



SM4 Rendezvous SOC Profile

Based on SMIT BU10.1

March 9, 2007



SM4 Rendezvous SOC Profile

Based on SMIT BU10.1



- Overview
 - This analysis estimates the battery SOC during rendezvous/capture
 - Since the last POWG (Jan. 2006) an improvement in the battery SOC trend has been realized
 - The SOC projection that was based on the 2004 battery capacity tests suggested a system SOC of 197Ah for a SM4 date of Dec. 2007.
 - Battery capacity testing performed in 2006 indicated a positive shift in the trend
 - Present working SOC for a Sept. 2008 launch date is 255Ah
- What happened?
 - Operational changes to battery charge control
 - Change in the method for extrapolating the SOC
 - Projection considers battery pressure trends as well as capacity test results



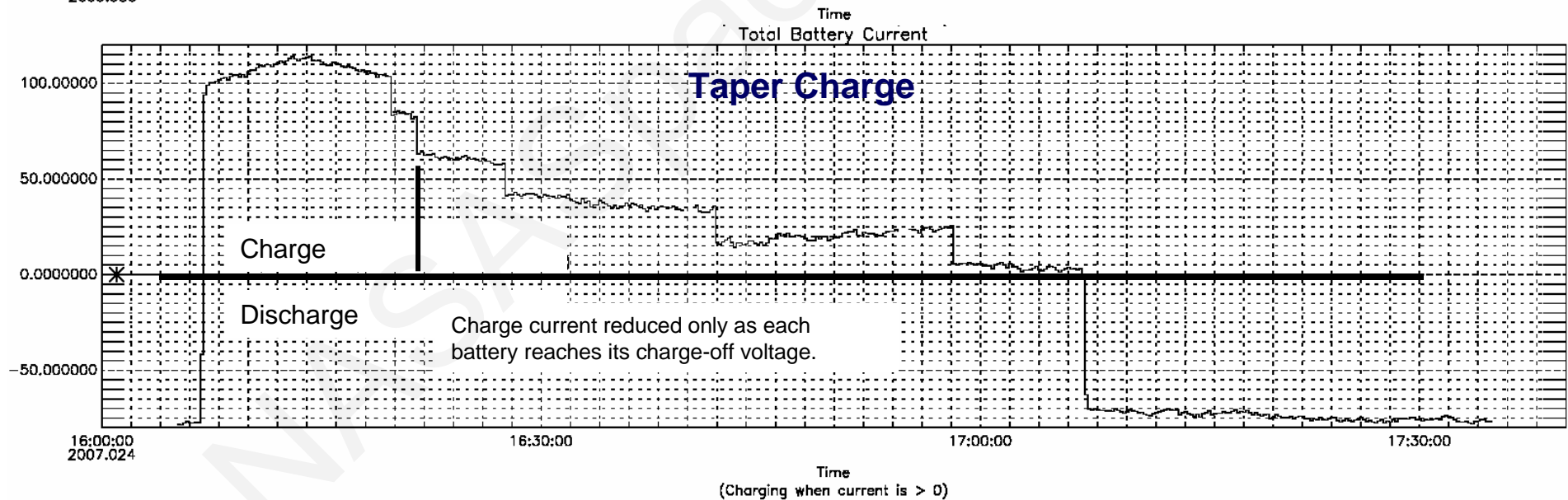
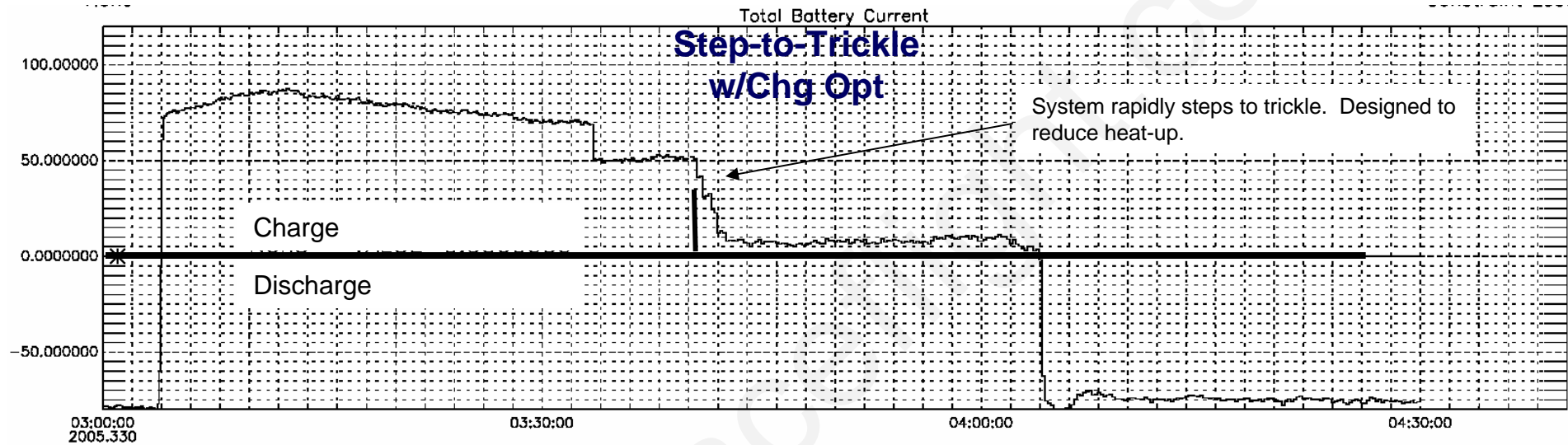
Operational Changes

Battery Charge Control

- Charge Rate Optimization added to Step-to-trickle (Oct. 2003)
 - Reduces the full charge rate to extend the time in full charge (keeps the battery charger on longer)
- New Taper Charge Scheme (Jan. 2006)
 - Relays are opened only on the battery that reaches charge-off allowing other batteries to continue charging at the highest charge rate possible vs entire system stepping to trickle charge
 - Charger stays on the entire orbit day – more energy in
 - Batteries remain at a higher terminal voltage late in orbit day.
 - Improved battery balance
 - Improved battery loadshare balance
 - Reduced and balanced battery temperatures
 - Battery operates in a more efficient temperature regime



Step-to-Trickle vs. Taper Charge





SOC Determination

SOC Determination

- Previously, the battery SOC extrapolation was based solely on the battery capacity test results and did not consider battery pressure performance
- Most recent SOC extrapolation is based on a statistical projection of present on orbit battery pressure based SOC trends.
 - Battery capacity test data is used to calibrate the pressure to SOC relationship



SOC Determination

Determine Daily SOC Using Data to DOY 353 / 2006 (most recent update)

- To compute smoothed pressure based system SOC, apply a 49-day average on the raw system SOC

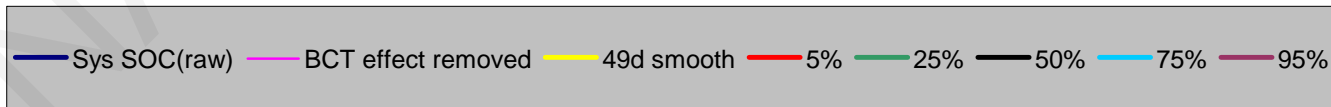
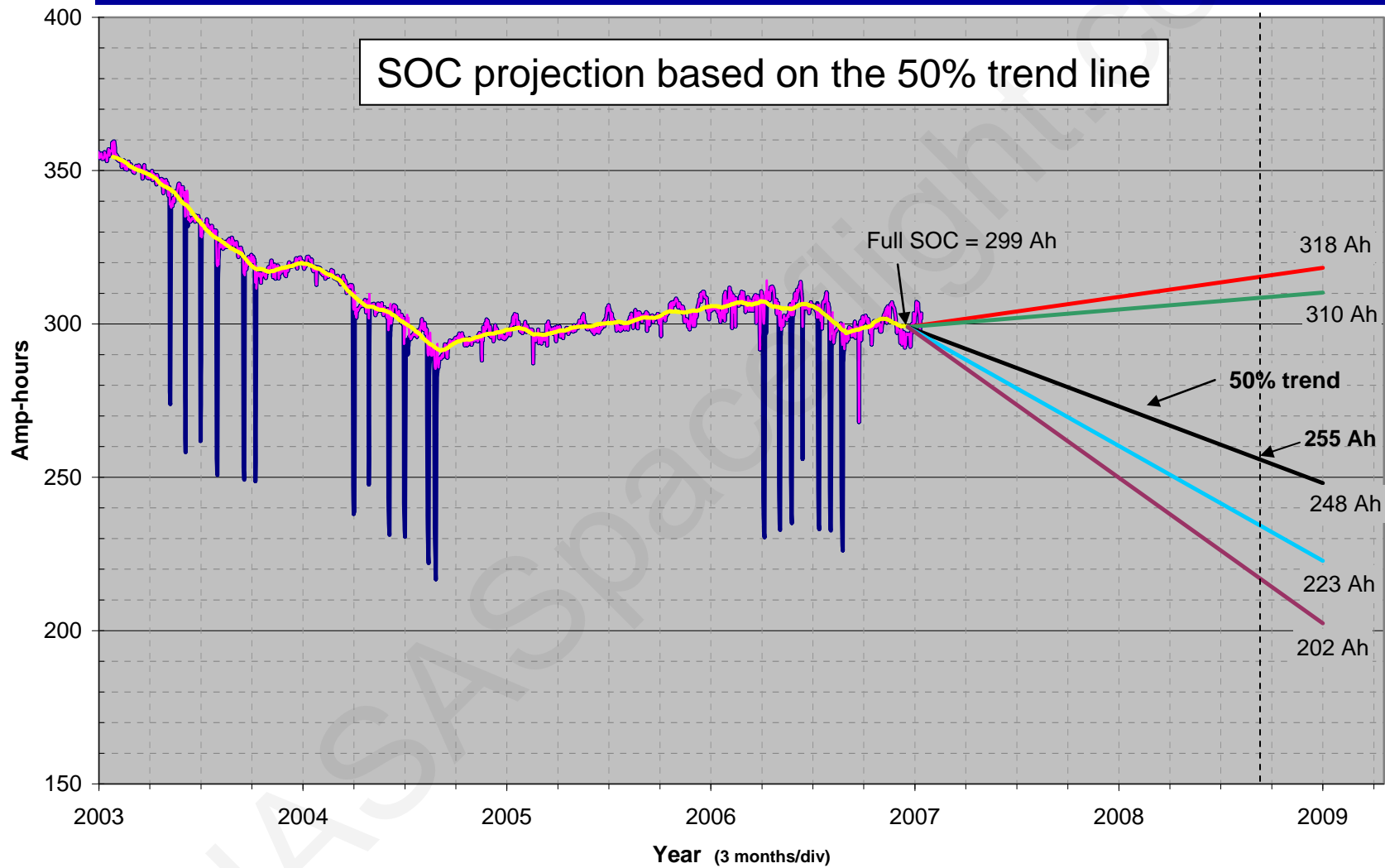
Find the Estimated Rate of Change

- Using the 49 day average from SM3B (03/08/2002) to present, find the slope of the smoothed SOC with respect to time using a regression fit for the previous one year period
- Develop a probability distribution for the change (slope) in capacity over a year.
- Extrapolation of the 50% trend line indicates a system SOC of 255Ah for the 9/11/08 launch date



SOC Trend

(DOY 353, 12/19/2006)





SM4 Rendezvous SOC Profile

Based on SMIT BU10.1



- “Get Wells” implemented since SMIT BU5 (Jan. '06 POWG):
 - Maintain all SA SPAs on-line as long as possible
 - Present string failures are assumed (2 string loss)
 - Preventing charge cut-off is no longer necessary due to SA3 cold temperature characteristics vs SA2.
 - Reassess the load and reduce where possible
 - “Safe” the Science Instruments
- Assumptions:
 - System SOC = 255Ah @ SM4 date of 9/11/08
 - Vehicle load during rendezvous = 43.4 A
 - Based on SA incidence angle = $\cos^{-1}[\cos(31)^*\cos(52 + \text{beta angle})]$
 - Best case: Beta = -52° , Roll = 0° , Sun-SA incidence = 31°
 - Worst case: Beta = $+52^\circ$, Roll = 104° , Sun-SA incidence = 101°
 - 9/11/08 case: Beta = -16° , Roll = 36° , Sun-SA incidence = 45.4°



SM4 Rendezvous SOC Profile

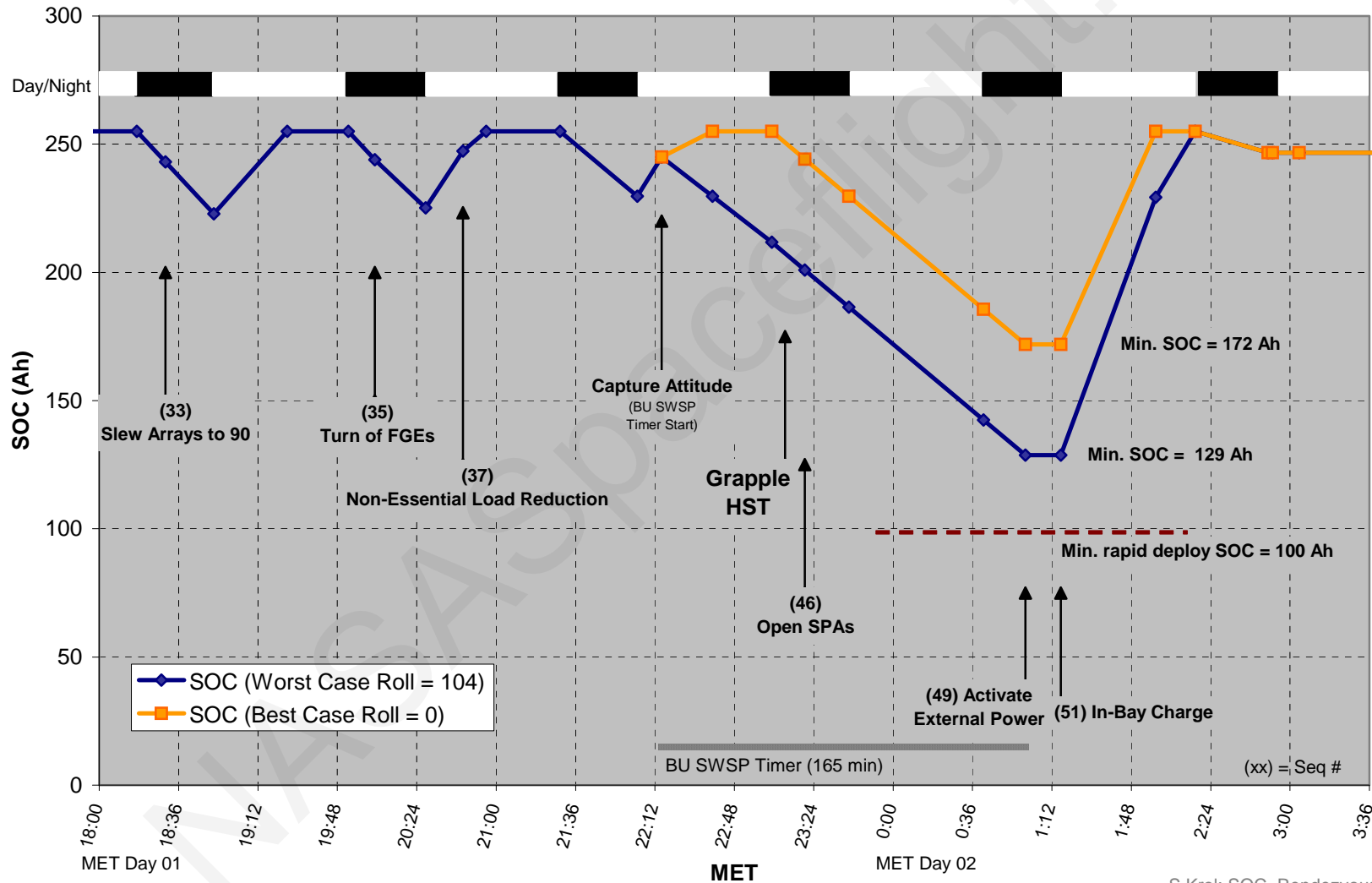
Based on SMIT BU10.1

- Minimum HWSP rapid deploy SOC is 100 Ah (from SM4 Battery Capacity Assessment, EM MOSES 1274)
 - 3 RWAs
 - 99% of the simulations required 100 Ah or less to capture the sun
- Reassessed and reduced vehicle load
 - SMIT BU5 Load was 56.8 A
 - Due to lack of SOC margin, SIs were safed in subsequent SMITs to reduce load during rendezvous
 - SMIT BU10.1 Load is 43.4 A
- DOD estimate between pre-grapple battery charge and transfer to external power has decreased since the Jan '06 POWG power profile:
 - SMIT BU5 DOD was Best case roll = 109 Ah
Worst case roll = 168 Ah
 - SMIT BU10.1 DOD is Best case roll = 83 Ah
Worst case roll = 126 Ah



SM4 Rendezvous SOC Profile

SM4 SOC Profile - Rendezvous / Capture
Based on SMIT BU 10.1, Full SOC = 255Ah





Conclusion



- The analysis shows sufficient SOC for the nominal rendezvous capture sequence. Made possible by:
 - Battery capacity test and battery pressure trends appear more favorable
 - EPS configured to maximize charging during rendezvous / capture
 - More stringent load management to reduce the depth of discharge



Backup Charts



Battery Performance Trend

Battery Temperature and Pressure Performance
Jan. '02 through Feb. '07

