Goddard Space Flight Center

Recent GSFC Space Power Systems Flight Experience

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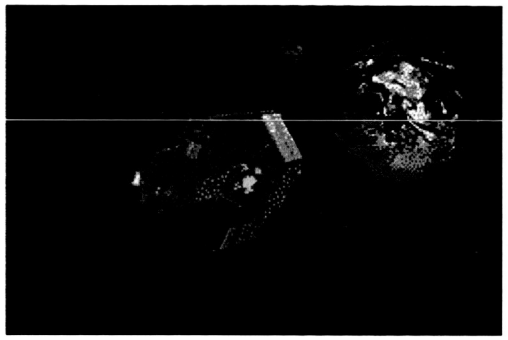
Recent GSFC Missions

- TRMM - Tropical Rainfall Measuring Mission
- LANDSAT 7
- TERRA - EOS AM
- EO1 - Earth Observing Mission
- MAP - Microwave Anisotropy Probe
- AQUA - EOS PM
- ICESAT - Ice, Cloud and Land Elevation Satellite

TRMM



- Launched Nov. 1997 from Japan's Tanegashima Space Center
  - Circular 350 Km orbit at 35 degree inclination
  - Mission Life Requirement – 3.5 years
  - Orbit Raised August 2001 to 402 Km circular orbit to extend life
- Power System Design
  - Battery Regulated Bus: 28 V +/- 7 Volts
  - Peak Power Tracker using Standard Power Regulator Unit (SPRU)
  - Designed for 1100 Watt Orbital Average Load (Actual Load 800 Watts)
- Gallium Arsenide (GaAs/Ge) Single Junction Solar Array - Tracking
  - 2 Wings – 2 panels per wing – Total Area 195 sq. ft (18.1 sq meter)
- 2 – 22 Cell 50 Ampere Hour Super Nickel Cadmium Batteries
  - Battery Temperature: 5.2 – 12.9 degrees C, Battery DOD Average 15%

TRMM In Flight Operations - Power Anomalies

- Battery 2 Cell 1 Anomaly
  - Battery 2 Cell 1 reaching 1.53 Volts during initial Charge as VT Level is reached. (It has reached 1.62 V during higher charge rates while other cells remained at 1.44 V)
  - Concern: Evolution of hydrogen gas in cell.
  - Constant Current Mode of 12 Amps/battery being used to minimize battery peak charge.
  - Battery 2 Cell 1 telemetry no longer available. Differential Voltage being monitored.
- Power System Telemetry Anomaly
  - All voltage and current telemetry has failed on A side, and most cell Voltages have failed on B side including anomalous cell
- Solar Array Drive Anomaly
  - - Y Wing SADA experienced high temperature, and began exhibiting intermittent "sticking"
  - - Y wing is parked at 0, other wing tracking

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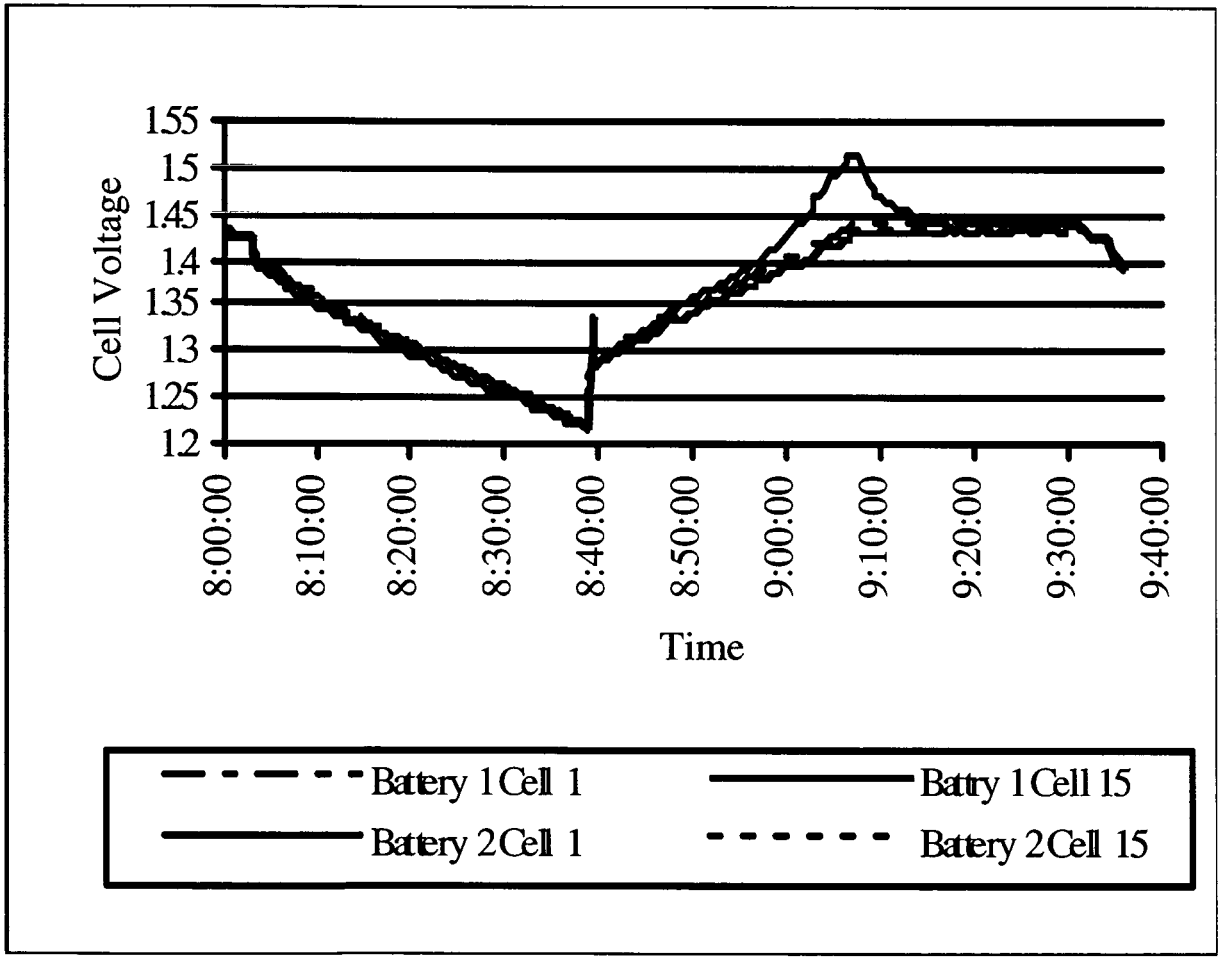
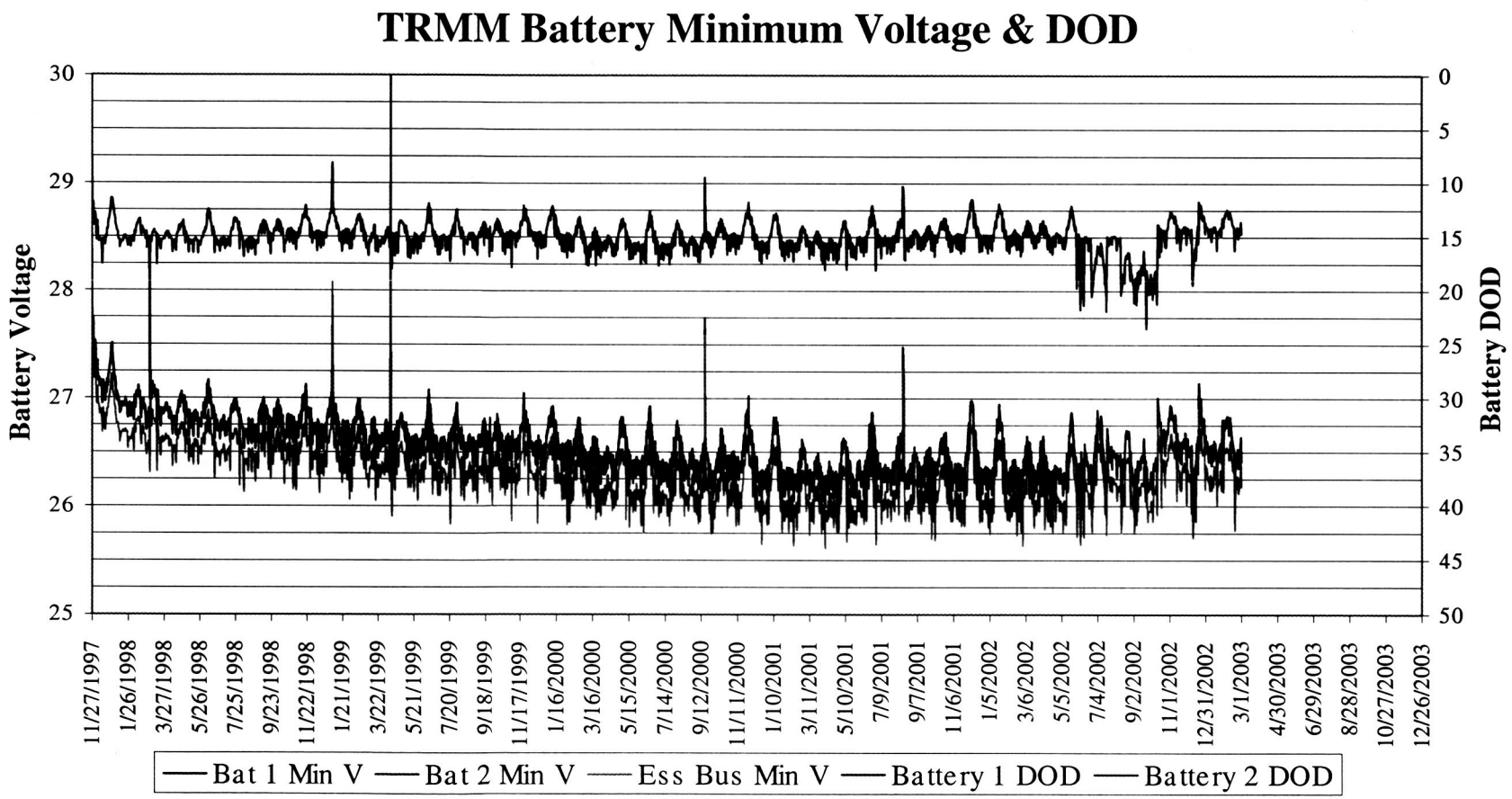
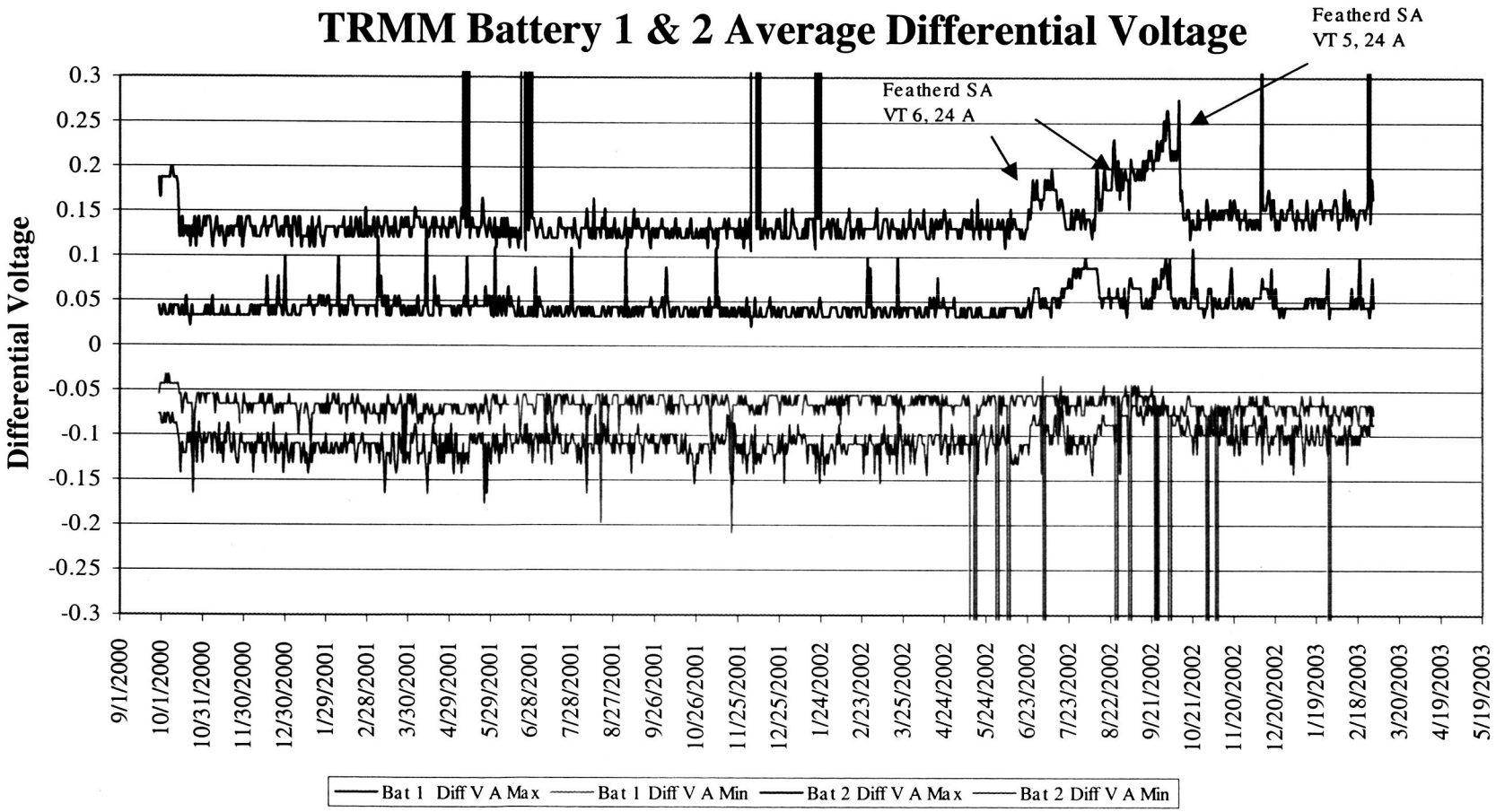
TRMM Battery 2 Cell 1 Anomaly



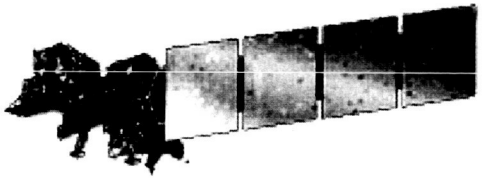
TRMM In Flight Operations



TRMM In Flight Operations



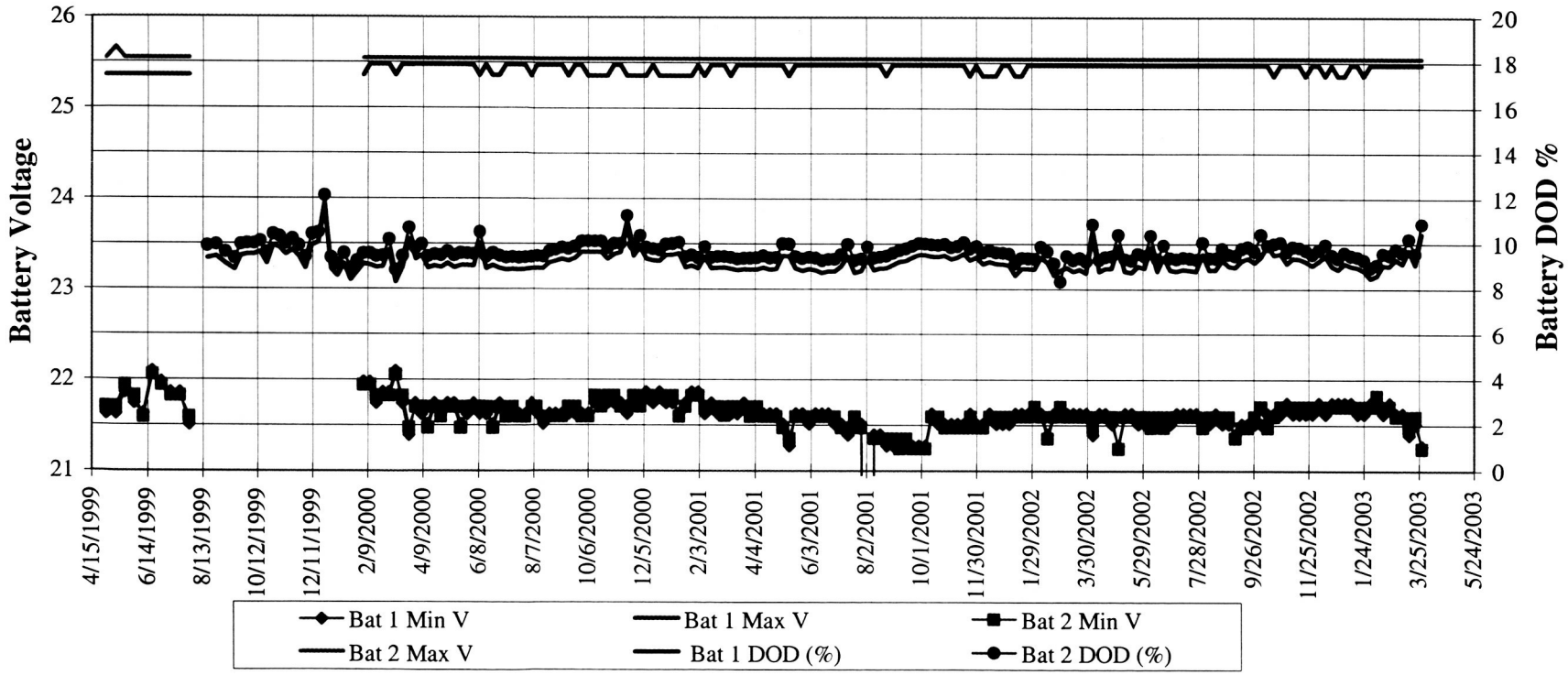
LANDSAT 7



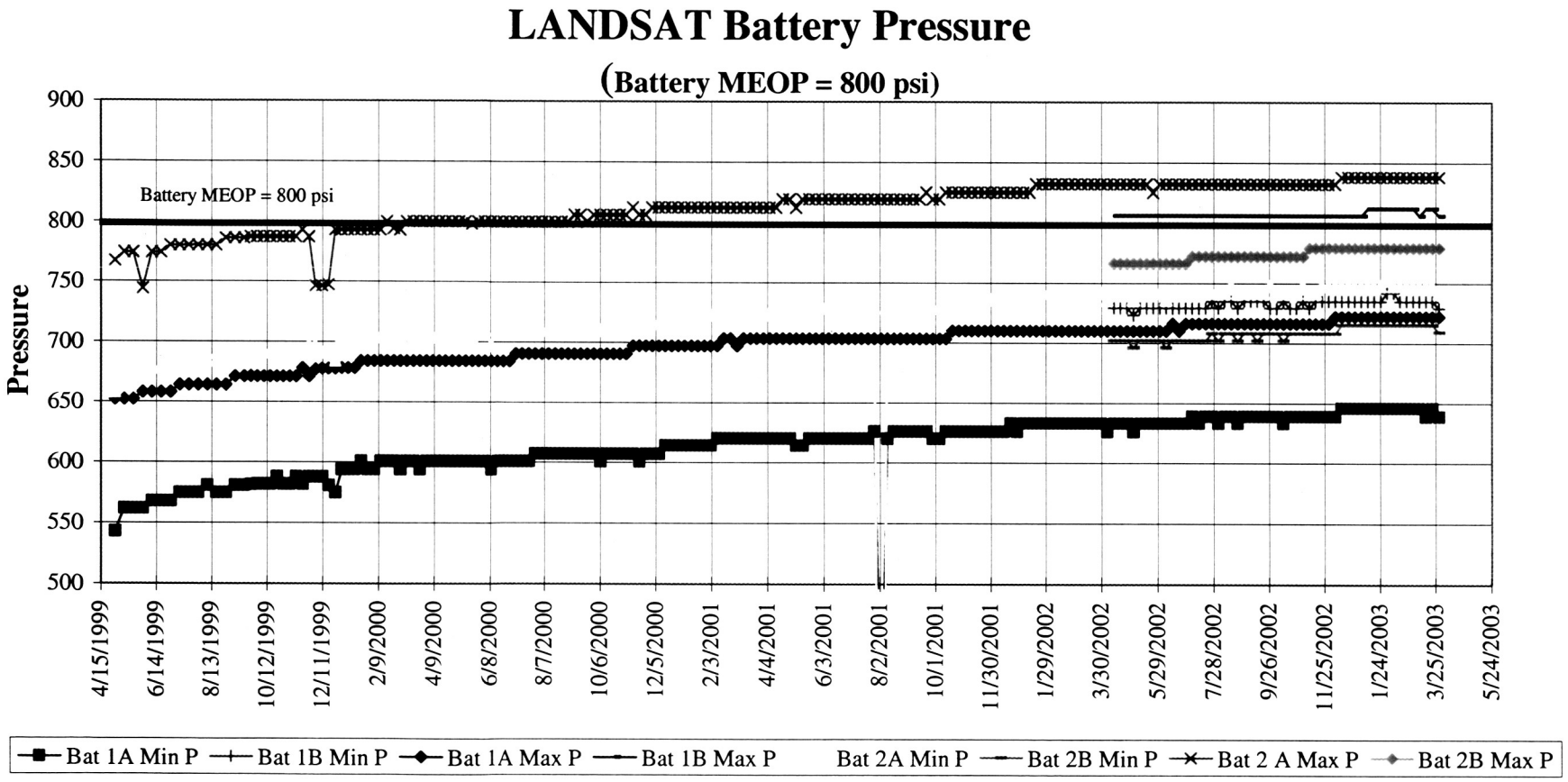
- Launched April 15, 1999 from Western Test Range at Vandenberg Air Force Base on a Delta-II Rocket
  - Orbit: 705 km sun-synchronous, 98-degree inclination
  - Mission Life Requirement – 5 years
- Joint venture between the US Geological Survey (USGS) and NASA
  - NASA responsible for development and launch
  - Flight Operations Management handed over to USGS October 2000
- Spacecraft Bus Built by Lockheed Martin Missiles and Space
- Power System Design
  - Regulated 28 Volts Direct Energy Transfer – Battery Boosted to the Bus
  - 1000 Watt Orbit Average Load (Actual 650 Watts)
- Silicon Cell Solar Array - Tracking
  - Single Wing with 4 Panels – Total Area: 183 square ft (17.1 sq meter)
- 2 - 50 Ampere Hour NiH_2 batteries
  - Two parallel stacks of 17 IPV cells (One 9 cell stack and one 8 cell stack)
  - Battery Operating Temp: 2 degrees C
  - Battery DOD 10 %

LANDSAT 7– In Flight Operations

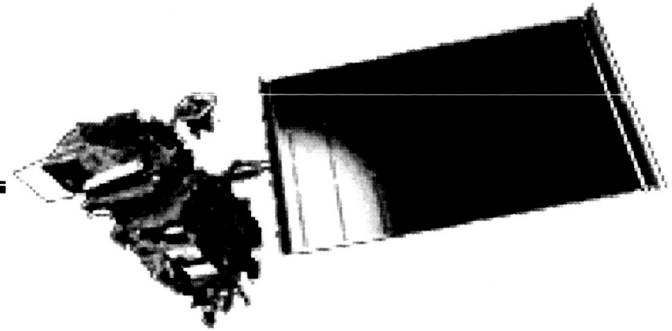
LANDSAT Battery Voltage & DOD



LANDSAT 7 – In Flight Operations



TERRA – EOS AM



- Launched Dec. 18, 1999 from Western Test Range at Vandenberg
  - Orbit: 705 Km near circular sun-synchronous, 98 degree inclination
  - Mission Life Requirements - 5 years
- Spacecraft Bus Built by Lockheed Martin Missiles and Space
- Power System
  - Regulated 120 Volts Direct Energy Transfer - Battery Boosted to the Bus
  - 2.5 KWatts Orbit average Load
- Flexible Blanket Single Wing Solar Array – single junction GaAs/Ge
  - Total Area: 482 sq ft (45 sq meter)
- 2 - 50 Ampere Hour NiH_2 IPV Batteries - 54 Cell per Battery
  - Average Battery DOD 23 %, Battery Temperature: -3 degrees C

TERRA – EOS AM – Shunt Anomaly

- Solar Array Shunt Anomaly occurred on 9/24/2000
- Loss of Power of 1circuit of Solar Array
  - 1/24 of total Array Power
- Insufficient telemetry data exists to pinpoint the exact cause of the anomaly.
- Sufficient Power Margin exists to complete mission
- To date, no other shunt failure.

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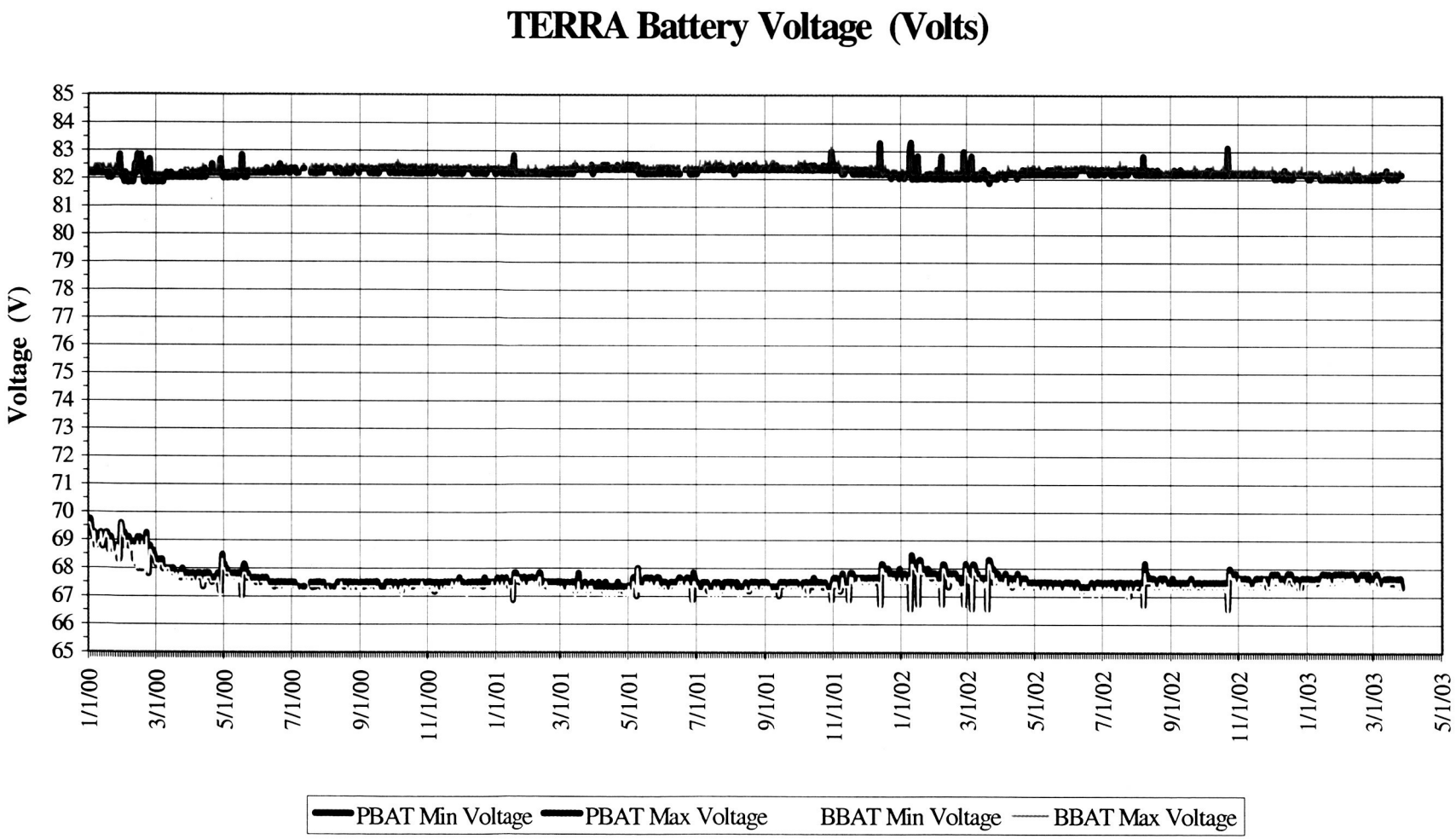
TERRA – EOS AM Battery Voltage Plot



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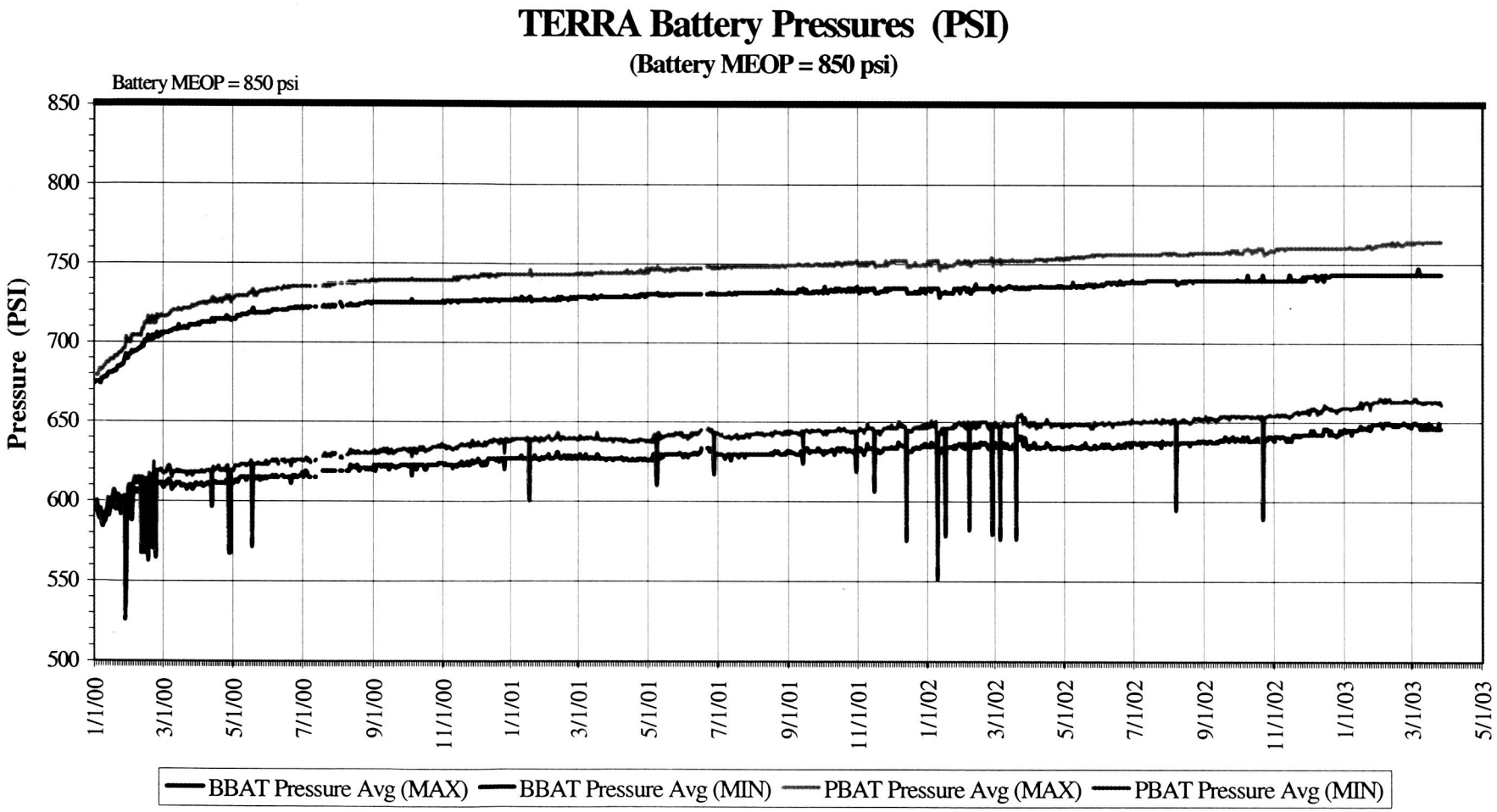
TERRA - EOS AM Battery Pressure Plot

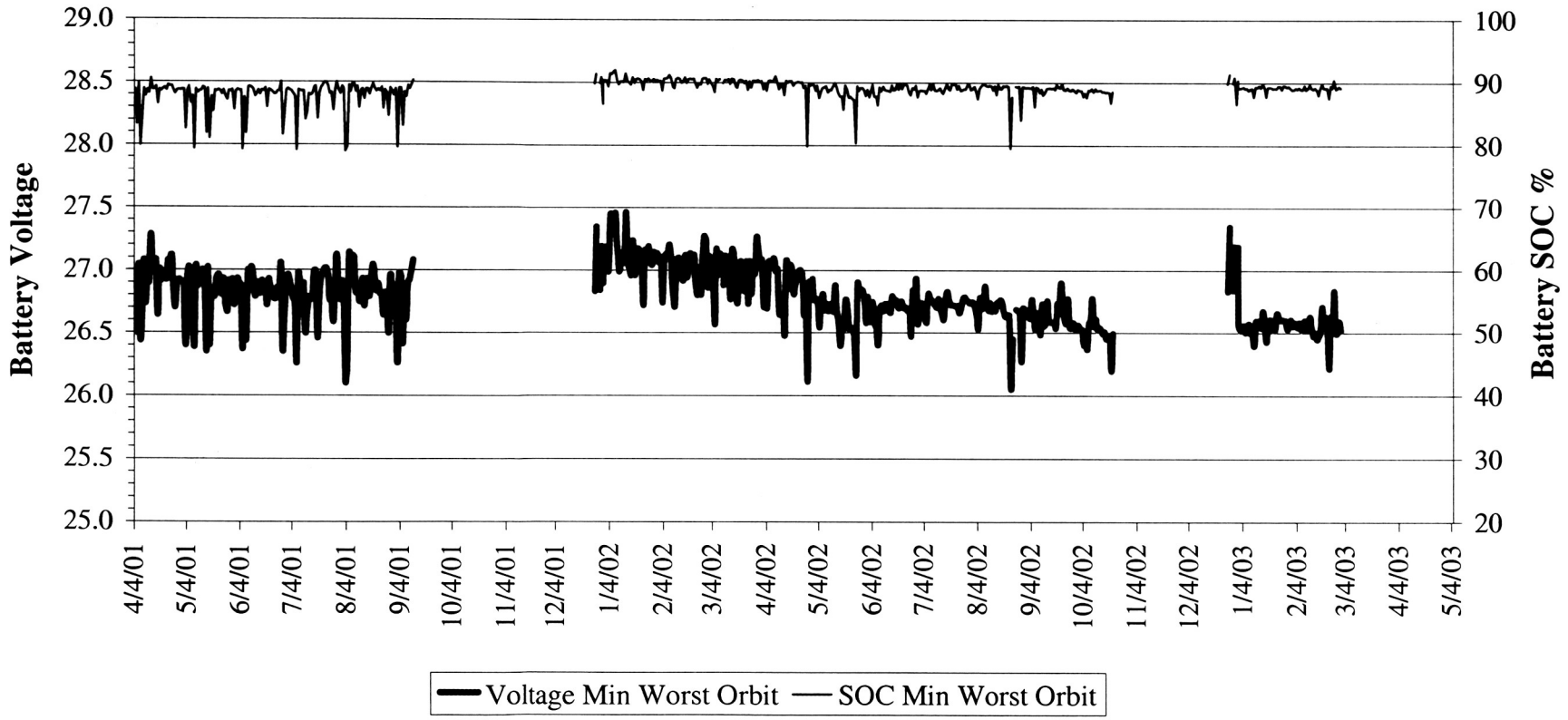


EO-1

- Launched Nov. 21, 2000 from Vandenberg AFB
  - 705 km circular, sun-synch. orbit, 98.7 deg inclination
  - Flying in formation 1 minute behind Landsat 7
  - Mission Life Requirement – 1 year
- Power System
  - Battery Regulated Direct Energy Transfer (28 V +/- 7)
  - 300 Watt Orbit Average Load
- Silicon and GaAs/Ge Solar Array – 1 Wing with 3 Panels
  - 20 Strings Si BSFR (14.8 %),
  - 4 Strings of 1st generation multijunction GaAs/Ge (22 %)
  - Total Array Area 58 sq ft (5.4 sq meter)
- 1 - 50 Ah Super Nickel Cadmium Battery with 22 cells
- Average DoD = 10 %, Peak = 17 - 22 % (Lunar Calibrations)
- Battery Temperature = 14.9 – 17.2 degrees C

EO-1 In Flight Operations

EO-1 Minimum Battery Voltage and SOC



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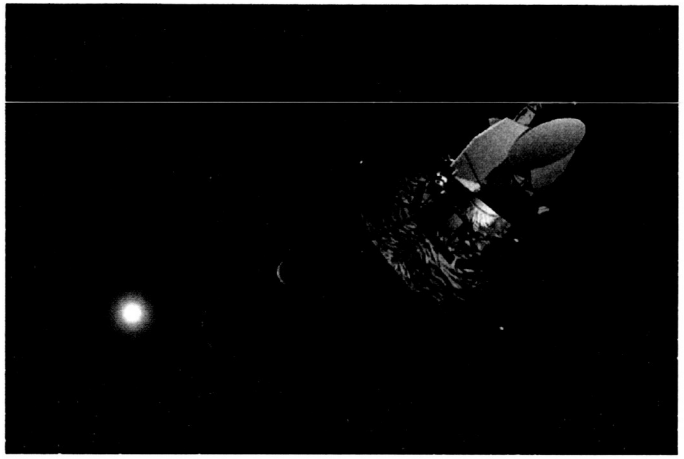
MAP



- Launched June 30, 2001 from KSC
  - Transition orbit for 3 months to L2 (Full Sun)
  - Station keeping maneuvers ~ every 3 months
- Mission Life Requirement – 2 years at L2
- Power System
  - Battery Regulated Direct Energy Transfer (28 V +/- 7 Volts)
  - 400 Watt Orbital Average at L2
- Solar Array - 6 Identical Panels
  - GaAs/Ge single Junction
  - Total Area: 36 sq ft (3.4 sq meter)
- 1 - 23 Ampere Hour NiH_2 CPV battery
  - 11 modules – 22 Cells (5 module pack and a 6 module pack)

MAP In Flight Operations – Cell Anomaly

- Cell Anomaly occurred in February 2002
  - Battery Differential Voltage began rising and on 2/24/2002 (2002/055) hit a yellow high of 0.27 V
  - Differential Voltage continued rising ~ 0.1 V/day
  - A slight rise in Battery Temperature, temperature changed from 4.7 to 5.9 C in 4 days
  - A small increase in Taper current, from 5 mA to 30 mA in 4 days
- All telemetry Indications suggested a loss of a cell, probably a short in one of the CPV module
- Lower the VT level from VT 3 to VT 0 next day to Minimize overcharge
- Present Battery Operations:
  - Battery Differential Voltage has stabilized
  - Battery Voltage is at VT 0: 29.7 V
  - Battery Temperature has stabilized to 3.0 C
  - Taper Current has stabilized to 4 mA

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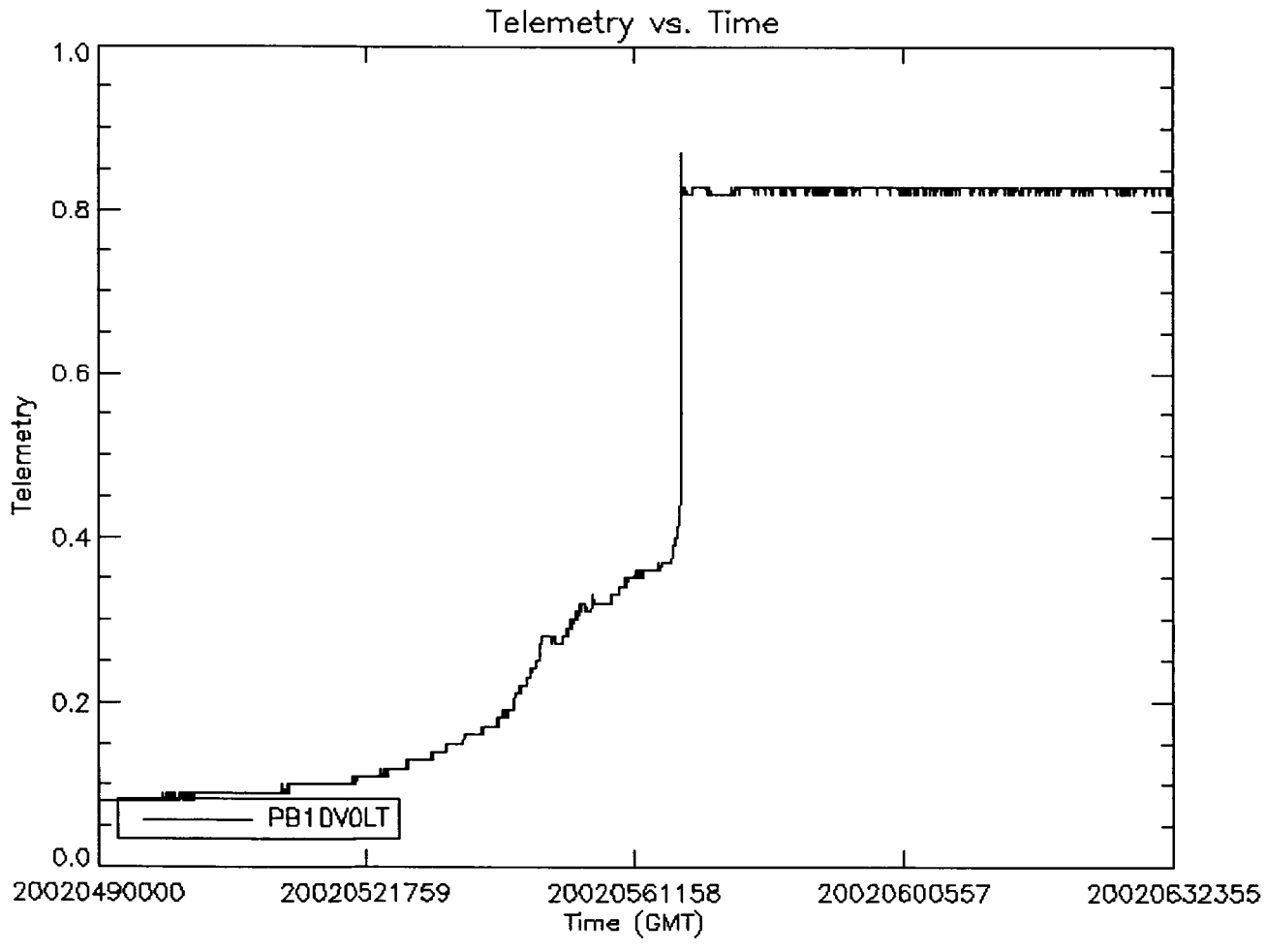
MAP Battery Cell Anomaly

Battery Differential Voltage Plot



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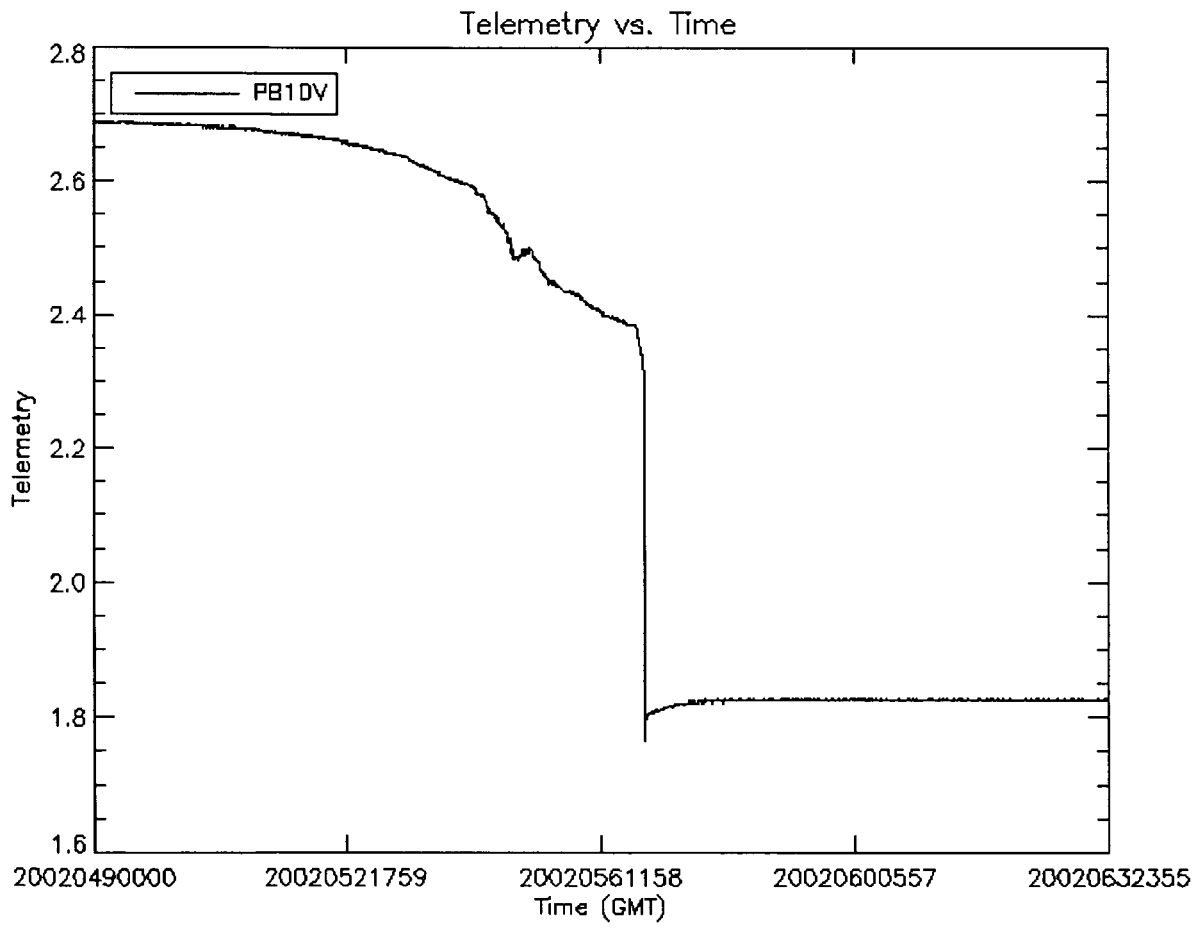
MAP Battery Cell Anomaly

Battery Differential Voltage Plot (1 CPV)



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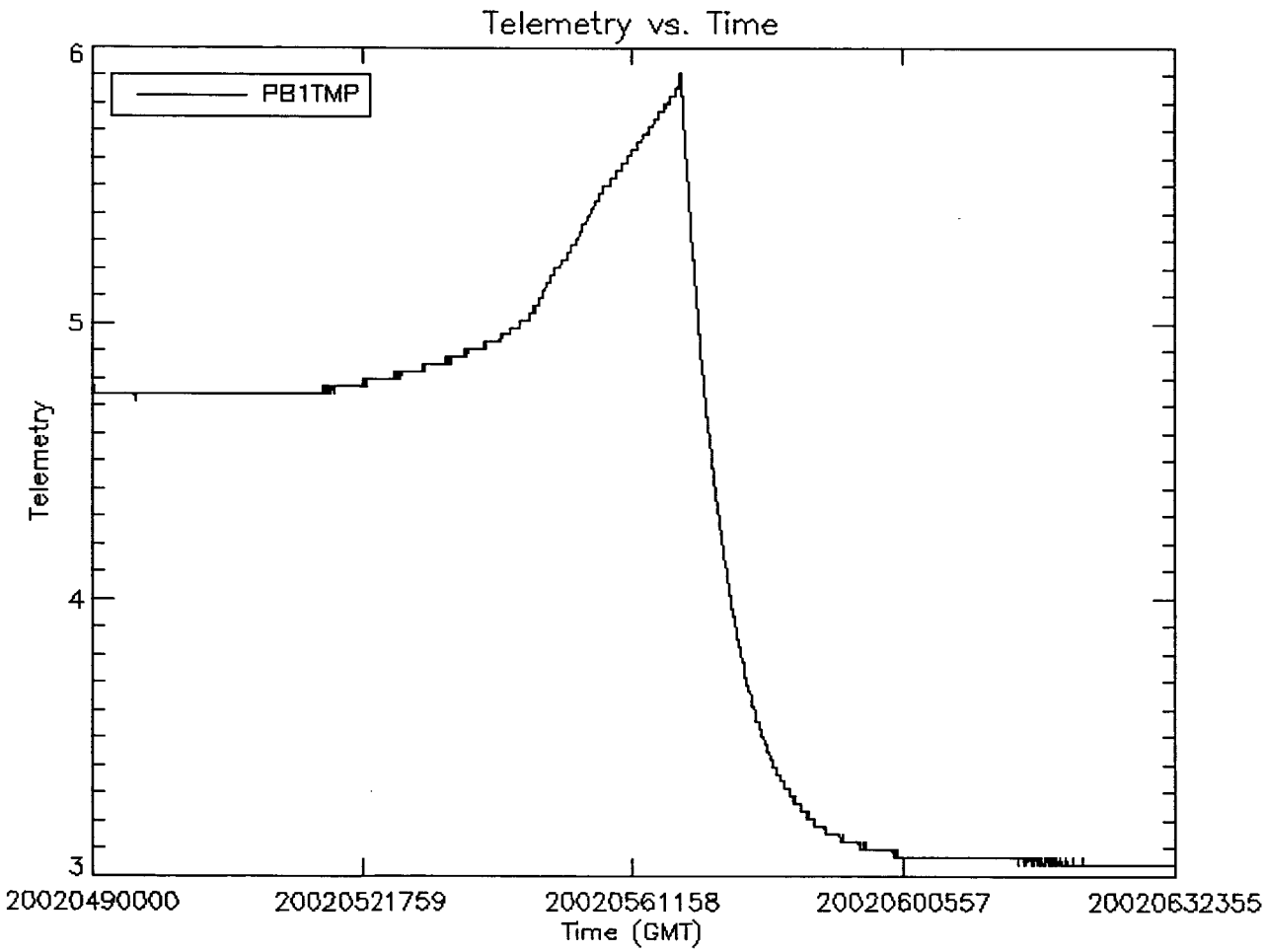
MAP Battery Cell Anomaly

Battery Temperature Plot



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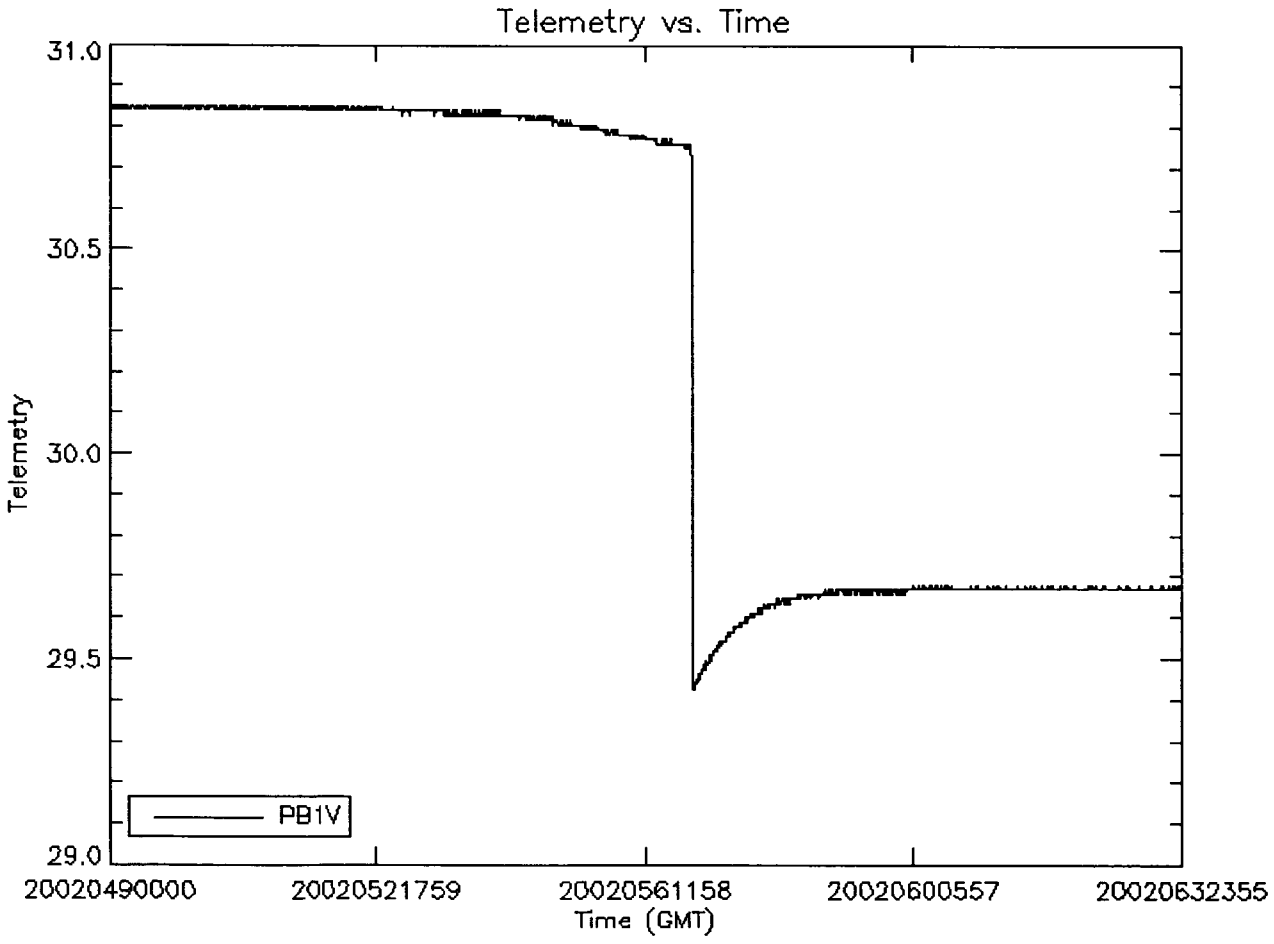
MAP Battery Cell Anomaly

Battery Voltage Plot



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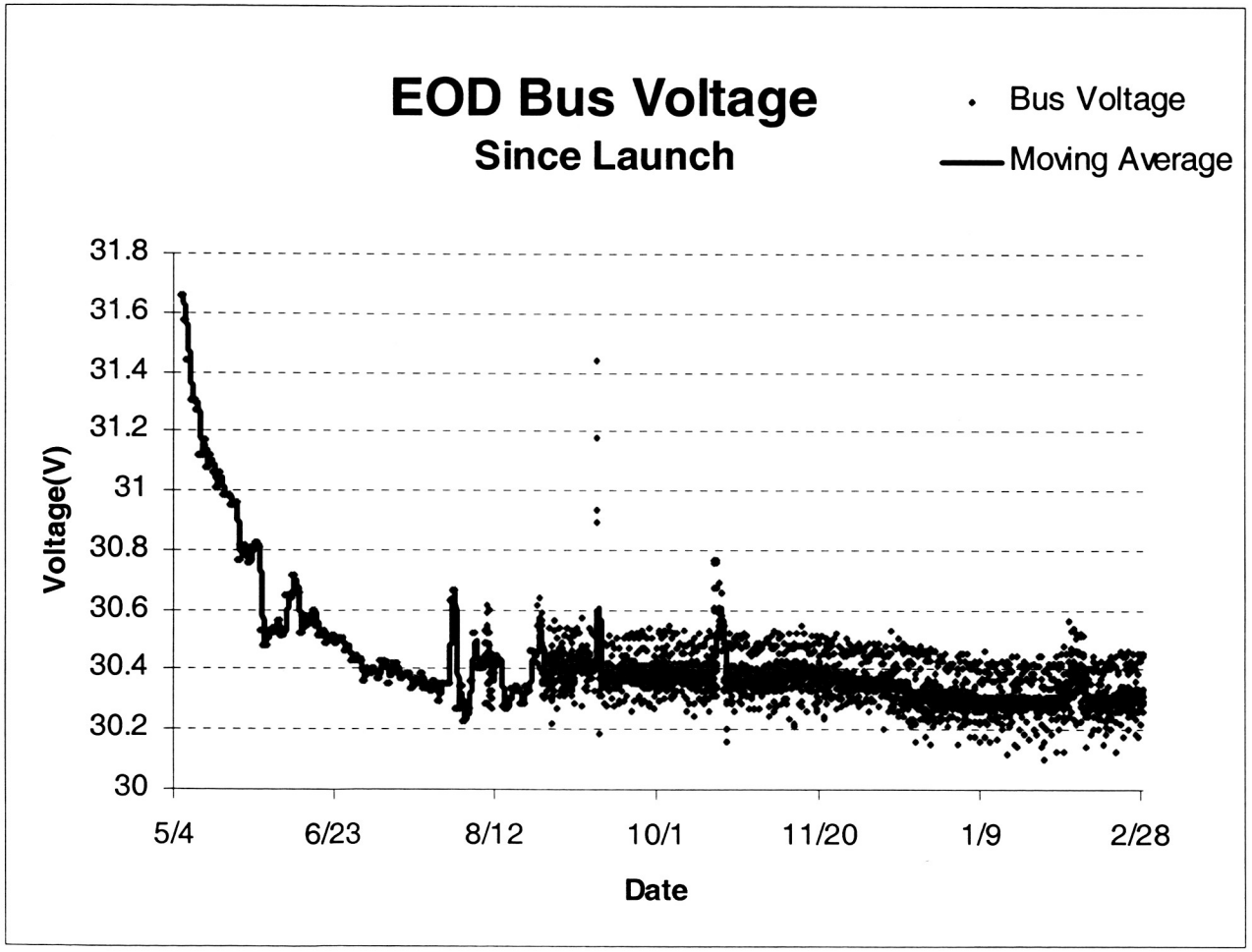
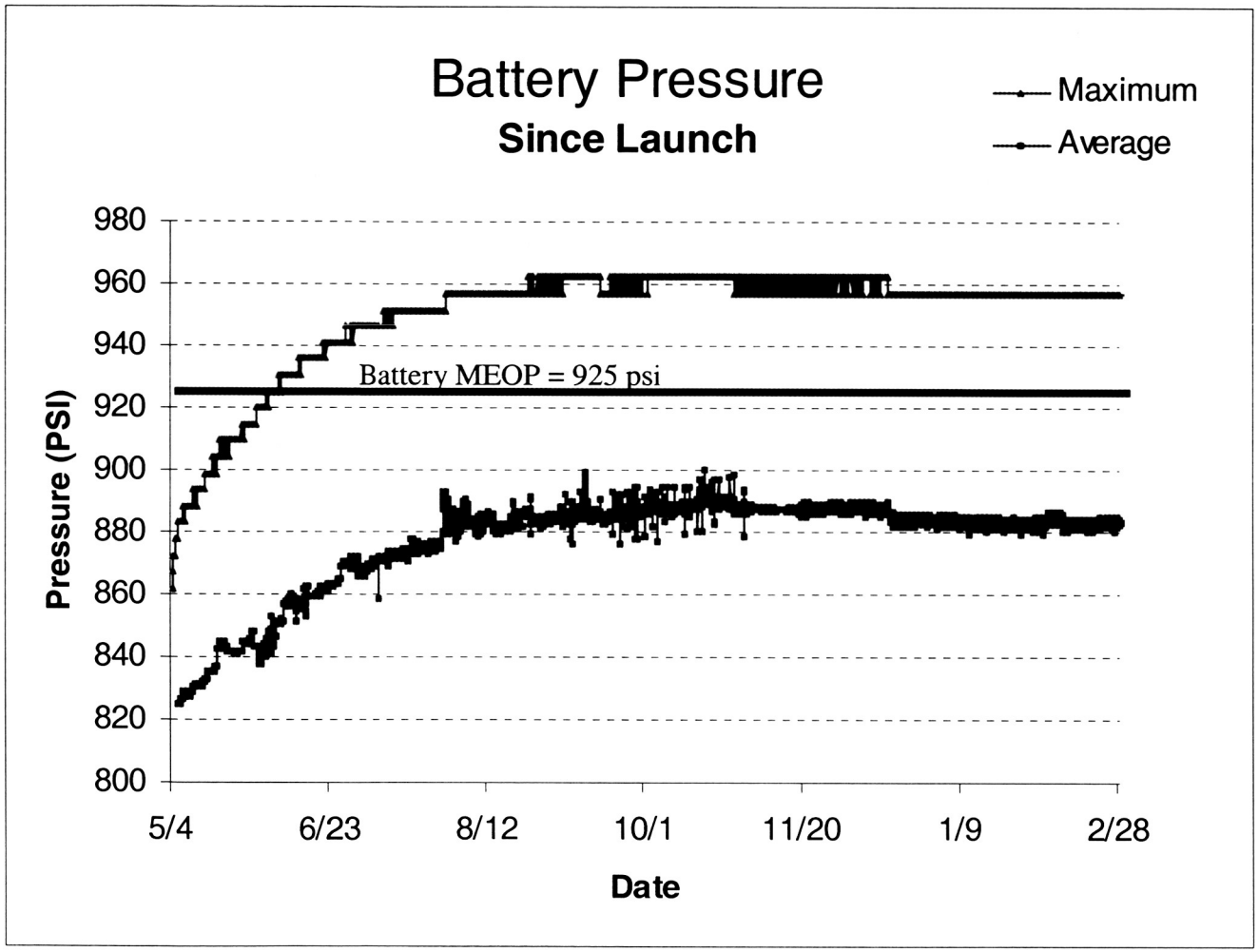
AQUA – EOS PM

- Launched May 4, 2002 from Vandenberg AFB
  - Orbit: 705 Km Polar sun-synchronous, 98 degree inclination
  - Mission Life Goal - 6 years
- Spacecraft Bus Built by TRW
- Power System
  - Battery Regulated Bus, DET
  - 1.8 KWatts Orbit average Load
- Solar Array – Silicon BSFR 14.4 % efficient cells
  - 1 Wing with 12 Panels, Total Area: 600 sq ft (55 sq meter)
- 2 Battery Module Assemblies connected in series with 12 cells each
  - 160 Ampere Hour NiH_2 IPV Cells
  - Average Battery DOD 16 %, Battery Temperature: 2 degrees C

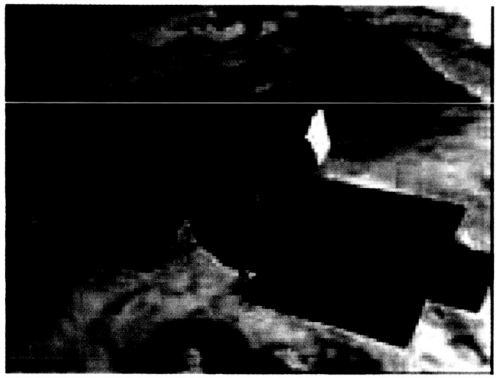
AQUA – EOS PM Battery Voltage Plot



AQUA – EOS PM Battery Pressure Plot



ICESAT



- Launched January 12, 2003
  - Orbit: 600 Km 94 degree inclination
  - Mission Life Requirement – 3 years with a goal of 5 Years
- Spacecraft provided by Ball Aerospace
  - Adapted Ball Commercial Platform 2000 (BCP 2000) spacecraft bus
- Power System supports orbit average load of 640 Watts
- Bus Voltage: 30 V +/- 4
- Dual Junction GaAs/Ge Solar Array
  - two single-axis articulated solar array wings, consisting of three winglets each.
  - Total Area: 18.3 sq ft (1.7 sq meter)
- 1 - 40 Ah NiH_2 CPV Battery
  - 11 series connected cells with one spare CPV
  - Cell bypass added