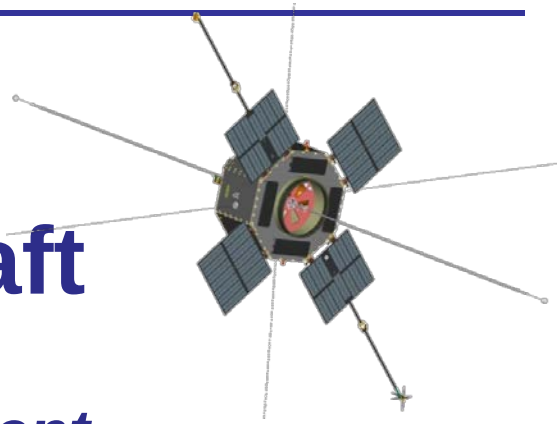
Van Allen Probes



Mission/Spacecraft

Mission status

Extended Mission Assessment

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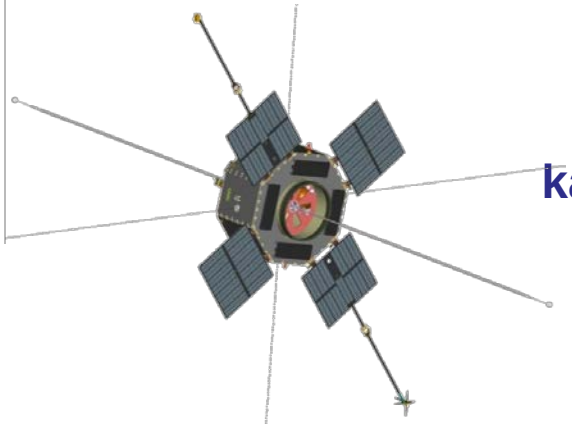
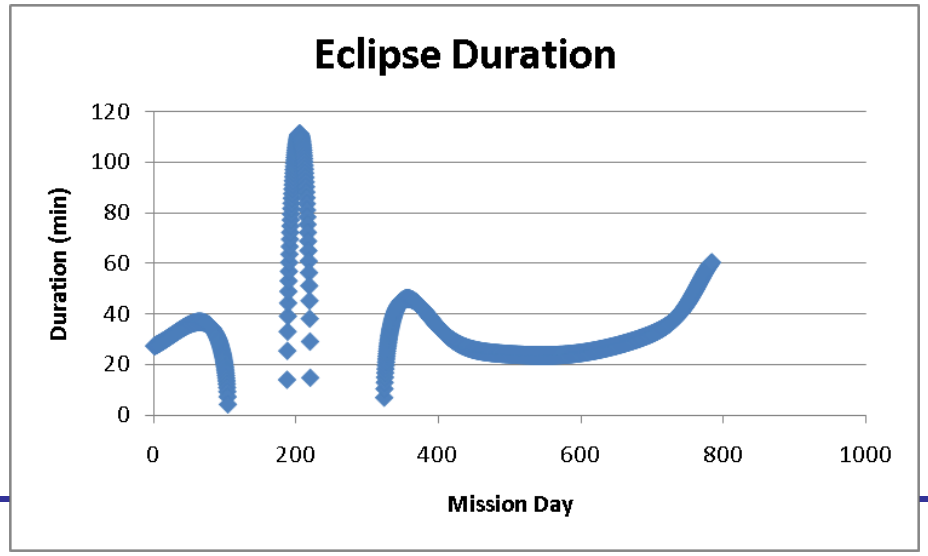
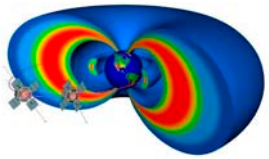


Mission Status

- **Both Van Allen Probe spacecraft are healthy!**
  - Monitoring SSPA, Single Event Effects, Solar array IV curve
  - Propellant usage better than predicted
- **Operations are nominal**
  - Minor issues only with ground tracking stations @ APL and USN
  - Meeting all data return requirements, data compression enabled
  - Orbit crossover on: Sept 26 (SCA) Sept 23 (SCB)
  - Eclipses will occur for the remainder of the primary mission



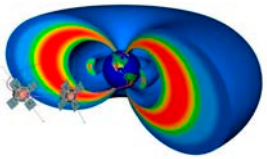
Extended Mission Life Assessment



- **Van Allen probes was designed for a 2.2 year mission life**
- **Total Dose**
  - 350 mil radiation shields designed for 2.2 year life with RDM=2
    - Radiation transport predictions based on AP8/AE8 models
    - 15 krad internal box dose was predicted at end of mission
    - Parts radiation tolerance required to be >15 krad
  - ERM measured data slightly below predicted dose at 260 days
    - 12 krad predicted at 350 mils depth using ERM data extrapolation
  - 50 krad tolerant parts would easily survive 3x mission life
- **Spacecraft assessment for extended mission underway**
  - Evaluate on-board propellant usage
  - Review radiation tolerance of on-board parts and materials
  - Update transport analysis using fastrad for critical assembly: radio

Updated transport assessment shows critical parts in radio are shielded with more 350 mils Al

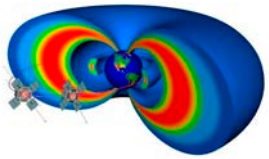
Radiation Effects Assessment



- **Review test results for softest parts on spacecraft (< 50krad)**
  - Reviewed parts testing memos and as-built design packaging
  - Radio predicted dose update in progress
    - Quick look Fastrad model with as built packaging and S/C configuration
- **Plans**
  - Complete radiation model for radio on spacecraft
  - Retest DAC part at expected dose for extended mission
    - Include parameter monitor for current degradation
    - Include annealing effects to mimic orbit effects, 5 krad dose steps

Mission Life			2.2 Years	2.2 Years	4.2 Years	6.2 Years	
Part	**Where used**	**Hardness per 2009 Test (krad)**	**CDR Dose Predict RDM=2 (krad)**	**Updated Dose Predict RDM=2 (krad)**	**Predict Dose RDM=2 (krad)**	**Predict Dose RDM=2 (krad)**	**Notes**
DAC-AD7943	Receiver	15	10.2	6	11.5	17	Spot shielded, Updated parts testing in work
Amp-AD620	PSE	100	12.5				Some degradation after 20 krad at lower voltages
Asic-PRIO-2	many	50	10.8				
V ref-AD780	Radio, SSPA	40	10.2				
OP amp-AD8012	Radio	20	10.2	6	11.5	17	

On-board Propellant Usage



- **Van Allen spacecraft propellant predicted to last until Nov 2018**
  - Assuming nominal operations continue
  - Maintains EOM de-orbit burn and COLA propellant budget as is
- **24 kg propellant adequate for a four year extended mission**
  - G&C Precessions predicted to take <10 kg for 2 years
  - Spinup/down expected to be minimal (<0.1 kg for 2 yrs)

Spacecraft A - 657 kg launch mass

Propellant Budget	ΔV	Used (071713)	Propellant planned (kg)
Phasing/Collision Avoidance	2.4 m/s	0.28	0.7
G&C - Precession		3.86	11.16
G&C - Spinup/Spindown		0.52	0.6
EOM Off sun precession			1
EOM Deorbit Burn	59.6 m/s		17.8
Total - 2.2 Year Mission			**31.26**
Residual Propellant			0.6
Total Propellant Loaded			56.5
Total GN2 Pressurant Mass			0.6
Uncertainty			0.03
Available propellant for extended life			**24.61**

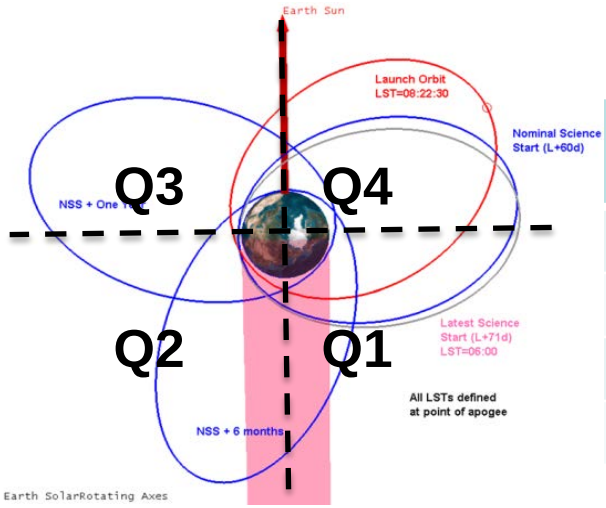
Spacecraft B - 676 kg launch mass

Propellant Budget	ΔV	Used (041513)	Propellant planned (kg)
Phasing/Collision Avoidance	2.4 m/s	0.28	0.7
G&C - Precession		3.83	11.16
G&C - Spinup/Spindown		0.51	0.6
EOM Off sun precession			1
EOM Deorbit Burn	59.6 m/s		18.3
Total - 2.2 Year Mission			**31.76**
Residual Propellant			0.6
Total Propellant Mass			56.5
Total GN2 Pressurant Mass			0.6
Uncertainty			0.03
Available propellant for extended life			**24.11**

Propellant on-board to support a four year mission extension

Mission Trajectory Status
Provided by Fazle Siddique

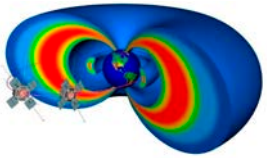
Quadrant Entry/Exit Dates	RBSPA	RBSPB
Enter Q1	09 Nov 2012 13:59:57.120	09 Nov 2012 03:00:00.000
Enter Q2	**03 Apr 2013 01:59:57.120**	**02 Apr 2013 04:59:57.120**
Enter Q3	**26 Sep 2013 06:00:00.000**	**23 Sep 2013 04:59:57.120**
Enter Q4	28 Feb 2014 13:00:02.880	24 Feb 2014 19:59:57.120
Exit Q4	18 Aug 2014 12:00:00.000	13 Aug 2014 10:00:02.880



[Predicted] Lapping Rate Per Quadrant	05-Jun-2013
Q1	2.10
Q2	2.56
Q3	2.27
Q4	2.51

Lap Dates
08 Nov 2012 23:43:17.760
16 Jan 2013 20:29:45.600
26 Mar 2013 17:16:22.080
03 Jun 2013 14:02:49.920
11 Aug 2013 10:49:17.760
19 Oct 2013 07:35:45.600
26 Dec 2013 19:23:13.920
05 Mar 2014 16:09:50.400
12 May 2014 18:58:19.200
19 Jul 2014 21:46:56.640
26 Sep 2014 00:35:34.080

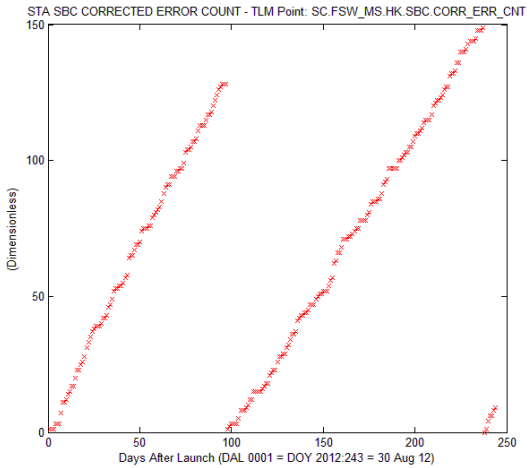
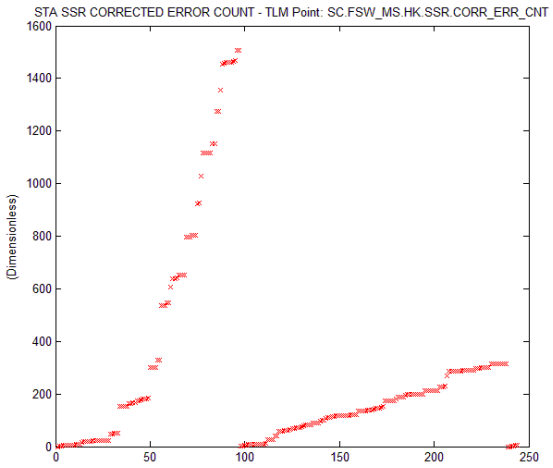
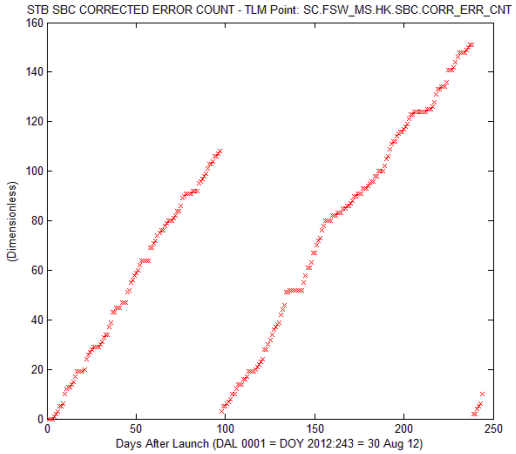
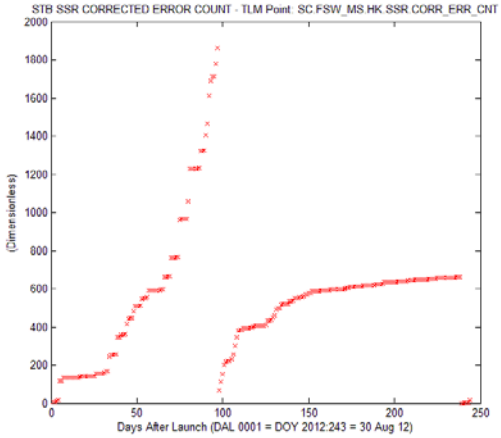
Engineering Monitoring to support Spacecraft/Environment Interaction



- **Spacecraft Telemetry Trending**
  - Spacecraft memory errors Single Event Effects (SEE) in Avionics and radio
    - FSW records counts of all errors detected in SSR SDRAM and Processor SRAM
      - Software scrubbing is enabled
      - Corrected and uncorrected(none to date) errors are counted and reported
    - Transceiver software counts errors detected in SRAM
      - Counter is reset after each pass, scrubbing is not enabled
  - Solar cell displacement damage
    - Monitor degradation of the spacecraft solar array output
    - Two solar patch IV curves are reported every ~3 min
  - Engineering Radiation monitor
    - Total dose
    - Deep dielectric discharge

Single Event Effects

- No uncorrected errors have occurred on either spacecraft
- Corrected error counters reset when FSW updated

	SBC	SSR
SCA		
SCB		

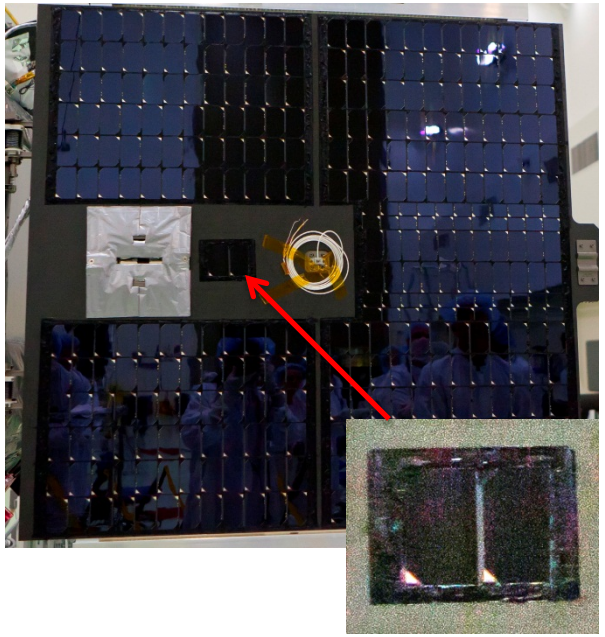
SSR errors were artificially inflated due to memory scrubbing error. Corrected on DAL97.

Counts were reset by FSW updates on DAL 097 (12/4/12) & DAL 238 (4/24/13).

Solar Cell Monitor

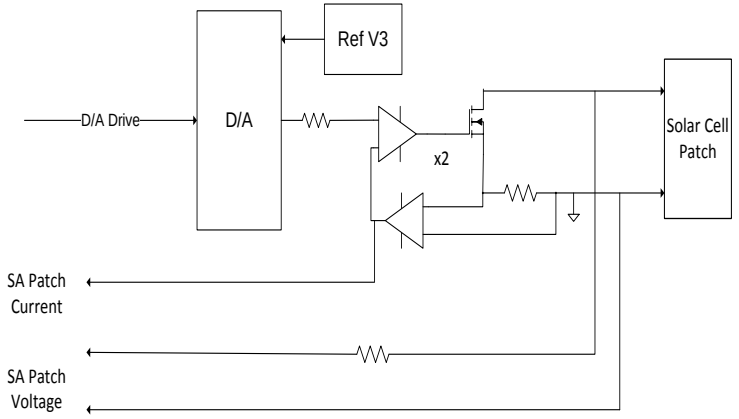
Solar Cell Degradation Patches:

- One patch located on both the +Y and the –Y solar array panel of each spacecraft
- Each patch has two series connected 28.3 cm2, 28.5 % efficient, Emcore BTJ, InGaP/InGaAs/Ge solar cells
- Coverglass: 500 microns cerium-doped microsheet (CMG) with ITO coating
- Coverglass adhesive: 0.1mm, DC93-500



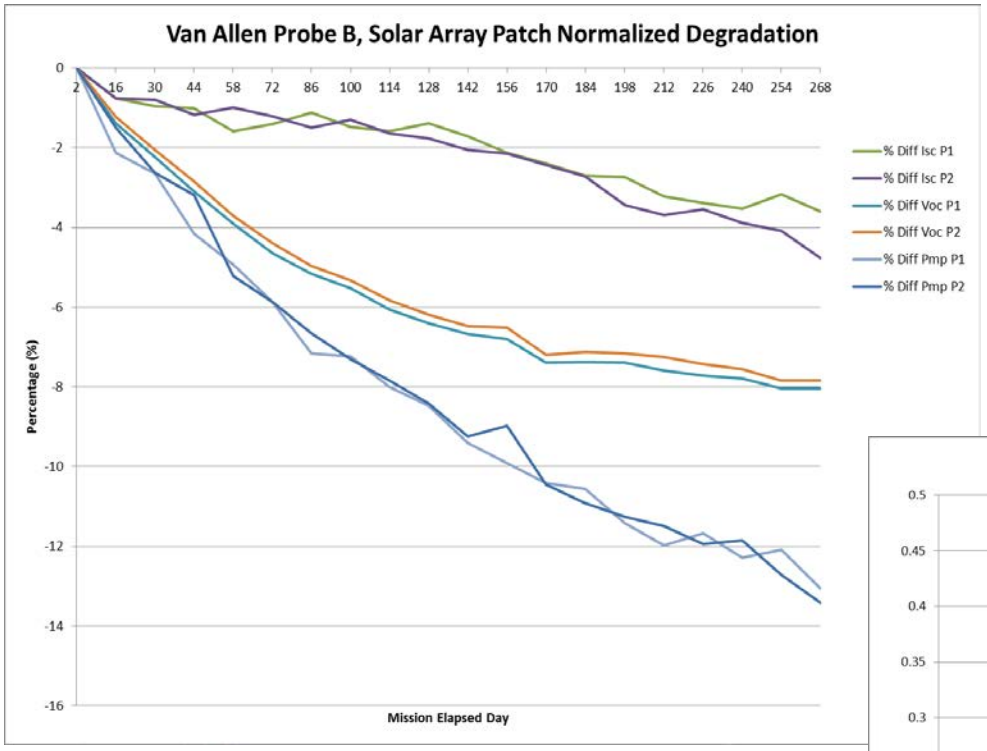
Patch IV Measurement:

- The IV curve of each patch is continuously swept by the interface card of the power system electronics.
- The voltage and current are measured with a 12-bit A/D converter once per second.
- The solar cell patches operating point is varied using an 8-bit D/A whose output voltage is proportional to the current drawn from the patch.
- The current change is 10mA/count.
- The operating point is varied once per second, requiring 256 seconds to complete one sweep.

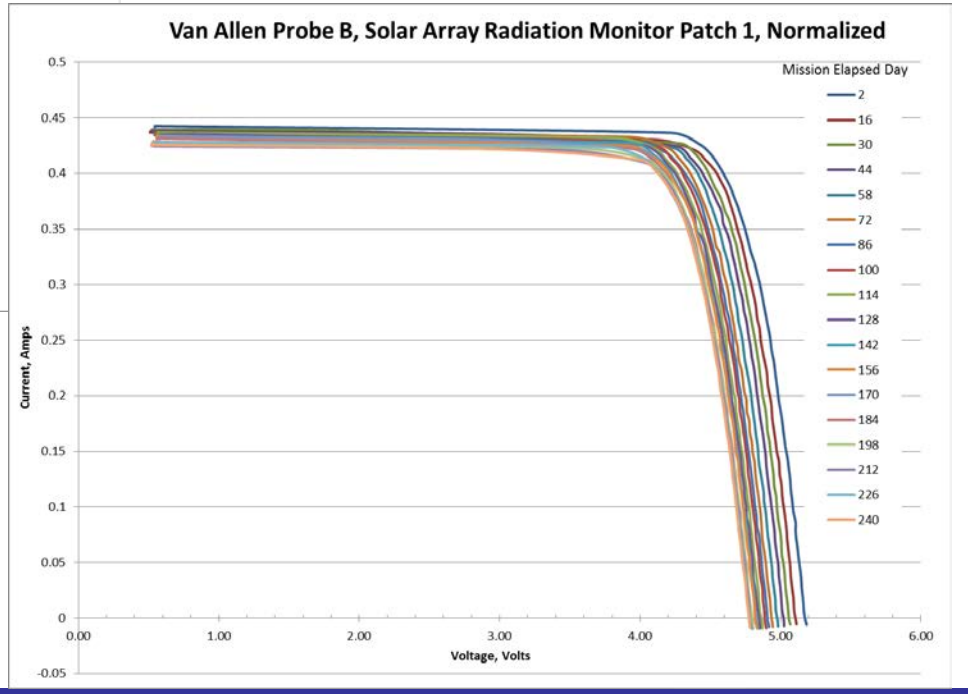


Reference: Maurer, Goldsten et al, “Early Results from ERM on Van Allen Probes”, IEEE NSRE, July 2013

Solar Cell Monitor Results

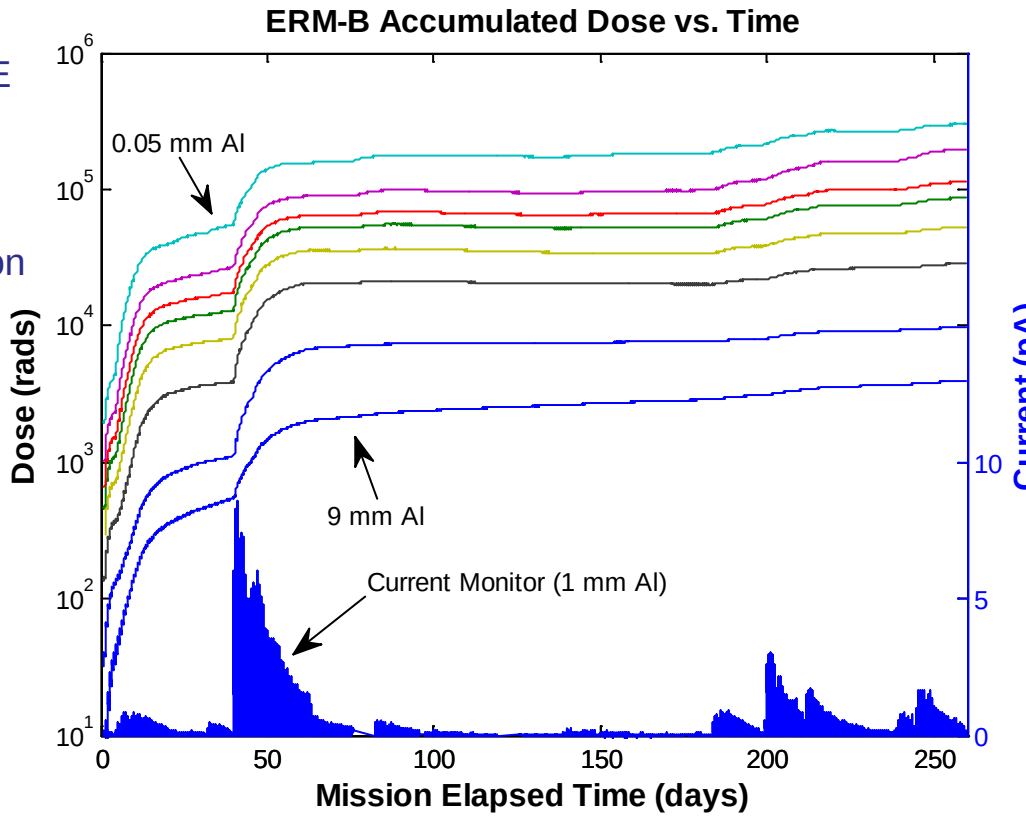


- The two plots show the data from Van Allen Probes B spacecraft. The data is normalized to 1AU, 28ºC.
- After 268 days---
  Isc has degraded ~4%
  Voc 8%
  Pmp 13%
- Abscissa is mission elapsed days



ERM Measured Data

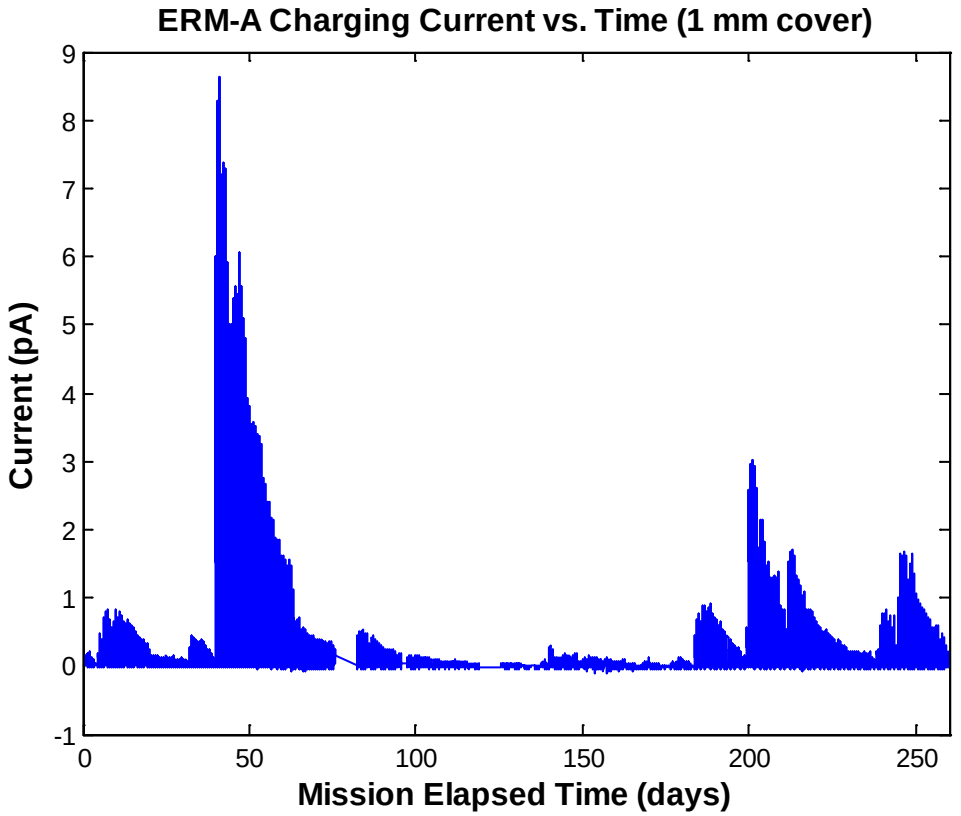
- **SC A/B dosimeters match within 5%**
- **Total Dose at 350 mils Al @ 260 days**
  - Measured dose behind 9 mm Al (350 mils) is ~4 krads versus 5 krads predicted for worst case using NOVICE transport of the AP8/AE8 static environment models and a Radiation Design Margin (RDM) of 2.
  - End of mission predicted dose based on extrapolating measured data is 12.3 krad, prediction was 15.4 krad.
- **Total dose at spacecraft surface**
  - Minimum shielded RadFET (0.05 mm Al) has seen ~300 krads or 1.1 krads/day. Extrapolates to 0.9 Megarads at end of mission.
  - Surface materials were tested to 10 Mrad



Reference: Maurer, Goldsten et al, "Early Results from ERM on Van Allen Probes", IEEE NSRE, July 2013

Cumulative Charge Monitor Results vs Time

- **Current monitors are primarily intended to monitor deep dielectric charging conditions in spacecraft: pA versus mission elapsed time (days).**
- **Also provides a convenient real time view of space weather conditions.**
- **Dynamics of the outer electron belt due to storms is clearly visible; 400:1 variation observed.**



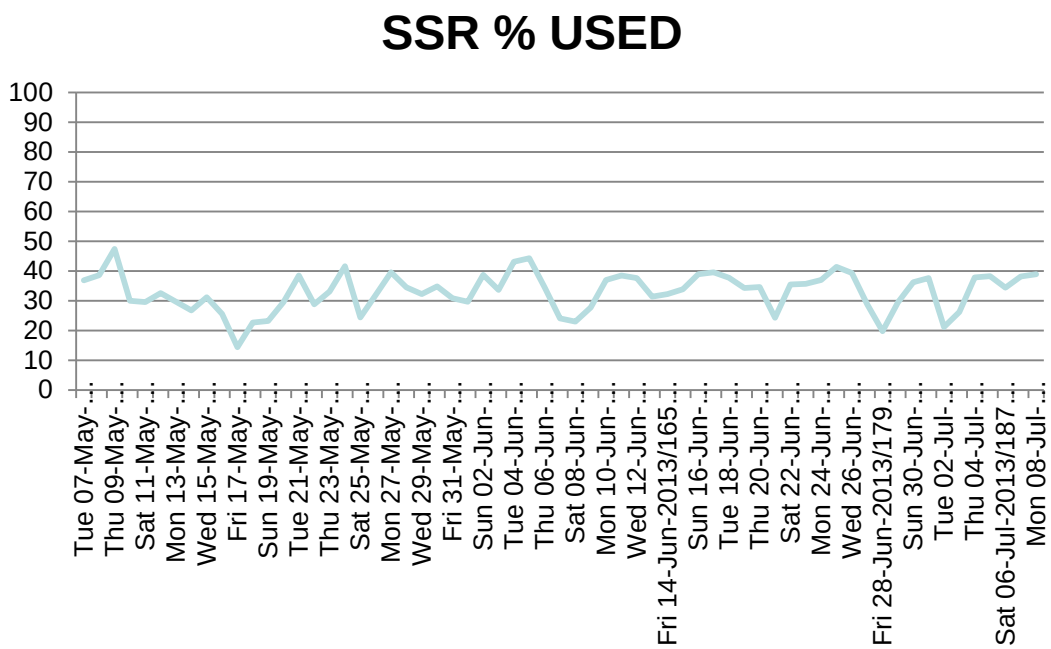
Reference: Maurer, Goldsten, et al “Early Results from ERM on Van Allen Probes”, IEEE NSRE, July 2013.

Data Return Performance

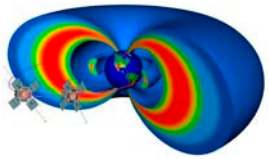
- **Spacecraft flight software implemented zip data compression**
  - Spacecraft housekeeping & science data May 8-9, 2013 (DOY 128-129)
- **Spacecraft SSR under-utilized, more data available for science**

Recommended instrument data allocations and rate adjustment:

- Uncompressed data rates from instrument to SC same or higher
- EMFISIS, EFW, ECT and RBSPICE able to increase data rates to CDH
- EMFISIS burst data allocation increased
- Adjustments of data storage on the SSR updated Aug 7, 2013



Data Compression Performance



- Zip performance evaluated for average/storm
  - Data pre/post compression compared
- SSR usage monitored
  - SC to hold 2.5 days data for missed contact
  - Maintain SSR usage average at 40%
  - Telemetry available per instrument usage
- As data rates are increased on-board the SSR usage should be monitored to be always <40%

Instrument	Compression Performance	Peak Perf
	DOY125 observed data	May 11-19
ECT - 00	0.5	0.55
EFW - 01	0.5	0.8
EMF_SURV - 02	0.9	0.9
EMF_BURST - 03	0.9	0.9
EMF_MAG - 04	0.5	0.5
RBSPICE - 05	0.5	0.65
RPS - 06	0.5	0.65
CDH_SSR_HK -7	0.5	0.5

			Recommended Updates 7/11/13			
Allocations	Allocated space on SSR	Data Rate^ Uncmprsd	% of original	Allocated space on SSR	Data Rate^ Uncmprsd	Notes
	Bytes	kbps		Bytes	Est	
ECT - 00	538,804,224	20.4	70%	377,162,956	23.4	ECT could generate some added data
EFW - 01	316,964,864	12	100%	316,964,864	14	More EFW data possible within alloc
EMF_SURV - 02	176,979,968	6.7	100%	176,979,968	6.7	
EMF_BURST - 03	612,761,600	23.2	144%	884,736,000	33.4	More EMFISIS burst data
EMF_MAG - 04	60,751,872	2.3	40%	24,300,748	2.3	No added mag data
RBSPICE - 05	142,639,104	5.4	100%	142,639,104	8.1	More RBSPICE data within allocation
RPS - 06	52,854,784	2	100%	52,854,784	2.4	More RPS data possible within alloc
CDH_SSR_HK -7	138,510,336	5.4	50%	69,255,168	5.4	No added SC housekeeping
TOTAL	2,040,266,752	77		2,044,893,592		

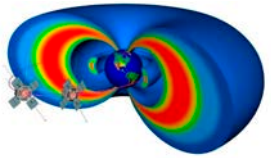
^Uncompressed data rate

2,044,893,592

95.5% of MAX clusters in RAT table in SSR

APL

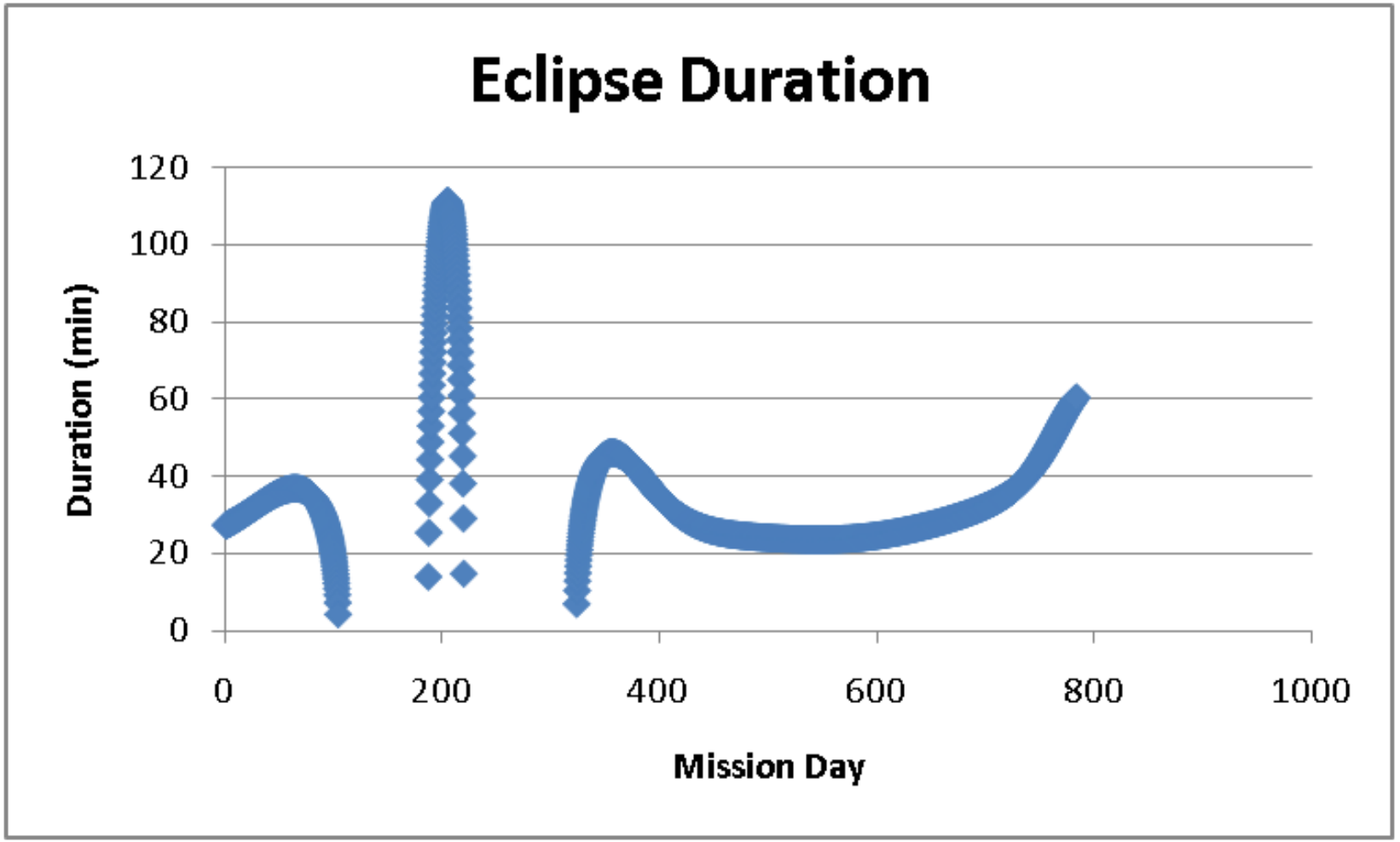
SSR Telemetry (% full) is available in Time and Status message



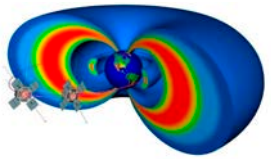
Backup Material

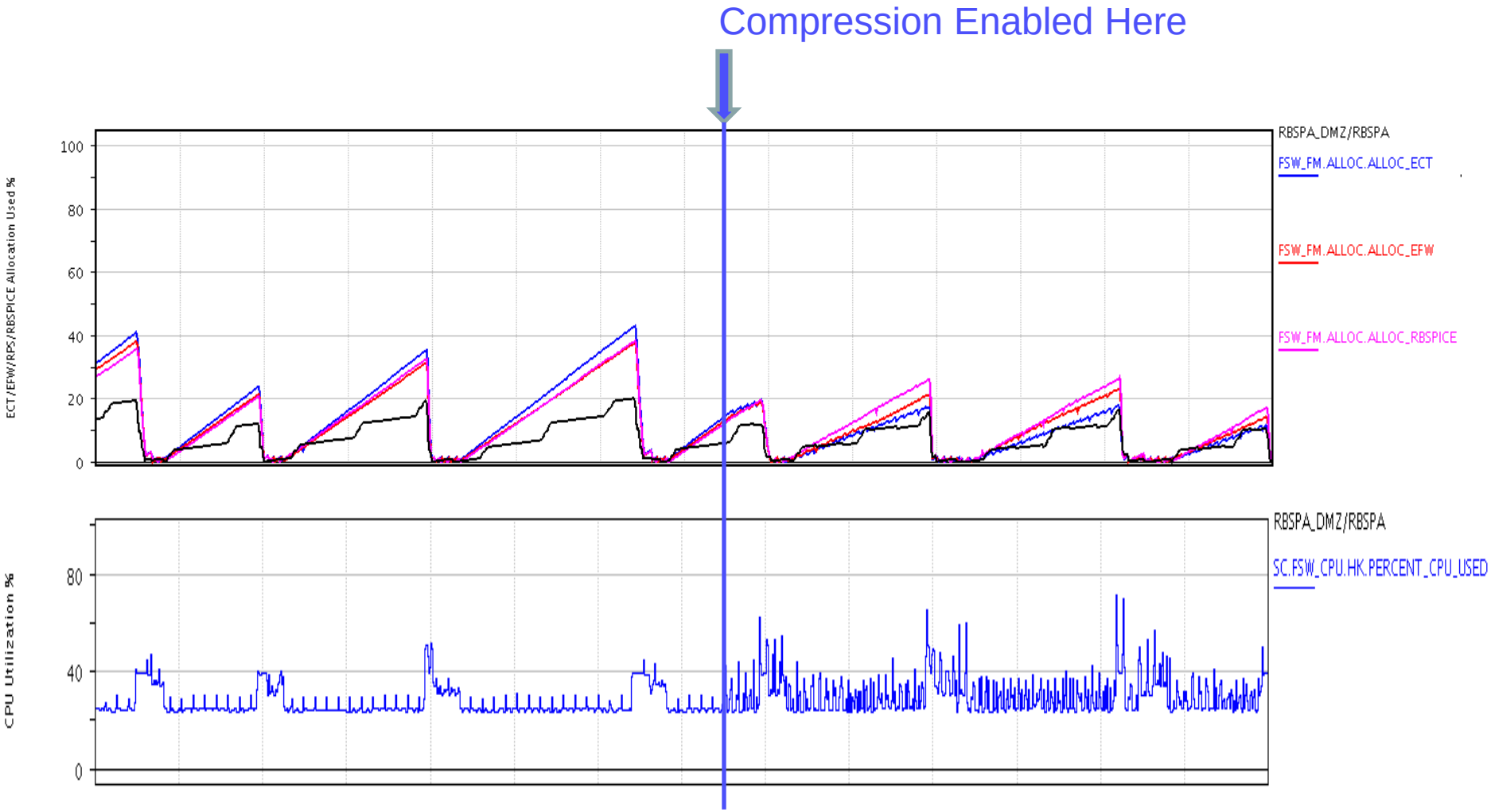
Eclipses

Eclipses will exist for the remainder of the two year nominal mission



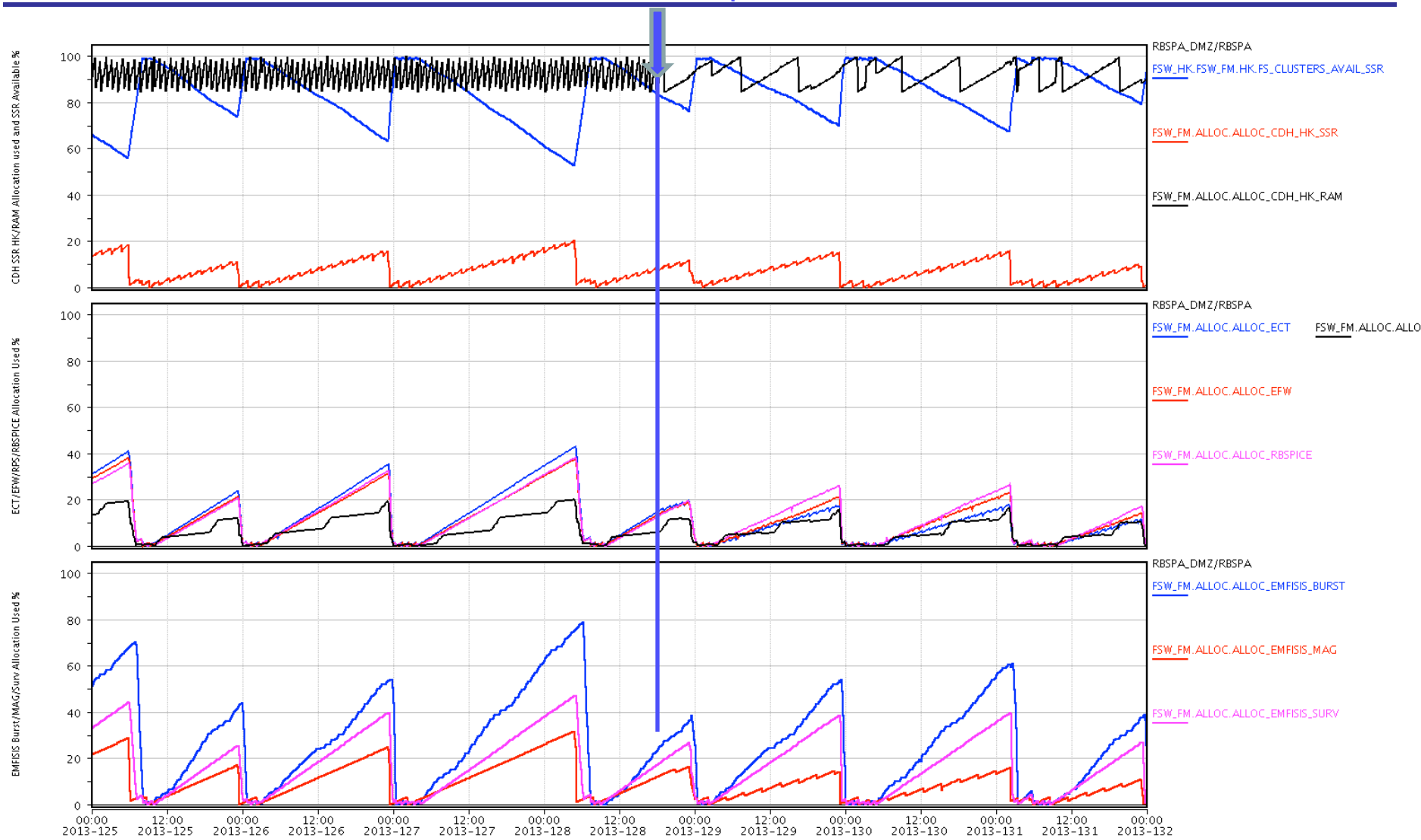
Trends that Could Impact Future Operations





SCA Performance with Compression

Compression Enabled Here



SCA Performance with Compression

Compression Enabled Here