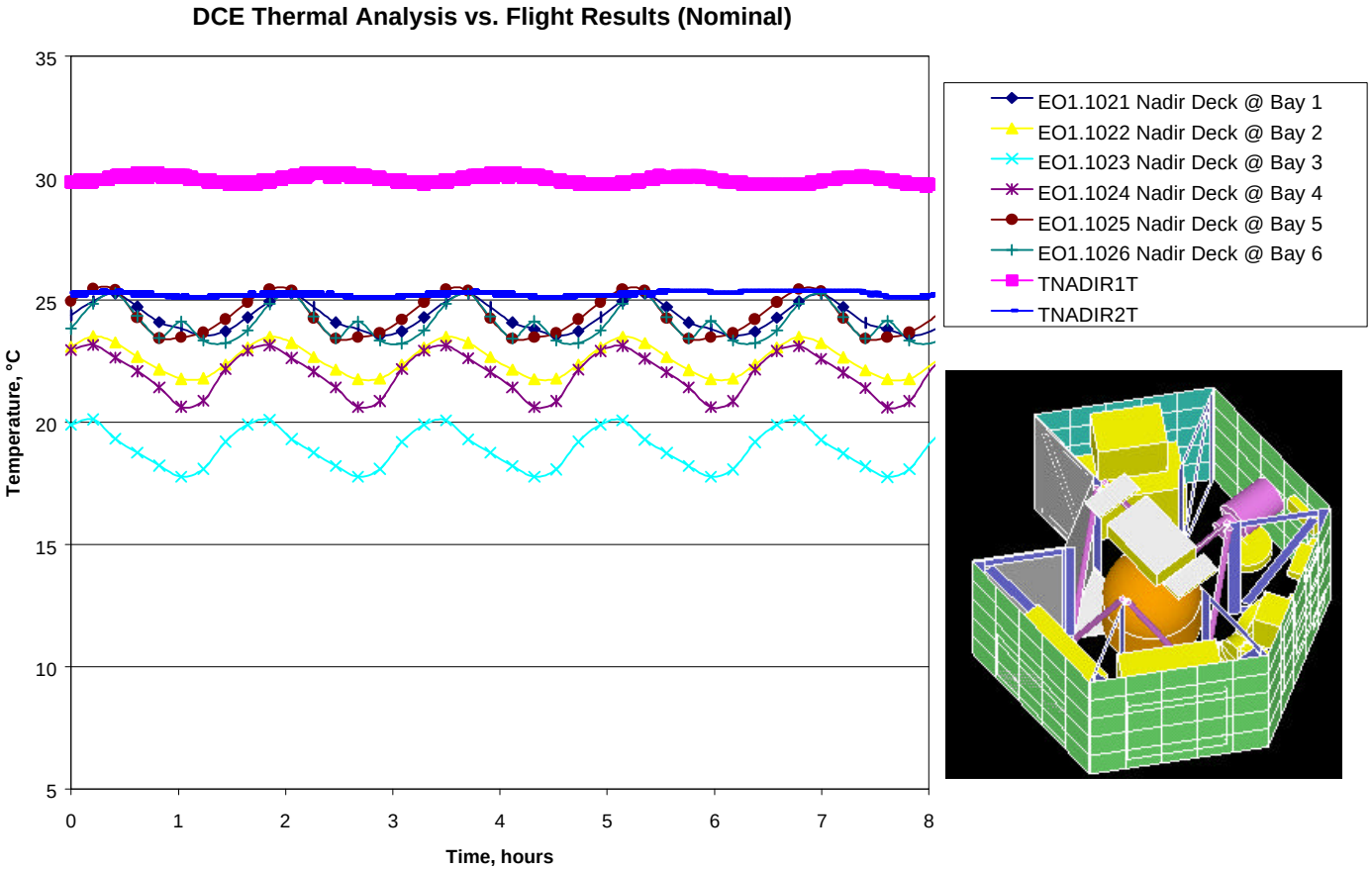


Instrument Thermal Status Overview

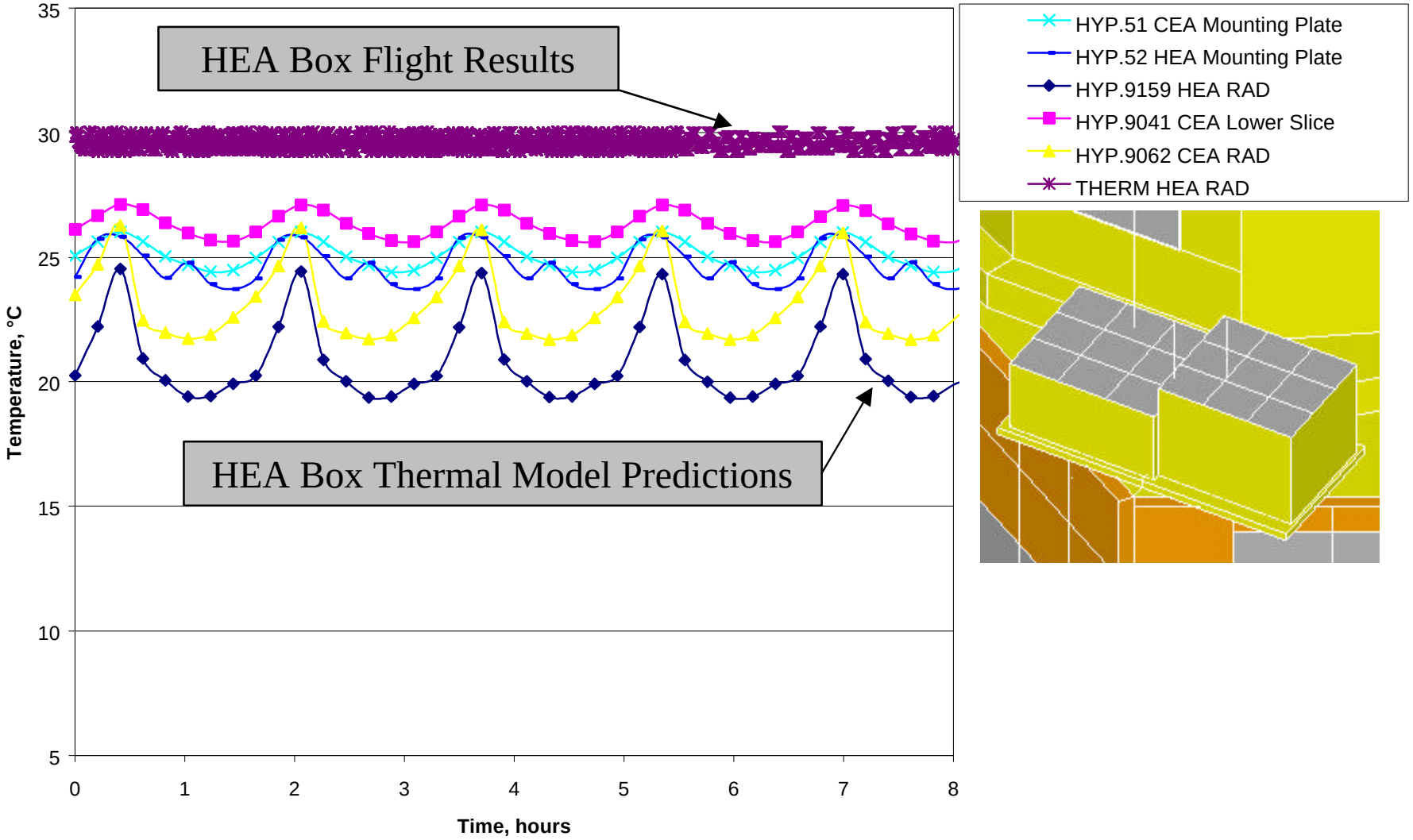
- ***Advanced Land Imager (ALI)***
  - ***ALI reporting nominal conditions***
  - ***Integrated Thermal Math Model agrees with Flight Results***
- ***Hyperion***
  - ***Hyperion reporting nominal conditions***
  - ***Integrated Thermal Math Model DOES NOT agree with Flight Results***
    - *HEA/CEA warmer than predicted*
- ***Atmospheric Corrector***
  - ***AC/LEISA reporting nominal conditions***
  - ***Integrated Thermal Math Model agrees with Flight Results***

More Details will be Presented in Final Thermal Report

Nadir Deck 5°C Warmer (at Sensor Near Bay 6 Below HEA/CEA Boxes) than Predicted



DCE Thermal Analysis vs. Flight Results (Nominal)



Key to Success

- ***Passive Thermal Design Philosophy – Keep it Simple***
  - ***Radiators, Heaters, Louvers***
- ***Power Dissipations***
  - ***Obtain accurate and measured values***
- ***Set and Verify Requirements***
  - ***Thermal Interfaces (Coupled or Isolated)***
- ***Maintain Visibility***
  - ***Make regular inspections during I&T to Verify Thermal Design***
- ***Thermal Analysis***
  - ***Verify Integrated Models (Instruments, Technologies,etc)***
  - ***Sufficient Detail (Articulating Solar Array, Louver, Coatings)***
- ***Thermal Coating Properties***
  - ***Measure and maintain cleanliness***

Key to Success

- ***Thermal Balance Testing***
  - ***Identify Test Heaters and Include Margin***
  - ***Identify Thermal Limits***
  - ***Generate Thermal Model of Test Setup***
  - ***Verify Thermal Math Model***

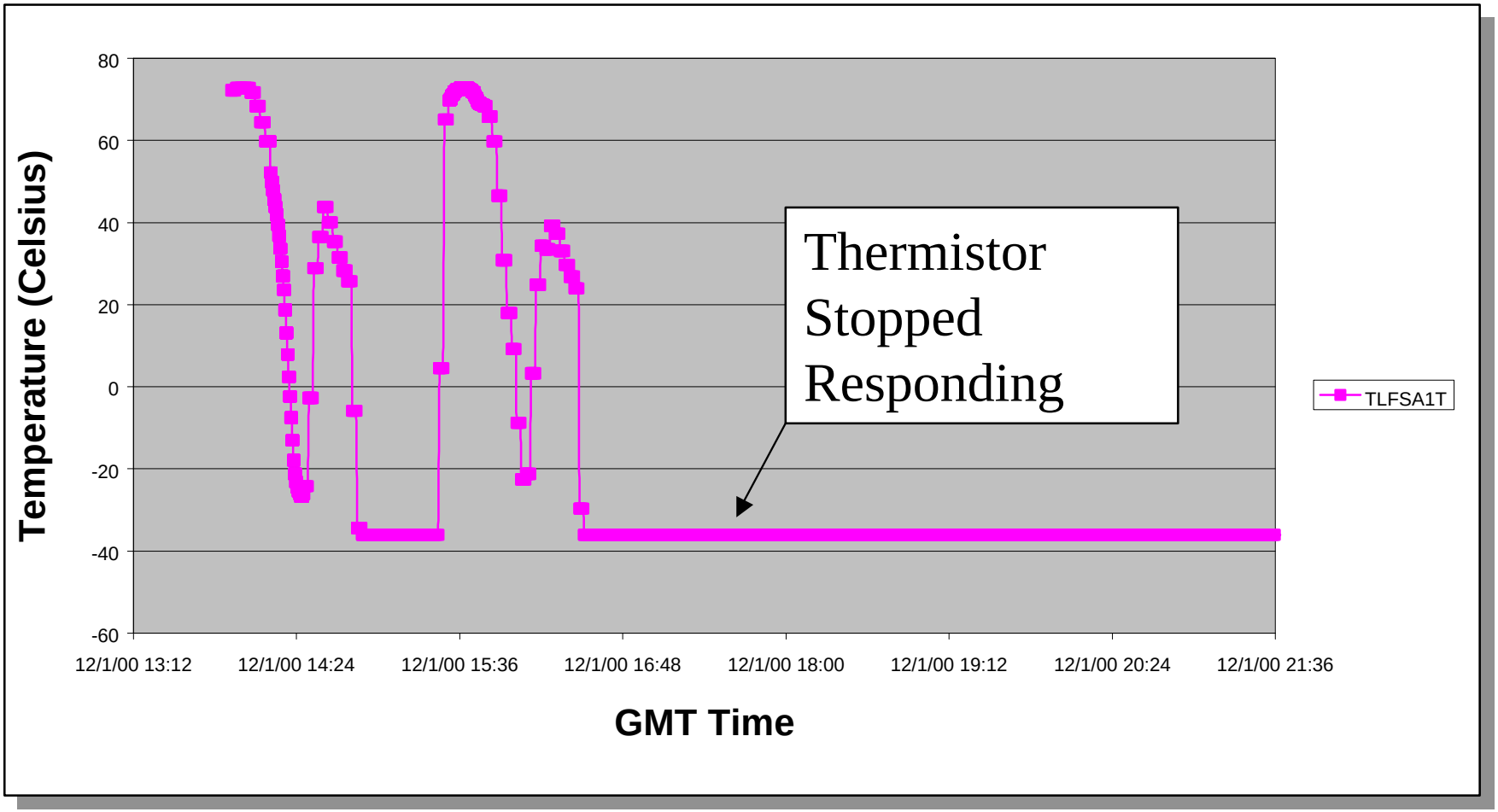
Lessons Learned

- ***Aeroglaze A276 Solar Degradation***
  - ***Solar Absorptance degrades > 0.40***
- ***Integrate Battery Cooling into Equipment Panel Mechanical/Thermal Design***
  - ***I&T for NiCd Battery requires substantial cooling***
    - *Chiller Plate + A/C Air required for EO-1*
- ***Silver Teflon Radiator Areas***
  - ***Radiators can get damaged during I&T without having protective covering***
  - ***Proper Application of AgTe needed – Special Training Required***
  - ***Identify purge lines & harness routing to avoid blockage of Radiator Areas***
- ***Box Level Thermal Vacuum Testing***
  - ***Test Early and Document Results***
  - ***Thermal Cycling vs. Thermal Vacuum Testing at Box Level***
    - *GEVS needs to address this in more detail*
    - *5°C addition to TC vs. TV appeared to be adequate for EO-1*
    - *Saved Time and $$$ performing TC vs. TV and Box Level*

Lessons Learned

- ***Heater Circuits***
  - ***Commercial Parts vs. Flight Qualified Parts***
    - *Swales purchased commercial parts for EO-1 which saved schedule time (Flight Parts have longer lead time) and $$$ (Flight Parts are 2x Commercial Parts)*
    - *Little to No Support from GSFC on Commercial Parts – Cost engineer time to justify commercial grade parts are acceptable for mission*
  - ***Test Circuits and Set Points "Completely" Prior to TV Testing***
    - *Keep it Simple (Case in Point: Nadir Deck Anomaly)*

LFSA Thermistor: TLFSA1T



Current Status

- ***EO-1 Thermal Subsystem is Nominal !***

Spacecraft Communications

Tom Spangler
EO-1 Communication Systems, Swales Aerospace

Overview

- ***S-Band System Performing Nominally***
- ***Space Network (TDRSS)***
- ***Ground Network (GN)***
- ***Issues***
- ***Lessons Learned (EO-1 performed well)***
- ***Lessons Learned (for next Spacecraft)***

S-Band System

- ***Received first telemetry in the MOC @ 326-18:31 GMT (L+6.5 min as planned)***
- ***Sent first command from MOC @ 326-18:33 GMT***
- ***Signal levels are close to predictions (SN & GN)***
- ***Issues to date are related to operation and ground configuration***

Space Network

- ***Initial TDRSS Acquisition***
  - ***Telemetry***
  - ***Command (Forward Power ~ -116 dB)***
  - ***Tracking (2 TDRSS Satellites)***
- ***Engineering Testing of 2k, 4k, 6k, 8k, and 32k Downlink Data Rates***
- ***Coherent Operations***
- ***Non-Coherent Operations***
- ***TDRSS Support for Maneuvers and Emergency Ops***

Ground Network

- *First GN Acquisition (MGS) @ 326-18:50*
- *Ground Station Validation*
  - *SGS*
  - *AGS*
  - *WGS*
  - *MGS (SAC-C)*
  - *GGS (X-Band validation)*
- *Acquisition Time = 2 minutes*
- *Nominal Forward Power ~ -70 dB*
- *Ground Antenna Positioning*
  - *S-Band Autotrack*
  - *X-Band Autotrack*
  - *Program Track*

Issues

- *GN Tracking Data Invalid (Resolved)*
  - *GN using wrong frequency in files (800 Hz Offset)*
- *Program Track – could not achieve lock (Resolved)*
  - *Ephemeris updates not propagating to stations quickly enough*
- *Oscillation in Signal Levels during Acquisition*
  - *Artifact of GN acquisition sequence. No direct effect on S/C communications*
- *X-Band Autotrack*
  - *Steerable Phased Array conflicts with current design of GN X-Band Autotrack system. Currently under review.*

Lesson Learned

~ EO-1 Performed Well ~

- ***Comprehensive Functional Test Design***
  - ***Carrier Suppression Calibration***
  - ***Thresholds***
- ***Comm Simulations of Tumble Scenario***
  - ***Predictions prepared team for actual tumble***
  - ***Communication with network managers was practiced***
- ***New Transponder Integration & Testing (S/C at Launch Site)***
  - ***Thorough re-qualification of new box***
  - ***Complete functional and performance testing at S/C level provided detailed information for networks (I.e. thresholds, carrier suppression)***
- ***Network Compatibility Testing***
  - ***TDRSS End-to-End Testing at different phases of S/C development***
  - ***CTV Testing was crucial to the comprehensive testing of the EO-1 communication system***

Lesson Learned

~ For Next Spacecraft ~

- ***Use RF as much as possible during S/C performance testing***
- ***Need unmodulated carrier testing capability***
- ***Modulation Index needs to be considered during design of the comm electronics***
- ***RF GSE Rack Design should allow for maximum test configuration flexibility***
- ***RF GSE should have a network link to ground system to allow for automated RF GSE operation and data/settings archiving***
- ***A observatory EMI model should be tested in an anechoic chamber with antennas in designed position***
- ***BERTS testing capability should be included in RF GSE design***
- ***A back-up earth coverage X-band antenna should be added to operational design***

Command and Data Handling

Stephen Schumacher
EO-1 C&DH Lead, Swales Aerospace

Subsystem Performance

- ***Performance is Great!!***
- ***Miscellaneous Telemetry Output (TO) and Command Ingest (CI) errors attributed to ground station uplink and Operations procedure errors***
- ***Miscellaneous RTS/TSM events attributed to procedural errors***
- ***Memory Scrub functioning perfectly. Currently logging 110 M5 SEU's per day which is less than expected. No SEU's seen in RSN's which is also expected***
- ***Eight S-Band Dumps performed flawlessly***
- ***GPS over 36,000 data points analyzed less than 100 dropouts. M5 properly kept time through dropouts.***

C&DH Anomalies

- ***Unable to completely dump VR-2 due to possible corruption of last event message***
- ***Anomaly seen only once***

C&DH Configuration Changes

- *Memory Scrub rate set to 1800 to help map Sbit events to SAA*
- *C&DH LVPC set from Launch mode to nominal flight mode*
- *Discussion continuing to change DS filter table to high rate storage*

Database and Limit Changes

- ***DBCR 262 submitted to remove all Solar Array deployment start and enable commands. All deployment halt commands left intact.***
- ***Requested Yellow high limit of 1 put on Software Bus overrun counter***

Lessons Learned

- ***Involve Flight Operations team early. Training since box level testing yielded a very competent Flight Ops team.***

Flight Software

Gary Smith
EO-1 Lead FSW Engineer, Litton

EO-1 FSW Computer Software Configuration Item (CSCI's)

HW component	SW component	Function
Attitude Control and Data System (ACDS)	Command and Data Handling System (C&DH)	Commands and telemetry processing, bus controller
	Attitude Control System (ACS)	Attitude determination and control, SA control, guidance and navigation
	Communications (COMM) RSN	S - Band Command and telemetry interfaces to transmitters and receivers
	Xband Communication RSN	X – Band Command and telemetry interfaces to transmitters and receivers
	Housekeeping (HK) RSN	Telemetry collection and formatting, pulse command routing, GPS interface
	Attitude Control Electronics (ACE) RSN	Accept and process data from ACE, Safehold processing
Power Systems Electronics (PSE)	Power Systems Electronics (PSE) RSN	Battery charging control, telemetry formatting, Power distribution

Primary C&DH Software Functions

- ***Health and Safety Monitoring***
- ***Telemetry Output***
- ***Time Code Management***
- ***Command processing***
- ***Memory management***
- ***Data Storage***
- ***Telemetry Statistics Monitoring***

Health and Safety Monitoring

- ***Critical Task Execution Monitoring***
  - ***All 15 tasks (including ACS & EFF) in the M5 processor have performed as designed with no event messages or warm restarts caused by either critical or non critical tasks not reporting in to health and safety on a timely basis***
- ***Event Monitoring***
  - ***All Spacecraft events are being sent to the ground in real-time and are being stored in the solid state recorder events buffer.***
  - ***Only one event message appears to have been corrupted in the SSR events buffer. The corrupt event packet caused an event message to be generated during the playback of the event buffer.***
- ***Housekeeping Telemetry collection***
  - ***All housekeeping data is being sent to the ground in real-time and is being stored in the solid state recorder as engineering data with no unexplained anomalous behavior***
- ***Processor restart handling and reporting***
  - ***No restarts have occurred in the main onboard computer during the 30 day checkout period***

Telemetry Output

- *Write Housekeeping telemetry to the SSR via the 1773 bus*
- *Telemetry volume reduction by filter application*
- *Dump HK telemetry in real time and playback mode at all allowable rates*
  - *1 Mbps*
  - *2 Mbps*
  - *32 kbps*
  - *2 kbps*
- *All housekeeping data is being sent to the ground in real-time & also is being stored in the solid state recorder as engineering data as designed. To date there has been no unexplained anomalous behavior in the C&DH telemetry output S/W. All of the ground passes at the various telemetry downlink rates has performed nominally. The first S/C contact after launch was at the 2 Kbps contact with TDRSS. The 2 kbps downlink requires the lower filter table for reducing the amount of real-time data to the ground. All of the TDRSS passes that have had good ground contacts experienced no telemetry dropouts or loss of data caused by flight software.*

Time Code Management

- ***Maintain and distribute time sufficient***
  - ***Time Code management on the EO-1 S/C has consistently distributed time to all the critical processes with no known disturbances in the system***
- ***Provide sufficient timekeeping to support technologies***
  - ***Time Code management on the EO-1 S/C all Data Capture events, stored command sequences, and ground contacts that are time driven events has occurred exactly as scheduled***
- ***Provide sufficient timekeeping to support attitude determination and control***
  - ***Time Management was performed by the M5 processor using internal time propagation for Attitude Control and all other critical processes until day 4 with no adverse impacts experienced. Comparison with ground system receipt of the time correlation packet indicated that the difference between ground time and S/C time was about ¾ of a second.***
  - ***Time Management has been performed using GPS receiver time for Attitude Control and all other critical processes since day 4 with no adverse impacts experienced***

Command Processing

- *Process commands for execution aboard the observatory*
- *Provide sufficient commanding to support validation the technologies*
- *Provide real-time command ingest and execution*
- *Provide stored command capability*
- *Real time commands*
  - *All real time ground commands that have been sent to the S/C that have been validate by the command ingest has been routed to the intended destination and executed as expected. Command with code block errors that have been attributed to the ground command link drop outs have been rejected by the command ingest appropriate event messages and error indicators have been sent to the ground..*
  - *All 1773 Bus Controller commands to the remote terminals has been routed to the intended destination and executed as expected. To date there has been no unexpected 1773 bus errors or retries.*

Stored Command Processing

- ***Absolute time command sequence (ATCS)***
  - ***Absolute Time Sequences are loaded and executed on a daily basis and are used to provide scheduling of all EO-1 S/C Data Capture events, stored command sequences, and ground contacts that are time driven events has occurred exactly as mission planners scheduled them to occur.***
- ***Relative time command sequence (RTCS)***
  - ***Relative Time Sequences that are loaded into EEPROM and used for S/C safety management have performed as designed. The RTSs that are used by the flight Operations team to configure the S/C for ground passes have executed as expected with no known anomalous behavior. Data capture events, stored command sequences, and ground contacts that are time driven events has occurred exactly as mission planners have scheduled them to occur. One occurrence of RTS usage led to a spacecraft emergency caused by an RTS needed for Hyperion safing that was not enabled for use before it was called to be executed. This process is in conflict with the design of the RTS system and the S/W performed as designed.***

Memory Management

- ***Memory Loads/ Dumps***
  - ***To date there has been no need for performing memory loads or dumps since launch***
- ***Table Loads/ Dumps***
  - ***ACS team regularly uses table loads for optimizing the attitude control parameters of the EO-1 spacecraft. When a table is loaded it is dumped to the ground to validate that it has been received correctly by the S/C before it is committed for onboard use. To date there has been no problems identified with the memory management s/w during the on orbit checkout.***

Data Storage In Solid State Recorder

- ***Command and Control***
  - ***All Data storage features has worked as designed with no unexplained anomalous behavior in the commanding and control of the data storage subsystem. The filter tables are routinely changed as part of daily operations. The close dataset, playback dataset, and release dataset commands are working as designed.***
- ***Virtual Record Storage***
  - ***All engineering data and spacecraft events are being stored in the solid state recorder as designed***
- ***Virtual Record Playback***
  - ***The FOT team is consistently able to playback and dump the stored data down to the ground during the scheduled ground passes. There has only been one anomalous incident seen with the playback of the stored data. The investigation of this anomoly identified that the problem is a ground procedure error.***

Anomaly Management

- ***Single-bit errors in memory***
  - ***There has been over 2000 single bit errors detected in the recorder memory and over two hundred detected in the processor memory to data with no adverse impact on system performance***
- ***Multi-bit errors in memory***
  - ***No multi-bit errors has been detected***
- ***Memory Checksum Failures***
  - ***No Memory Checksum Failures been detected in any of the processors***
- ***On-board event logging***
  - ***All events that are being generated are being stored in the event buffer as designed***
- ***Event notification via telemetry***
  - ***All events generated are being sent to the ground and seen as real time telemetry when the S/C is in ground contact***

Telemetry and Statistics Monitoring

- ***Telemetry Collection And Monitoring***
  - ***All required telemetry data is being routed to the TSM task as designed and is being monitored for significant events***
- ***Corrective Action Response***
  - ***TSM task has responded as designed in response to occurrence of spacecraft events as required. To date there has been no anomalous behavior in the TSM processing.***

PSE RSN Software

- ***Housekeeping Telemetry collection***
  - ***All housekeeping data is being sent to the ground in real-time and also is being stored in the solid state recorder as engineering data. To date there has been no unexplained anomalous behavior in the PSE RSN software.***
- ***Command Processing***
  - ***All command to the PSE RSN has been received and executed correctly. To date there has been no commands being rejected by the PSE RSN and the error counters are indicating that no command errors has been experienced.***
- ***Processor Restart Handling And Reporting***
  - ***No restarts have occurred in the PSE RSN during the 30 day checkout period***
- ***Battery Charging***
  - ***PSE RSN is consistently controlling battery charging and monitoring battering state of charging***
- ***Output Module Control & Monitoring , power switching, and payload power control***
  - ***The PSE is consistently providing power to the various loads as commanded via the output modules and reporting the status in telemetry as designed***

Housekeeping RSN Software

- ***Housekeeping Telemetry collection***
  - ***All housekeeping data is being sent to the ground in real-time and also is being stored in the solid state recorder as engineering data. To date there has been no unexplained anomalous behavior in the HK RSN software.***
- ***Command Processing***
  - ***All command to the HK RSN has been received and executed correctly. To date there has been no commands being rejected by the HK RSN and the error counters are indicating no command errors has been experienced.***
- ***Processor Restart Handling And Reporting***
  - ***No restarts have occurred in the HK RSN during the 30 day checkout period***

Housekeeping RSN Software *(CONTINUED)*

- ***Launch Vehicle Separation and Deployment***
  - ***One hour into the launch the HK RSN detected separation from the launch vehicle and fired the HOPS in the primary actuators resulting in Solar Array deployment in less than three minutes***
  - ***The HK RSN correctly sent the deployment status and solar hinge deployment status to the M5 processor resulting in timely and accurate telemetry and statistic monitoring actions***
- ***LFSA Command and Telemetry Monitoring***
  - ***The following functions has been successfully demonstrated in the HKRSN with no anomalous behavior experienced:***
    - *Commanding the LFSA switches independently for variable lengths*
    - *Pulse LFSA Deploy Panels 1&2*
    - *Pulse LFSA Restraint*
    - *Start LFSA Pulse*

Housekeeping RSN Software *(CONTINUED)*

- ***GPS Data Management***
  - ***GPS receiver powered and configured for flight use on mission day 1. The GPS receiver locked on to 1 satellite within about 10 minutes to start receiving GPS time. Within about 30 minutes later the receiver had locked onto a total of 4 satellites to receive good navigation data.***
  - ***There has been one significant issue in the HK GPS data collection that results in ACS to stop using the GPS data from the HK RSN. On a predictable basis the GPS receiver will send a data pattern that will cause the HK RSN to erroneously mark valid packets as being invalid and this condition will persist long enough for the ACS to quit using GPS for attitude control. The problem is understood and operational work around has been implemented to get around the problem.***
- ***HK RSN collection of S/C Analog and discrete telemetry***
  - ***HK RSN is routinely collecting and transmitting all of the required with no anomalous behavior including:***
    - *Structural temperatures*
    - *Carbon-Carbon Radiator temperatures*
    - *Solar Array deployment status*
    - *Lightweight Flexible Solar Array status*

S-Band (Comms) RSN Software

- ***Telemetry Downlink Rates***
  - ***1 Mbps***
  - ***2 Mbps***
  - ***32 kbps***
  - ***2 kbps***
  - ***Data has been successfully downlinked at the programmed rates with no unexplained anomalous behavior***
- ***Command Processing***
  - ***All commands to the Comms RSN from both the ground and the onboard stored command processor has been received and executed correctly. To date there has been no commands being rejected by the Comms RSN and the error counters are indicating no command errors have been experienced.***

S-Band (Comms) RSN Software *(CONTINUED)*

- ***Downlinking Science Data at 2 MBPS***
  - ***The first successful image was downlinked via S-band at the 2 MBPS on mission day 4***
- ***Housekeeping Telemetry Collection***
  - ***All housekeeping data is being sent to the ground in real-time and also is being stored in the solid state recorder as engineering data. To date there has been no unexplained anomalous behavior in the Comms RSN software***
- ***Processor Restart Handling And Reporting***
  - ***No restarts have occurred in the Comms RSN during the 30 day checkout period***

Lessons Learned (some Motherhood)

- ***Requirements Definition***
  - ***The software development process is significantly more productive when starting with firm well defined requirements***
- ***Independent Verification & Validation (IV&V)***
  - ***IV&V should be involved in the development cycle starting with requirements definition to the final stages of testing. IV&V should help verify the testability of all requirements***
- ***Test Facility***
  - ***Having fully functional test capability outside of flight hardware integration environment significantly reduces troubleshooting and problem resolution time***
- ***Requirements to Test Traceability***
  - ***The requirements to test traceability should be made a part of the development plan and implemented in the early stages of the development cycle***
- ***Code Reviews***
  - ***Code reviews of all of the flight software should be made a part of the scheduling and budgeting process***

Management Wrap-Up

Michael J. Cully
EO-1 Program Manager, Swales Aerospace

Spacecraft Bus Risk Matrix

Risk Description	Risk Mitigation	Potential Impacts	Risk Rating	Key Milestones
MIDEX C&DH S/W Deliverables. MAP C&DH Build 1 slipped from April to July 1997. Build 2 slipped from 9/30 to 11/6/97. Subsequent slip to 12/1 affects EO-1 S/W schedule.	EO-1 S/W team co-located with MAP developers. EO-1 developers supporting MAP C&DH S/W as part of Space Act agreement. MAP Build 1 rec'd July 97; 12 of 15 modules modified for EO-1 & running on EO-1 breadboard.	Cost & Schedule	Retired	See deliverable list
The ACDS box design, fabrication & test schedule is aggressive. Schedule slips in MIDEX ETU development & test have resulted in EO-1 moving forward with designs prior to ETU design finalization.	EO-1 ACDS based on MIDEX core designs. EO-1 flt boards may have to be modified late based on MIDEX ETU test results. EO-1 designers working closely w/ MIDEX/MAP counterparts in support of ETU & breadboard design/test.	Cost & Schedule	Retired	MIDEX ETU test completion ~~5/97~~ 9/97 EO-1 Board Fab 5/98. EO-1 Board Test 6/98. Environmental Testing 9/98
ACS component procurement was delayed while WIS-derived pointing requirements were worked. AST (Star Camera) is primary concern due to possible 15 mo. delivery schedule (vs. 10-12 mo. promise). CDR postponed; LM not ready (technical).	EO-1 has established common environmental & performance test requirements with MAP procurement. AST simulator was built for first CPT. Mass model available for S/C sine vibration. MAP is funding NRE for 1773 accommodation. Cameras already delivered to SSTI Clark, et al. Integrate to S/C late if AST not ready.	Schedule	Retired	MAP AST kickoff 4/97 EO-1 Procurement 5/97. AST continues to slip AST delivered 6/22/99
Boeing 1773 transceiver flight parts originally scheduled for Aug 97delivery continue to slip. Flight ASICs fabricated at National (del'd to Boeing 10/3) did not incorp guard band design mod to prevent output saturation.	ETU parts ordered for EO-1 ACDS, PSE & WARP boxes to permit card test prior to receipt of flt parts.	Cost & Schedule	Retired	Flight delivery ~~9/97~~ ~~11/97~~ 2/12/98 Hybrid characterization 10/15/97 New ASICs to Boeing 11/6 (done) ETUs delivered 1/6/98. All 1773 Transceiver received (Type 3)
Type 4 Integration issue currently in process at GSFC		Cost & Schedule	Retired	Delivery of PSE Trans 2/12/99 Delivery of ACDS Trans 2/18/99
GPS I/F: 12 V relay (retired), I/F osc (retired), Pwr converter box (long lead part avail), Radiation characteristics of FIFO & UART (under evaluation)	S/C Bus I&T standdown affords recovery for late delivery however S/C contingency reduced.	Cost & Schedule	Retired	GPS delivered
PSE ETU testing has resulted in significant design changes to the solar array & battery modules required for both MAP & EO-1.	EO-1 to follow MAP redesigns due to concerns re: extensive cuts/jumpers to ETU PWB design. Redesign of battery module completed by GSFC; new flight PWBs ordered for EO-1 9/29/97. S/A module redesign update on 10/3.	Schedule	Retired	S/A card PWB design 10/97
FODB experiencing delays due to low part yields.	Parallel FODB approach adopted in lieu of serial.	Schedule	Retired	FODB removed from program
Honeywell will only certify M5 at 12 MHz, which is sufficient for MIDEX/MAP C&DH/ACS S/W. A potential EO-1 risk has been identified relative to processing the backup 4Mbps S-Band downlink for science data (max MAP downlink rate is <1Mbps).	MIDEX CPU utilization conservatively estimated at 30% @ 25Mz Serial I/O from WARP is bent-pipe thru multiplexor; no impact to M5 processing	Performance	Retired	S/W-Breadboard Testing 9/97 Flight S/W Build 1 1/15/98
New Delta II 3720 Dual Payload Attach Fitting (DPAF) design has not been finalized resulting in local clearance issues & load concerns,	OLS Option for Adapter Ring. Design to higher loads than MDA recommended & use no-test factors for primary structure.	Schedule	Retired	DPAF PDR 9/97 (TBR)
WARP late delivery to S/C Bus I&T. S/W integration re-open box @ S/C I&T.	Support WARP I/F as required. Continue schedule risk mitigation by moving as much effort prior to WARP delivery Performed mechanical fitcheck of WARP to panel	Cost & Schedule	Retired	S/C Bus CDR 6/97 WARP delivered 6/25/99
Solar Array procurement	Solar array now under contract.	Cost & Schedule	Retired	SA delivered

PM Lessons Learned

- ***EO-1 Solar Array Cable Wrap Up FPPD-LL #0005***
  - *Critical external harness that are vulnerable during I&T process should be protected (I.e. temporary cover)*
  - *Include spare wiring for Solar Array Cable Wrap & any major harness runs*
  - *Minimize the use of sharp objects around the S/C*
  - *Limit the extent of test Thermal Couple and Heater termination work in the TV chamber following the test*
  - *GSE fixturing should be inspected for sharp edges that could potentially damage GSE cabling*
  - *Evaluate chamber lighting and general work conditions in the chamber prior to commencing with flight hardware work*
  - *Provide amble time for chamber operations (GSE/facility wiring, GSE blanketing)*
  - *Route spare cable wrap wires to an access location conducive*
- ***Corrective Action by Mechanical & Electrical team was Outstanding!***

PM Lessons Learned

- ***IRU (HRG) Exposure to Helium FPPD-LL #0005***
  - ***Implement a continuous purge system on the IRU at the beginning of the I&T flow***
  - ***Develop a continuous helium monitoring system (Building 7)***
  - ***Develop procedures and controls for Helium Dewar change out (Building 7)***
  - ***Do not allow unused Helium bottles or Dewars to be stored in the I&T area***
  - ***Plan in advance the helium controls during launch site activities***
- ***Following initial helium exposure at GSFC EO-1 team response was excellent! (See specific action plan)***

PM Lessons Learned (some Motherhood!)

- ***Identify Instrument final cleaning requirements early on***
  - ***Hyperion final Mirror cleaning requirement was identified at Delta Pre-Ship review. This required removing solar array at launch site. This activity could have been easily performed during Calibration Lamp inspection. This was a higher risk operation at launch site and cost several days of schedule.***
- ***Verify Launch Vehicle and Spacecraft contamination specifications***
  - ***Confusion over LV V3 requirement and Spacecraft visibly clean requirement during Flight Readiness Review***
- ***Verify critical interfaces as early in the program as possible***
  - ***EO-1 did a fairly good job of this (i.e ALI Mockup, Hyperion template, etc.)***
- ***Better document output/actions from Peer Reviews***
  - ***You will never know if you have to present this to a Red Team***
- ***Validate any heritage statements by vendors (Best commercial practice / ISO 9001)***
  - ***This caused us some heartache in the final phase of the program relative to traceability of verification matrix***

PM Lessons Learned (some Motherhood!)

- ***Review Statistics speaks for itself:***
  - ***Planned per SOW (Phase C/D/E) = 5 (L-1, PER, PSR, LRR, IOC)***
  - ***Actual (Phase C/D/E) = 21***
- ***Plan many Launch Simulations (but not in Fairing)***
  - ***It keeps everyone on their toes***
- ***Risk Mitigation plan should be dynamic and continues through out the life of the program***
  - ***Fuse Plugs for non essential services implemented late in program in response to LVPC switch short issue (Nadir Deck Heater PR)***
  - ***LFSA Interface Change***
  - ***Interpoint DC-DC Converters stiffeners added***
  - ***IRU Removal, Purge initiation and continuous helium monitoring***
  - ***1773 Ceramic sleeves replaced with phosphor bronze***
  - ***AST EMI Filter replacement for additional clearance***
- ***Provide time for FSW Code walkthroughs and do it early on***

PM Lessons Learned (some Motherhood!)

- ***Dynamic scheduling (balance between detail scheduling and top level scheduling) & excellent engineering response***
  - ***EO-1 I&T scheduling was flexible & workarounds were assessed on daily basis to address late deliveries of both hardware & software***
  - ***Addition of Hyperion late in the program is a perfect example of dynamic scheduling (Mechanical, PSE, Solar Array, FSW, Harness, GSE). Baseline program was maintained while detail design and procurement of parts was implemented in parallel.***
  - ***WARP anomaly provided significant time to perform launch simulations and other FSW testing that reduced risk***
  - ***Late change in venue and scope of Launch Site Processing was an excellent example of dynamic scheduling (Solar Array Removal, S-band Integration, Hyperion Mirror & LEISA cleaning, etc, VAFB Fires, SAC-C Fueling, etc.)***
  - ***Shipment of Spacecraft in parallel with S-band troubleshoot***
    - *S-band Simulator box allowed limited functional testing of the Spacecraft at GSFC and VAFB*

Swales Support Post Task 454 Closure

- ***Task 454 Ends Saturday 12/16/00. Following 12/16/00 all Subsystem at MOC Support will be picked up on Task TBD and will be covered up through January 31, 2001. All subsystem leads will be available on call as required. MOC should not hesitate to call if there is an issue.***
  - ***In general weekday coverage on Primary Shift for Systems, Power and ACS. All other Subsystems on call unless issues come up or special operations are required.***
  - ***Post 1/31/01 All Subsystems on call. Vehicle is TBD***
- ***Swales planning to complete Final Report on 1/31/01 for internal use and will provide to GSFC when available***

Wrap-Up

- ***The success of EO-1 was due to a team effort and tremendous dedication by all core team members***
- ***Organization Affiliation was not a barrier to getting the job done!***
  - ***Amri Hernandez-Pellerano on LVPC testing (heater short)***
  - ***Phil Luers on C&DH and A/D Conversion problem***
  - ***Vickie Moran on Power Support***
  - ***Dean Charlson on RF Support***
  - ***Swales at Litton for PSE and ACDS Testing***
  - ***Litton at Boeing for 1773 Transceivers & at LMCO for Star Tracker***
  - ***Swales at TECSTAR for Array Integration***
  - ***Swales supporting SAC-C Interface issues at Launch Site***
  - ***Everybody working Interpoint DC/DC Converter problem***
  - ***Stuart Frye on Vocals and Guitar at Launch celebration***
- ***GSFC and Swales have provided a textbook example of Government and Industry working together to provide NASA with "more science for the dollar".***